ACADEMIA International Journal for Social Sciences
Volume 5, Issue 3(b), 2026 ISSN-L (Online): 3006-6638

Chinese FDI, Digital Adoption, and Labor Productivity in the Democratic Republic of the Congo: Evidence from Annual Time-Series Data, 2005–2023

Nimy Ta Nimy Raissa
raissanimy@yahoo.fr
School of Economics and Trade, Hunan University, Changsha, China

Zakia Sultana
zakia155@qq.com
School of Economics and Trade, Hunan University, Changsha, China

Corresponding Author: Nimy Ta Nimy Raissa raissanimy@yahoo.fr

Received: 29-01-2026 **Revised:** 13-02-2026 **Accepted:** 28-02-2026 **Published:** 15-03-2026

ABSTRACT

This study examines the relationship between Chinese foreign direct investment (FDI), digital adoption, and labor productivity in the Democratic Republic of the Congo (DRC) over the period 2005–2023. The analysis is motivated by the increasing importance of Chinese investment in African economies and the growing role of digital transformation in shaping productivity outcomes. Using annual time-series data, the study evaluates whether Chinese FDI inflows are associated with labor productivity, measured by output per worker, and whether this relationship remains robust after accounting for digital and structural factors. The empirical strategy is based on ordinary least squares estimation and includes baseline, structural, macroeconomic, and robustness specifications.The descriptive findings show that labor productivity improved over the study period, while Chinese FDI inflows remained highly volatile. At the same time, internet use, mobile subscriptions, insurance development, and capital formation generally increased, indicating broader structural change in the DRC economy. The baseline regression suggests that Chinese FDI inflows are positively associated with output per worker. However, this effect weakens after additional structural variables are introduced. In the final model, internet use and gross fixed capital formation emerge as the most robust predictors of labor productivity, while Chinese FDI inflows and insurance penetration lose statistical significance. Robustness tests further show that Chinese FDI stock is positively associated with productivity, implying that the long-term accumulated presence of Chinese investment may matter more than short-term annual inflows.Overall, the results suggest that the productivity effects of Chinese FDI in the DRC are conditional rather than automatic and depend on complementary domestic factors, particularly digital adoption and capital formation.

Keywords: *Chinese FDI; digital adoption; labor productivity; output per worker; Democratic Republic of the Congo; time-series analysis*

INTRODUCTION

Foreign direct investment (FDI) remains one of the most widely discussed drivers of development in low- and middle-income economies. In development economics, FDI is often viewed not only as a source of external finance, but also as a channel through which host countries may access new technologies, managerial practices, productive linkages, and international market opportunities. Classical development thinking already emphasized the importance of structural transformation, technological catching-up, and the movement of less productive economies toward more advanced production systems (Akamatsu 1962). Later literature expanded this view by arguing that multinational firms can generate spillovers through

imitation, labor mobility, supplier upgrading, and competitive pressure, thereby improving productivity in host economies (Blomstrom and Kokko 1998).

Yet the developmental effects of FDI are far from automatic. A large empirical literature shows that the impact of foreign investment depends on local absorptive capacity, institutional quality, financial development, political stability, and the broader structural conditions of the host country (Bénassy-Quéré et al. 2007; Abbas, Afshan, and Mustifa 2022; Asante et al. 2023; Bayraktar et al. 2023). In other words, external capital may create opportunities, but whether those opportunities translate into productivity and welfare gains depends on the environment in which the investment is embedded. This question is particularly important in African economies, where infrastructure constraints, digital divides, weak productive capacity, and institutional fragilities often shape the transmission of investment into economic outcomes.

Within this broader debate, China's role in Africa has become increasingly prominent. Over the last two decades, Chinese economic engagement has expanded across the continent through trade, aid, infrastructure finance, and outward FDI. This has generated intense scholarly and policy interest, both because of the scale of China's presence and because of the distinctive features of its investment patterns. Chinese investment has often been linked to resource extraction, infrastructure provision, logistics, construction, and other strategically important sectors, which has led many observers to view it as a potentially transformative force for African economies (Bräutigam 2009; Alden and Large 2011, 2017; Calabrese and Tang 2022). At the same time, debates persist regarding the extent to which Chinese investment generates durable development benefits, reinforces dependency, or reshapes domestic policy incentives (Brautigam 2019; Carmody, Taylor, and Zajontz 2022; Achidi, Carla, and Mengge 2024).

The empirical literature on Chinese FDI offers mixed but generally nuanced findings. On the one hand, Chinese outward FDI has been shown to support economic growth in various regions, including Asia and North Africa under the Belt and Road Initiative (Abdulsalam et al. 2021). Some studies also find that Chinese engagement can improve welfare and inclusive development in African contexts under certain conditions (Atitianti and Dai 2022; Arogundade, Biyase, and Eita 2021). On the other hand, the development impact of Chinese investment is shaped by local institutions, governance, economic conditions, and the presence or absence of complementary capabilities. Thus, rather than asking whether Chinese FDI is simply "good" or "bad," the more relevant question is under what conditions it contributes to productive transformation.

At the same time, digital adoption has emerged as a central pillar of development strategy across Africa. Expanding access to the internet, mobile connectivity, digital services, and data-based economic activity is increasingly seen as critical for productivity, innovation, trade integration, and inclusion. The African Union's Digital Transformation Strategy for Africa (2020–2030) explicitly positions digital infrastructure and digital access as foundations for long-term structural change on the continent (African Union 2020; African Union Commission 2019). Empirical research also supports this view. Studies show that ICT development can promote economic growth, support trade, improve market coordination, and expand opportunities for more inclusive development in Africa (Aker and Mbiti 2010; Adeleye and Eboagu 2019; Adeleye et al. 2020; Abendin and Duan 2021; Awad and Albaity 2022).

The relationship between FDI and digital adoption is therefore especially important. Foreign investment may bring productive potential, but digital infrastructure and digital usage may determine whether host economies can actually absorb and operationalize the benefits associated with that investment. Where internet use, mobile connectivity, and information access are limited, knowledge diffusion and technological adaptation may be constrained. Conversely, where digital adoption is expanding, local firms and workers may be better positioned to access information, coordinate production, reduce transaction

costs, and benefit from foreign investment-related spillovers. In this sense, digital adoption may not only affect productivity directly, but may also shape the effectiveness of FDI.

These issues are particularly relevant in the Democratic Republic of the Congo (DRC). The DRC is one of Africa's most strategically significant economies due to its natural resource endowment, demographic weight, and development potential. At the same time, it faces substantial structural challenges, including low productivity, limited industrial diversification, infrastructure gaps, governance constraints, and uneven access to digital and financial services. Chinese investment has become an important component of the DRC's external economic relations, especially in sectors linked to mining, infrastructure, and associated value chains. However, relatively little empirical work has focused specifically on how Chinese FDI relates to labor productivity in the DRC, and even less attention has been paid to the possible conditioning role of digital adoption.

This study seeks to address that gap. It examines the relationship between Chinese FDI, digital adoption, and labor productivity in the Democratic Republic of the Congo over the period 2005–2023. Rather than focusing only on aggregate economic growth, the study uses output per worker as a proxy for labor productivity. This choice is important because productivity is more directly connected to efficiency, technological use, and structural transformation than aggregate GDP growth alone. The analysis evaluates whether Chinese FDI inflows are associated with labor productivity and whether this relationship changes once digital and structural variables are taken into account. It also assesses whether Chinese FDI stock, as a long-term measure of accumulated investment presence, is more strongly associated with productivity than annual inflows.

The study contributes to the literature in several ways. First, it shifts attention from growth to labor productivity, thereby emphasizing the efficiency dimension of development. Second, it brings together two strands of literature that are often studied separately: Chinese FDI and digital transformation. Third, it provides country-specific evidence for the DRC, which remains understudied despite its importance in China–Africa relations. Finally, it advances the idea that foreign investment should be analyzed together with domestic enabling conditions rather than in isolation.

The central argument of the paper is that Chinese FDI may matter for labor productivity in the DRC, but its effect is likely to be conditional on broader structural factors, especially digital adoption and capital formation. This means that the developmental effects of foreign investment cannot be fully understood without considering the domestic environment in which the investment operates.

The remainder of the paper is organized as follows. Section 2 reviews the literature on Chinese FDI, digital adoption, and productivity. Section 3 presents the methodology and data. Section 4 reports the empirical results. Section 5 discusses the findings, and the final section concludes and outlines directions for future research.

LITERATURE REVIEW

Theoretical Foundations: FDI, structural transformation, and productivity

The theoretical case for FDI as a driver of development is rooted in the idea that foreign firms can provide host economies with capital, technology, organizational knowledge, and access to wider production networks. Development theories of structural change have long emphasized that late-industrializing countries can progress by moving from low-productivity activities toward more advanced sectors and methods of production (Akamatsu 1962). In this context, foreign investment can potentially accelerate transformation by introducing new productive capabilities.

The spillover literature further explains how multinational corporations may affect host-country productivity. Blomstrom and Kokko (1998) argue that foreign firms can generate spillovers through imitation, competition, labor training, and backward or forward linkages. Similarly, Abebe et al. (2018) show that FDI can facilitate knowledge diffusion even in poorer and less developed locations. These arguments imply that FDI can affect productivity not merely through capital injection, but also through broader technological and organizational transmission mechanisms.

However, the same literature also makes clear that spillovers are not automatic. The extent to which host economies benefit depends on local firms' capacity to absorb technology, the quality of institutions, the stability of the political environment, and the development of complementary markets. This view is broadly consistent with the literature on financial development and growth, which stresses that positive economic outcomes depend on the quality of domestic institutions and supporting structures (Abbas, Afshan, and Mustifa 2022; Asante et al. 2023; Bayraktar et al. 2023). Therefore, the effect of foreign investment should be expected to vary across countries and across time depending on the structural environment.

Chinese FDI in Africa: opportunities and debates

The rise of China as a major economic actor in Africa has transformed the debate on foreign investment and development. Bräutigam (2009) argues that China's presence in Africa has often been oversimplified, while Alden and Large (2011, 2017) describe Chinese engagement as distinctive but not exempt from contradictions. China's outward investment strategy has been driven by a combination of commercial, strategic, and geopolitical motives, including market access, resource security, and international influence (Buckley et al. 2009; Benabdallah 2020, 2021).

Empirical research has produced mixed but informative results. Abdulsalam et al. (2021) show that Chinese outward FDI can support economic growth in countries along the Belt and Road, while Atitianti and Dai (2022) find evidence that Chinese FDI may improve welfare outcomes in Africa. Calabrese and Tang (2022) also emphasize the role of Chinese firms in Africa's economic transformation, although they note that this role varies across sectors and local contexts. Arogundade, Biyase, and Eita (2021) similarly show that the human development effects of FDI in sub-Saharan Africa depend on domestic economic conditions.

At the same time, this literature also highlights important caveats. Some analyses emphasize governance effects, political influence, and the broader policy implications of Chinese economic engagement (Atitianti and Asiamah 2023; Achidi, Carla, and Mengge 2024). Others question the developmental depth of some Chinese investment patterns, particularly when they are concentrated in enclave sectors or embedded in asymmetric financing arrangements (Brautigam 2019; Carmody, Taylor, and Zajontz 2022). These debates suggest that Chinese FDI should not be treated as uniformly beneficial or harmful. Rather, its effects depend on sectoral composition, domestic institutions, and the capacity of host economies to capture value from foreign involvement.

For the DRC, this question is especially important. Chinese investment is economically significant, yet the country's structural constraints raise the question of whether and how such investment translates into productivity gains. This makes the DRC a valuable case for examining the conditional nature of Chinese FDI's effects.

FDI and labor productivity

Although a large share of the FDI literature focuses on aggregate economic growth, labor productivity offers a more direct lens through which to evaluate whether investment contributes to productive transformation. Productivity reflects how effectively labor is combined with capital, technology, and

institutional support. If FDI truly enhances economic performance, one would expect at least part of its effect to appear through improved output per worker.

The knowledge diffusion framework is especially relevant here. Abebe et al. (2018) provide evidence that foreign investment can stimulate knowledge diffusion in poor locations, while Blomstrom and Kokko (1998) explain that multinational presence may create spillovers that influence domestic productive efficiency. These mechanisms suggest that foreign investment can contribute to productivity when firms and workers gain access to better technologies, more efficient production methods, or improved organizational capabilities.

However, not all forms of FDI are equally productivity-enhancing. The nature of the investment matters. Long-term embedded investment, such as accumulated FDI stock, may capture persistent presence, durable linkages, and continuing capital formation better than annual inflows, which can be volatile from year to year. This distinction is particularly relevant in contexts such as the DRC, where annual inflows may fluctuate significantly while longer-term investment stock may better reflect sustained economic engagement.

Digital adoption and economic performance in Africa

Alongside FDI, digital adoption has become one of the most important themes in African development research. The expansion of internet access, mobile phone usage, and other digital technologies has transformed communication, market participation, access to information, and business organization. Aker and Mbiti (2010) famously documented how mobile phones reshaped economic life in Africa by lowering information costs and improving market coordination.

Subsequent studies have reinforced the importance of ICT for economic outcomes. Adeleye and Eboagu (2019) find that ICT development contributes to economic growth in Africa, while Adeleye et al. (2020) show that the ICT–trade nexus is critical for growth and inclusion. Abendin and Duan (2021) highlight the role of the digital economy in strengthening the trade–growth relationship in Africa. Awad and Albaity (2022) also demonstrate that ICT supports growth in sub-Saharan Africa through multiple transmission channels, while Awad (2024) shows that the gains from ICT and globalization may differ across national contexts. Belloumi and Touati (2022) and Ademosu and Solomon (2023) further confirm that ICT and FDI can jointly influence economic performance.

These findings are strongly aligned with continental policy priorities. The African Union's Digital Transformation Strategy (2020–2030) presents digitalization as central to productivity, innovation, inclusion, and competitiveness (African Union 2020; African Union Commission 2019). In the DRC, where digital infrastructure remains uneven but has expanded considerably over time, digital adoption may be especially important as a mechanism for connecting markets, reducing inefficiencies, and enabling technology use.

Digital adoption as an enabling condition for the productivity effects of Chinese FDI

One of the most important implications of the literature is that digital adoption may shape how effectively foreign investment translates into productivity gains. If internet use, mobile connectivity, and digital access remain weak, the host economy may be less able to learn from, integrate with, or adapt to foreign investment. By contrast, digital expansion may enhance absorptive capacity by allowing firms and workers to access information, improve coordination, connect to supply chains, and adopt technology more effectively.

This view is supported indirectly by several studies. Asongu and Odhiambo (2019) examine the dynamic relationship between FDI, information technology, and economic growth in sub-Saharan Africa, suggesting that digital and investment processes are interconnected. Ademosu and Solomon (2023) also show that ICT innovation and FDI are linked to economic performance. Belloumi and Touati (2022) similarly find that FDI inflows and ICT jointly matter for growth. In addition, Babalola et al. (2024) highlight the role of digital technologies in improving firm-level capabilities, suggesting that digital conditions can amplify productive responses to external opportunities.

For the DRC, this interaction may be particularly important. Chinese FDI may generate potential benefits through capital provision and sectoral engagement, but whether these benefits are translated into labor productivity depends on the domestic ability to absorb them. Digital adoption is therefore likely to function not only as an independent driver of productivity, but also as an enabling condition that determines how effectively foreign investment contributes to productive transformation.

Insurance, financial development, and supportive structural conditions

Although the title and core contribution of this study focus on Chinese FDI, digital adoption, and labor productivity, the literature on financial development remains relevant because productive transformation often depends on broader market-deepening processes. Abbas, Afshan, and Mustifa (2022) argue that financial development affects both growth and distributional outcomes, while Asante et al. (2023) show that the growth effect of financial development in sub-Saharan Africa depends on institutional quality. These studies imply that deeper financial systems can create conditions more favorable to productive investment and efficiency gains.

Insurance development can be viewed as one dimension of this broader structural environment. Although not always studied directly in FDI–productivity frameworks, insurance penetration may reflect institutional maturity, market development, and the capacity to manage economic risk. In developing economies, these conditions can affect investment behavior, resource allocation, and productive stability. For this reason, insurance-related variables can be interpreted as proxies for structural deepening rather than as isolated sectoral measures.

Research Gap

Despite the rich literature on FDI, digital transformation, and African development, several gaps remain.

First, much of the literature focuses on aggregate economic growth rather than labor productivity. While growth is important, productivity is a more direct measure of productive efficiency and structural upgrading. Second, many studies examine FDI and ICT separately, even though the interaction between external investment and digital adoption may be crucial in explaining productivity outcomes. Third, a large share of the evidence comes from multi-country panel studies, which are useful for identifying broad patterns but may miss important country-specific dynamics. Fourth, the DRC remains underexamined in the empirical literature, despite its significance within China–Africa economic relations.

This study addresses these gaps by examining the relationship between Chinese FDI, digital adoption, and labor productivity in the Democratic Republic of the Congo over 2005–2023. It explicitly places digital adoption within the FDI–productivity framework and distinguishes between short-run annual Chinese FDI inflows and long-run Chinese FDI stock. In doing so, it contributes country-specific evidence on how foreign investment and domestic structural conditions interact in shaping labor productivity.

Conceptual implication for the present study

The reviewed literature suggests a clear conceptual expectation. Chinese FDI may contribute to productivity, but its effect is unlikely to be direct, uniform, or automatic. Instead, the impact of foreign investment should depend on complementary domestic conditions, especially digital adoption, capital formation, and broader structural development. In the case of the DRC, this means that labor productivity is expected to be positively associated with Chinese FDI, but even more strongly associated where digital connectivity and capital accumulation are improving.

This conceptual perspective guides the empirical analysis of the present study. The paper therefore tests not only whether Chinese FDI is associated with labor productivity, but also whether domestic structural variables particularly internet use, mobile connectivity, and capital formation better explain productivity dynamics in the DRC over time.

METHODOLOGY

This study adopts a quantitative single-country time-series design to examine the relationship between Chinese foreign direct investment (FDI), digital adoption, and labor productivity in the Democratic Republic of the Congo (DRC). The empirical strategy is based on annual observations covering 2005–2023, yielding a balanced sample of 19 yearly observations. The methodology is designed to test whether Chinese FDI is associated with labor productivity and whether that relationship remains robust after accounting for insurance development, digital connectivity, capital formation, and selected macroeconomic conditions.

The analysis proceeds in three stages. First, descriptive statistics and graphical trend analysis summarize the behavior of the main variables over time. Second, pairwise correlations identify preliminary associations between labor productivity and the explanatory variables. Third, a sequence of ordinary least squares (OLS) regressions is estimated, beginning with a baseline specification and then progressively introducing structural and macroeconomic controls. This stepwise strategy is especially appropriate for a short annual series because it reveals the marginal contribution of each block of variables without over-parameterizing the final model.

Research design and study scope

The study is a macro-level country case analysis. All variables are measured at the national level for the DRC; there is no cross-country or provincial dimension in the empirical design. The dependent variable is labor productivity, measured as output per worker. The principal explanatory variable is annual Chinese FDI inflows. The core conceptual argument is that external investment may support productivity, but that the productivity effect of FDI may depend on domestic absorptive conditions, particularly digital connectivity and productive capital formation. Insurance development is included as a complementary structural variable because it reflects financial deepening and the ability of the economy to support investment and productive activity under conditions of risk.

Because the number of observations is limited, the study emphasizes parsimonious specifications and careful robustness testing rather than highly parameterized models. The empirical results are therefore interpreted as evidence of association rather than strict causality. This framing is methodologically appropriate for a short annual series in which endogeneity, omitted variables, and serial dependence cannot be eliminated fully through advanced time-series techniques without sacrificing degrees of freedom.

Data source, sample period, and data preparation

The dataset consists of annual observations from 2005 to 2023 compiled in the project workbook used for the empirical analysis. The working data sheet contains Chinese FDI inflows and stock, insurance indicators, digital adoption indicators, macroeconomic variables, and labor-related variables. Before estimation, the dataset was cleaned in Python, and all variables were converted into numeric format to ensure consistent statistical processing. A preliminary quality check confirmed that the final analytical sample contains no missing values in the variables used for the reported regressions.

Two variables were constructed directly during data preparation. First, output per worker was computed as the ratio of constant-price GDP to total labor force. Second, trade openness was calculated as the sum of imports and exports divided by constant-price GDP and then multiplied by 100 to express the indicator in percentage terms. These transformations ensure that the productivity and openness measures are internally consistent with the rest of the annual macroeconomic series used in the models.

$$Output\_per\_Worker_t = GDP\_Constant\_USD_t / Labor\_Force\_Total_t$$

$$Trade\_Openness\_pct_t = [(Imports\_USD_t + Exports\_USD_t) / GDP\_Constant\_USD_t] \times 100$$

The final estimation sample includes 19 observations for each selected variable. This small-sample property influenced the model design directly: variables with strong conceptual relevance were prioritized, but the number of regressors in any single equation was kept limited in order to preserve statistical power and avoid unnecessary overfitting.

Variable definition and measurement

Table M1 summarizes the variables used in the empirical analysis. The baseline models focus on the direct relationship between Chinese FDI inflows and output per worker. The extended models then incorporate structural variables, especially insurance penetration, internet use, and gross fixed capital formation. Alternative measures—including Chinese FDI stock, insurance density, and mobile subscriptions—are reserved for robustness analysis to test whether the main findings are sensitive to variable choice.

Table 1. Variable definition and measurement.

Variable	Role	Measurement	Expected sign
Output_per_Worker	Dependent variable	GDP constant divided by total labor force	—
Chinese_FDI_Inflows_USD	Main independent variable	Annual Chinese FDI inflows in USD	+
Insurance_Penetration_pct	Structural variable	Insurance penetration rate, percent	+
Internet_Users_pct	Digital variable	Percentage of individuals using the internet	+

Gross_Fixed_Capital_Formation_pctGDP	Capital variable	Gross fixed capital formation as a share of GDP	+
Trade_Openness_pct	Macro control	Imports plus exports as a share of GDP	+
Chinese_FDI_Stock_USD	Robustness variable	Accumulated Chinese FDI stock in USD	+
Mobile_Subscriptions_per100	Robustness variable	Mobile subscriptions per 100 inhabitants	+

Econometric specification

The empirical analysis uses OLS regression as the primary estimation method. OLS was selected because the sample is short, the dependent variable is continuous, and the objective is to compare the marginal contribution of successive sets of explanatory variables in a transparent and interpretable way. Five main specifications were estimated. The first is a baseline model that includes only Chinese FDI inflows. The second introduces insurance penetration. The third adds internet use as the key digital variable. The fourth includes macroeconomic controls—gross fixed capital formation and trade openness—alongside Chinese FDI inflows. The fifth is a compact final model that combines Chinese FDI inflows, insurance penetration, internet use, and gross fixed capital formation.

$$Model\ 1:\ Y\_t = \alpha + \beta_1 FDI\_Inflows\_t + \varepsilon\_t$$

$$Model\ 2:\ Y\_t = \alpha + \beta_1 FDI\_Inflows\_t + \beta_2 InsurancePen\_t + \varepsilon\_t$$

$$Model\ 3:\ Y\_t = \alpha + \beta_1 FDI\_Inflows\_t + \beta_2 Internet\_t + \varepsilon\_t$$

$$Model\ 4:\ Y\_t = \alpha + \beta_1 FDI\_Inflows\_t + \beta_2 GFCF\_t + \beta_3 Trade\_t + \varepsilon\_t$$

$$Model\ 5:\ Y\_t = \alpha + \beta_1 FDI\_Inflows\_t + \beta_2 InsurancePen\_t + \beta_3 Internet\_t + \beta_4 GFCF\_t + \varepsilon\_t$$

In these equations, Y_t denotes output per worker in year t, α is the intercept, β denotes the slope coefficients to be estimated, and ε_t is the stochastic error term. The coefficients are interpreted as partial associations, holding the other included regressors constant. A positive coefficient implies that an increase in the explanatory variable is associated with higher output per worker, while a negative coefficient suggests the opposite. In addition to the five main models, three robustness specifications were estimated: one that replaces annual FDI inflows with FDI stock, one that replaces insurance penetration with insurance density, and one that replaces internet use with mobile subscriptions per 100 inhabitants.

Estimation procedure, diagnostics, and decision rules

All computations were carried out in Python using standard data analysis and econometric libraries. The estimation sequence begins with data import and verification, followed by variable construction, descriptive analysis, and OLS estimation. After each model is estimated, coefficient signs, magnitudes, and p-values are examined alongside model fit statistics. Statistical significance is evaluated using conventional

thresholds of 10 percent, 5 percent, and 1 percent, but the interpretation is based jointly on statistical significance, economic plausibility, and consistency across specifications.

Several diagnostic procedures are used to assess the adequacy of the preferred specification. First, multicollinearity is evaluated through the variance inflation factor (VIF). Second, the Breusch–Pagan test is used to assess heteroskedasticity in the model residuals. Third, the Jarque–Bera test is used to assess whether the residuals depart significantly from normality. Fourth, the Durbin–Watson statistic is inspected to evaluate residual serial correlation, which is especially relevant in annual time-series data. In addition to formal tests, residual-versus-fitted plots, residual histograms, and actual-versus-predicted plots are used as visual diagnostics.

Robustness Strategy

A dedicated robustness strategy is implemented to determine whether the main findings depend excessively on the exact measurement of the explanatory variables. Three alternative specifications are estimated. The first replaces annual Chinese FDI inflows with Chinese FDI stock in order to test whether the long-term accumulated investment presence is more strongly associated with labor productivity than short-run annual inflows. The second replaces insurance penetration with insurance density, which captures insurance development in per-capita monetary terms rather than as a penetration ratio. The third replaces internet use with mobile subscriptions per 100 inhabitants in order to verify whether the digital adoption result is sensitive to the choice of connectivity indicator.

A result is considered robust when the sign of the key coefficient remains economically plausible and at least one conceptually related variable retains statistical relevance across alternative specifications. Under this framework, the analysis is expected to reveal whether Chinese investment has a direct productivity association, whether the relationship is better captured by stock rather than inflows, and whether digital adoption and capital formation remain the most stable correlates of labor productivity when the model is perturbed.

Despite the strengths of the selected empirical framework, several methodological limitations should be acknowledged. First, the analysis is based on a relatively small annual time-series sample covering the period 2005–2023, which may limit statistical power and the generalizability of the findings. Second, although the dataset was carefully prepared and completed where necessary, some variables include imputed values, which may affect the precision of the estimates. Third, the possibility of multicollinearity among structurally related indicators, particularly between insurance and digital variables, cannot be fully excluded. Finally, given the observational nature of the data, the estimated relationships should be interpreted as associations rather than strict causal effects. Notwithstanding these limitations, the methodological approach remains appropriate for identifying the main empirical patterns linking Chinese FDI, digital adoption, and labor productivity in the Democratic Republic of the Congo. The next section presents the descriptive and econometric results of the analysis.

RESULTS

Descriptive Analysis

Table 1 presents the descriptive statistics of the main variables used in the study. Chinese FDI inflows display substantial variation over the sample period, with a mean of approximately USD 291.7 million and a relatively high standard deviation, indicating considerable volatility in annual inflows. The minimum value is negative, which suggests that in at least one year net disinvestment or capital withdrawal occurred. By contrast, Chinese FDI stock shows a steadily increasing long-term presence, with an average value of

about USD 2.26 billion. Output per worker, used as a proxy for labor productivity, averages about 1,252.8 and ranges from 895.3 to 1,553.9, indicating an overall improvement in productivity over time.

The descriptive statistics also show that insurance and digital indicators improved considerably during the study period. Insurance penetration increased from 0.05 to 0.49, while insurance density rose from USD 0.20 per capita to USD 3.49 per capita. Internet use increased from 0.238 percent to 18.97 percent, and mobile subscriptions rose from 4.67 to 53.19 per 100 people. Gross fixed capital formation as a share of GDP and trade openness also display sufficient variation for empirical analysis. Overall, the data suggest that the study period was characterized by increasing productivity, expanding digital connectivity, deepening insurance development, and fluctuating Chinese investment inflows.

Table 1 : Descriptive Statistics

Variable	Count	Mean	Std. Dev.	Min	25%	50%	75%	Max
Chinese_FDI_Inflows_USD	19	291,682,100	312,132,500	-78,920,000	66,225,000	213,710,000	367,640,000	1,045,750,000
Chinese_FDI_Stock_USD	19	2,260,075,000	1,885,791,000	25,110,000	514,175,000	2,168,670,000	3,899,460,000	5,596,600,000
Insurance_Penetration_pct	19	0.169	0.137	0.050	0.076	0.117	0.200	0.490
Insurance_Density_USD_per_capita	19	0.985	0.972	0.200	0.365	0.630	1.110	3.490
Internet_Users_pct	19	6.609	6.839	0.238	0.640	3.000	12.365	18.968
Mobile_Subscriptions_per100	19	31.433	15.812	4.672	16.337	37.250	44.545	53.189
Gross_Fixed_Capital_Formation_pctGDP	19	26.282	5.889	15.535	22.198	27.529	29.843	36.683
Trade_Openness_pct	19	67.613	21.067	31.127	58.300	65.079	74.867	114.940
Human_Capital_Index	19	0.360	0.008	0.345	0.354	0.363	0.366	0.369
Regulatory_Quality	19	0.391	0.028	0.350	0.365	0.400	0.410	0.440
Urban_Population_pct	19	40.931	2.181	37.402	39.194	40.956	42.685	44.375
Output_per_Worker	19	1,252.818	201.583	895.324	1,067.959	1,360.788	1,397.630	1,553.877

Figure 1 illustrates the trend in Chinese FDI inflows from 2005 to 2023. The figure shows that inflows were highly volatile, with sharp increases, declines, and one negative value during the sample period. Although inflows generally became larger in later years, the pattern is clearly unstable rather than smooth. This suggests that annual Chinese investment flows were subject to substantial variation over time.

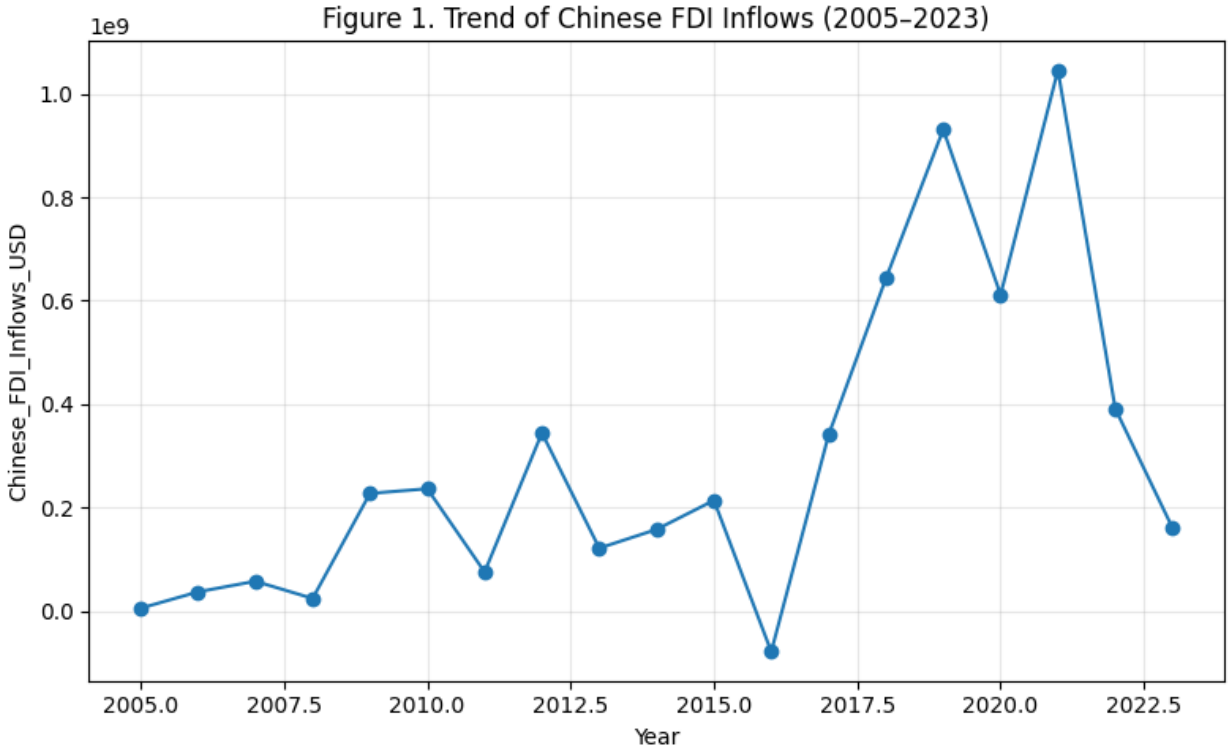

Figure 1: Trend of Chinese FDI Inflows, 2005–2023

Figure 2 presents the evolution of output per worker. The trend is generally upward, rising from about 895 in 2005 to more than 1,550 in 2023. While the increase is not perfectly linear and includes some episodes of slower growth or temporary decline, the overall pattern indicates a long-term improvement in labor productivity.

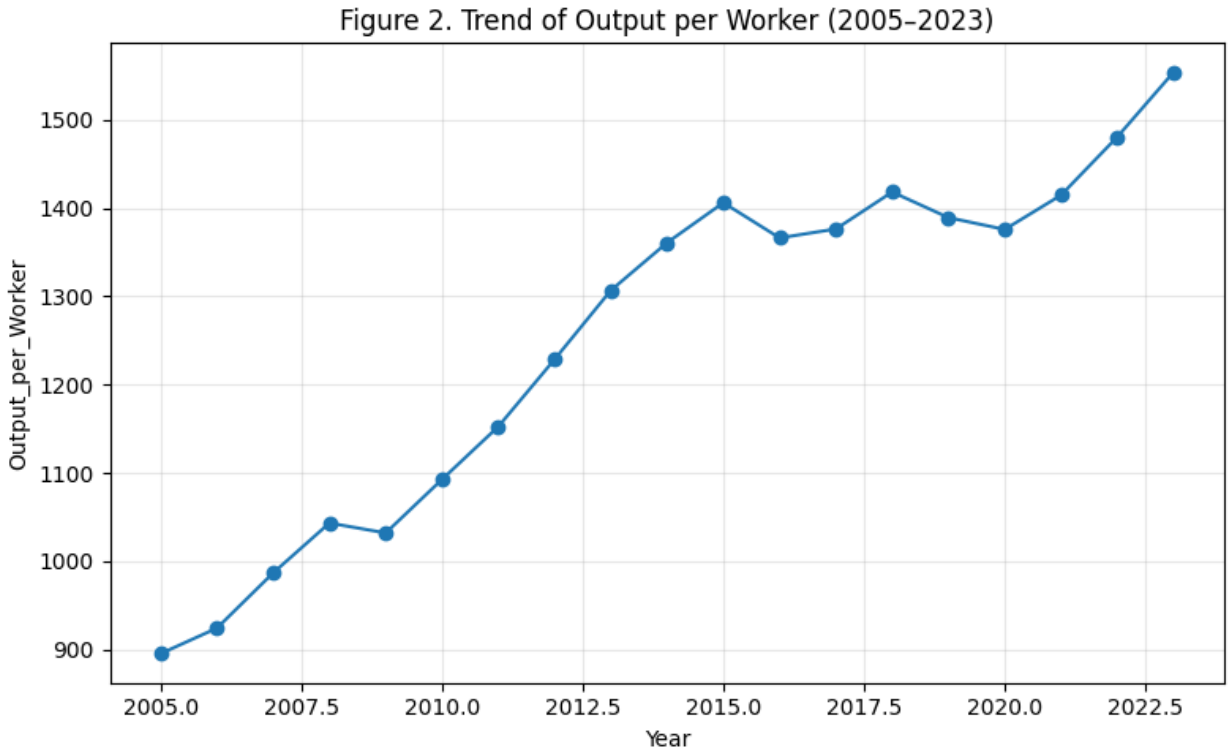

Figure 2: Trend of Output per Worker, 2005–2023

Figure 3 shows the evolution of insurance penetration and insurance density. Both indicators increase over time, although insurance density rises more sharply in the later years. This pattern points to a gradual deepening of the insurance market, particularly after the middle of the sample period.

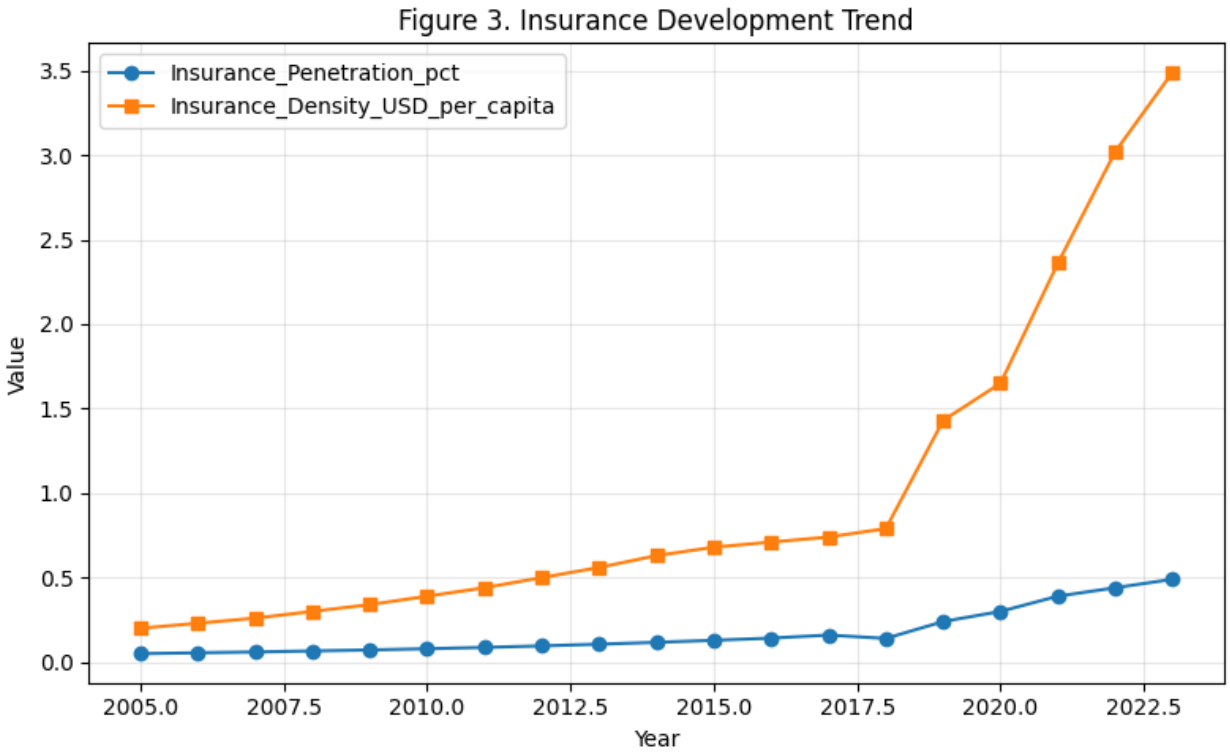

Figure 3: Insurance Development Trend

Figure 4 presents the trends for internet use, mobile subscriptions, gross fixed capital formation, and trade openness. Internet use and mobile subscriptions increase substantially throughout the sample, reflecting an expansion of digital access. In contrast, gross fixed capital formation and trade openness fluctuate more strongly over time, indicating changing macroeconomic conditions.

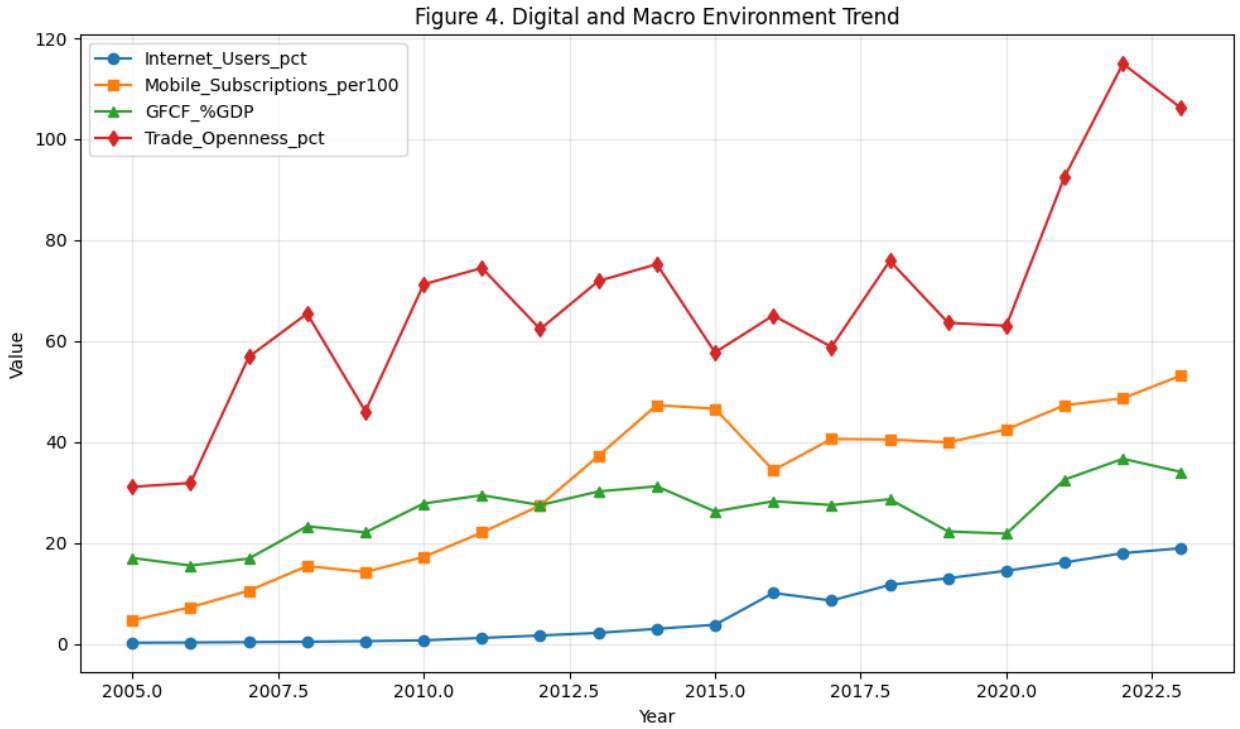

Figure 4: Digital and Macro Environment Trend

Table 2 reports the pairwise correlation matrix. Output per worker is positively correlated with all main explanatory variables. The correlation with Chinese FDI inflows is moderate (0.500), while stronger positive correlations are observed for insurance penetration (0.750), internet use (0.821), gross fixed capital formation (0.769), and trade openness (0.740). These results suggest that productivity is associated not only with foreign investment inflows, but also with digital adoption, capital formation, and financial sector development. However, some explanatory variables are also strongly correlated with one another, especially insurance penetration and internet use (0.932), which points to the possibility of multicollinearity in the regression analysis.

Table 2 : Correlation Matrix

Variable	Chinese_FDI_Inflows_USD	Insurance_Penetration_pct	Internet_Users_pct	Gross_Fixed_Capital_Formation_pctGDP	Trade_Openness_pct	Output_per_Worker
Chinese_FDI_Inflows_USD	1.000	0.521	0.613	0.228	0.329	0.500
Insurance_Penetration_pct	0.521	1.000	0.932	0.605	0.788	0.750
Internet_Users_pct	0.613	0.932	1.000	0.548	0.704	0.821

Gross_Fixed_Capital_Formation_pctGDP	0.228	0.605	0.548	1.000	0.888	0.769
Trade_Openness_pct	0.329	0.788	0.704	0.888	1.000	0.740
Output_per_Worker	0.500	0.750	0.821	0.769	0.740	1.000

Figure 5 provides a scatter plot of Chinese FDI inflows against output per worker. The fitted line suggests a positive relationship between the two variables, but the dispersion of the observations indicates that the relationship is not deterministic. This pattern supports the use of multivariate regression models to assess whether Chinese FDI remains important after controlling for other structural factors.

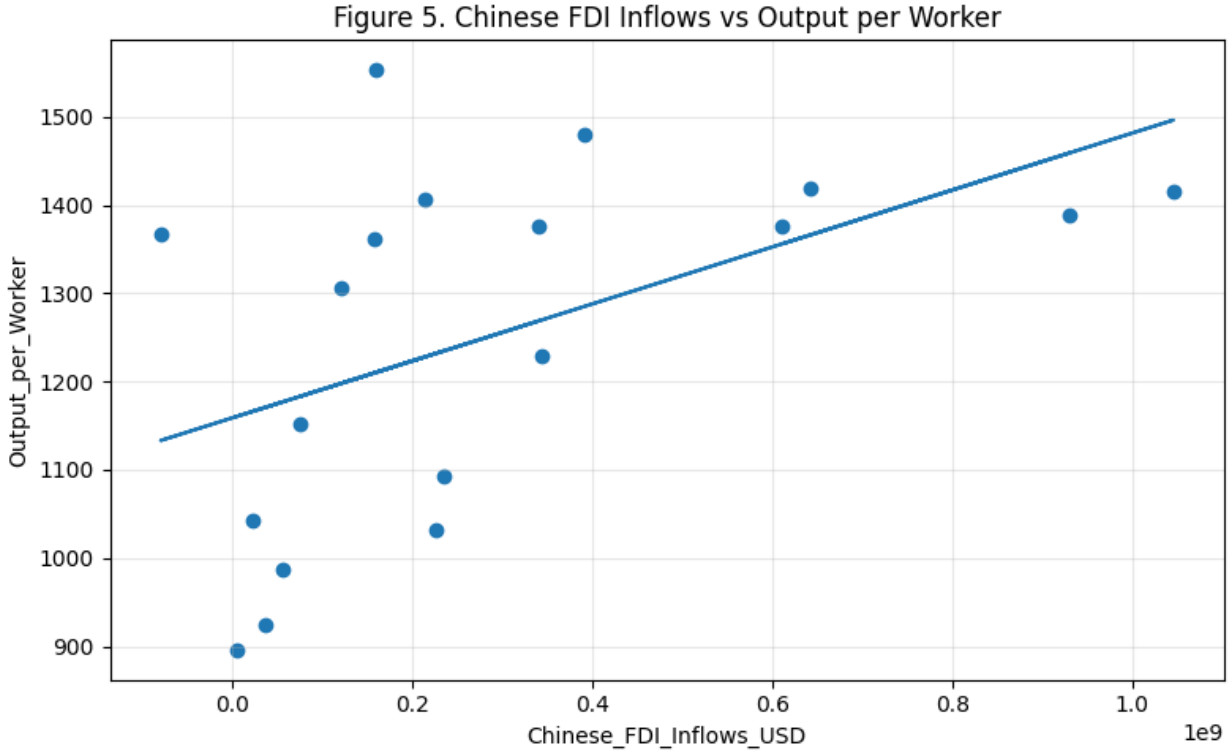

Figure 5 : Chinese FDI Inflows vs Output per Worker

Regression Results

Table 3 reports the estimated coefficients from the regression models, while Table 4 summarizes model fit.

The baseline model in Column 1 shows that Chinese FDI inflows are positively and significantly associated with output per worker. The coefficient is positive and statistically significant at the 5 percent level ($p = 0.029$), suggesting that higher Chinese FDI inflows are associated with higher labor productivity. However, the explanatory power of the model is limited, with an R-squared of 0.250. This indicates that Chinese FDI alone explains about 25 percent of the variation in output per worker.

When insurance penetration is added in Model 2, the explanatory power increases substantially, with R-squared rising to 0.579. Insurance penetration is positive and statistically significant ($p = 0.003$), while the coefficient of Chinese FDI inflows becomes statistically insignificant. This suggests that insurance development captures an important dimension of the structural environment associated with productivity growth.

Model 3 introduces internet use alongside Chinese FDI inflows. The results show that internet use is positive and highly significant ($p < 0.001$), whereas Chinese FDI inflows become insignificant. The model explains approximately 67.4 percent of the variation in output per worker. This indicates that digital connectivity is strongly associated with labor productivity and may be a more immediate driver of productivity than annual FDI inflows.

Model 4 includes Chinese FDI inflows, gross fixed capital formation, and trade openness. In this specification, Chinese FDI inflows remain positive and statistically significant at the 5 percent level ($p = 0.043$), while gross fixed capital formation is positive and marginally significant ($p = 0.059$). Trade openness is not statistically significant. The R-squared increases to 0.704, suggesting that macroeconomic conditions improve the model's explanatory power.

The final compact model in Model 5 includes Chinese FDI inflows, insurance penetration, internet use, and gross fixed capital formation. This is the strongest overall model in terms of explanatory power, with an R-squared of 0.850 and an adjusted R-squared of 0.807. In this specification, internet use remains positive and statistically significant ($p = 0.009$), and gross fixed capital formation is also positive and significant ($p = 0.001$). By contrast, Chinese FDI inflows and insurance penetration are no longer statistically significant. These results suggest that once structural factors are simultaneously considered, digital adoption and capital formation emerge as the most robust correlates of labor productivity.

Table 3 : Regression Coefficients

Variables	**Model 1 Baseline**	**Model 2 Digital**	**Model 3 Macro**	**Model 4 Final Compact**
Chinese_FDI_Inflows_USD	0.000000323 **	-0.000000004	0.000000215 **	0.000000030
	(0.000000136)	(0.000000117)	(0.000000097)	(0.000000086)
Insurance_Penetration_pct				-701.918
				(445.934)
Internet_Users_pct		24.307***		27.901***
		(5.323)		(9.215)
Gross_Fixed_Capital_Formation_pct GDP			21.666*	18.087***

			(10.586)	(4.485)
Trade_Openness_pct			0.650	
			(3.051)	
Constant	1158.633***	1093.256***	576.639***	703.103***
	(57.131)	(41.363)	(137.954)	(105.570)
Observations	19	19	19	19
R-squared	0.250	0.674	0.704	0.850
Adjusted R-squared	0.206	0.634	0.645	0.807

Table 4: Model Summary

Model	R-squared	Adjusted R-squared	F-statistic	F p-value	N	Durbin-Watson
Model 1: Baseline	0.250	0.206	5.666	0.029	19	0.380
Model 2: Insurance	0.579	0.526	11.002	0.001	19	0.241
Model 3: Digital	0.674	0.634	16.565	0.000	19	0.308
Model 4: Macro	0.704	0.645	11.882	0.000	19	0.949
Model 5: Final Compact	0.850	0.807	19.861	0.000	19	1.421

Diagnostic and robustness analysis

The diagnostic tests indicate that the final model is broadly acceptable. Table 5 shows the variance inflation factors. Chinese FDI inflows and gross fixed capital formation display low VIF values, but insurance penetration and internet use have relatively high VIF values, indicating moderate multicollinearity between these variables. This is consistent with the correlation matrix, where both variables were found to be strongly correlated.

Table 6 reports the Breusch–Pagan test, which does not indicate heteroskedasticity, while Table 7 reports the Jarque–Bera test, suggesting that the residuals do not significantly depart from normality. The residual plots also show no major violation of the regression assumptions, although some dispersion remains. The actual-versus-predicted plot indicates that the final model tracks the general movement of output per worker reasonably well without fitting the data unrealistically perfectly.

Table 5: Variance Inflation Factors

Variable	VIF
Constant	27.052
Chinese_FDI_Inflows_USD	1.676
Insurance_Penetration_pct	8.552
Internet_Users_pct	9.133
Gross_Fixed_Capital_Formation_pctGDP	1.604

Table 6: Breusch–Pagan Test

Test	Value
LM Statistic	0.936
LM p-value	0.919
F Statistic	0.181
F p-value	0.944

Table 7: Jarque–Bera Test

Statistic	Value
Jarque–Bera	2.462
p-value	0.292
Skewness	0.852
Kurtosis	3.455

The robustness checks in Tables 8 and 9 confirm the main findings. When Chinese FDI stock is used instead of annual inflows, the stock variable becomes positive and statistically significant, and the overall model fit improves substantially. This suggests that the long-term accumulated presence of Chinese investment may matter more for productivity than annual fluctuations in inflows. When insurance density replaces insurance penetration, the insurance variable is not statistically significant, but internet use and gross fixed capital formation remain significant. When mobile subscriptions are used instead of internet use, mobile connectivity becomes strongly positive and significant, while Chinese FDI inflows and insurance penetration remain insignificant. Taken together, the robustness checks reinforce the conclusion that digital

connectivity and capital formation are more stable predictors of productivity than short-run investment inflows.

Table 8: Robustness Coefficients

Variables	Robustness A: Use FDI Stock	Robustness B: Use Insurance Density	Robustness C: Use Mobile
Chinese_FDI_Stock_USD	0.000000087***		
	(0.000000021)		
Chinese_FDI_Inflows_USD		0.000000012	0.000000007
		(0.000000087)	(0.000000038)
Insurance_Penetration_pct	330.379		56.666
	(390.631)		(109.286)
Insurance_Density_USD_per_capita		-94.496	
		(54.187)	
Internet_Users_pct	-9.843	27.340***	
	(10.975)	(8.233)	
Mobile_Subscriptions_per100			11.561***
			(1.176)
Gross_Fixed_Capital_Formation_pctGDP	14.011***	18.420***	1.914
	(3.138)	(4.436)	(2.627)
Constant	696.509***	677.757***	827.529***
	(69.210)	(105.829)	(50.819)
Observations	19	19	19
R-squared	0.932	0.855	0.969
Adjusted R-squared	0.913	0.814	0.960

Table 9: Robustness Summary

Model	R-squared	Adjusted R-squared	F-statistic	F p-value	N	Durbin-Watson
Robustness A: Use Stock	0.932	0.913	48.185	0.000	19	1.908
Robustness B: Use Density	0.855	0.814	20.659	0.000	19	1.471
Robustness C: Use Mobile	0.969	0.960	108.109	0.000	19	1.436

DISCUSSION

This study examined the relationship between Chinese FDI, digital adoption, and labor productivity in the Democratic Republic of the Congo over the period 2005–2023. The results provide several important insights into how external investment and domestic structural conditions are linked to productivity performance in the Congolese economy.

First, the baseline estimates show that Chinese FDI inflows are positively associated with output per worker. This suggests that Chinese investment may contribute to labor productivity improvement when considered on its own. However, the relatively modest explanatory power of the baseline model indicates that annual FDI inflows alone do not fully explain productivity dynamics in the Democratic Republic of the Congo. In other words, foreign investment appears relevant, but it is not sufficient by itself to account for broader changes in labor productivity.

Second, the findings highlight the central role of digital adoption. Internet use is positive and statistically significant in both the digital model and the final compact specification, while mobile subscriptions are strongly significant in the robustness analysis. This pattern indicates that labor productivity in the Democratic Republic of the Congo is more consistently associated with digital connectivity than with short-term changes in annual Chinese FDI inflows. A plausible interpretation is that the benefits of foreign investment depend partly on local absorptive capacity. When firms, workers, and markets are better connected through digital infrastructure, the domestic economy may be better able to benefit from knowledge flows, market information, technology use, and productivity-enhancing adjustments.

Third, gross fixed capital formation emerges as another robust determinant of labor productivity. The positive effect of capital formation in the macro model and the final model suggests that investment in productive assets, infrastructure, and equipment remains an important channel through which labor productivity can improve. In the Congolese context, this result is particularly relevant because productivity gains are unlikely to be sustained without complementary domestic investment. This means that Chinese FDI may be more effective when it is accompanied by broader capital accumulation within the host economy.

The role of insurance development appears more nuanced. Insurance penetration is statistically significant when entered with Chinese FDI in the insurance specification, but it loses significance in the final model once internet use and capital formation are included. This suggests that insurance development may be

associated with productivity through broader structural and institutional improvement rather than as an independently dominant factor. In the case of the Democratic Republic of the Congo, insurance deepening may still matter, but its contribution appears less robust than digital adoption and capital formation in explaining labor productivity.

Another important result concerns the difference between Chinese FDI inflows and Chinese FDI stock. While annual inflows are significant only in some specifications, Chinese FDI stock is positive and significant in the robustness analysis. This indicates that the long-term accumulated presence of Chinese investment may be more relevant for labor productivity than year-to-year changes in new inflows. In practical terms, sustained investment relationships, established production linkages, and long-run capital presence may matter more for productivity enhancement than short-run fluctuations in investment flows.

Taken together, these findings suggest that the productivity effects of Chinese FDI in the Democratic Republic of the Congo are conditional rather than automatic. The results do not support a narrow interpretation in which foreign investment alone drives labor productivity growth. Instead, they point to a broader development process in which Chinese FDI interacts with domestic structural factors, especially digital adoption and capital formation. This implies that the economic value of foreign investment depends not only on the volume of inflows, but also on the domestic environment in which these inflows operate.

At the same time, the findings should be interpreted with caution. The analysis is based on a relatively small annual time-series sample, which limits statistical power. Some evidence of multicollinearity is present, particularly between insurance penetration and internet use, and the Durbin–Watson statistics suggest that some serial correlation may remain in certain specifications. For this reason, the results should be understood as evidence of association rather than strict causality.

Overall, the discussion reinforces the main message of the study: labor productivity in the Democratic Republic of the Congo is more consistently linked to digital adoption and capital formation than to short-term Chinese FDI inflows alone. Nevertheless, the significance of Chinese FDI stock in the robustness analysis suggests that sustained Chinese investment presence may still play an important supporting role in the country's long-term productivity transformation.

CONCLUSION AND FUTURE DIRECTION

This study examined the relationship between Chinese FDI, digital adoption, and labor productivity in the Democratic Republic of the Congo over the period 2005–2023. Using annual time-series data, the analysis focused on output per worker as a proxy for labor productivity and assessed the role of Chinese FDI inflows alongside digital, structural, and macroeconomic variables.

The results show that Chinese FDI inflows are positively associated with labor productivity in the baseline specification, suggesting that foreign investment may contribute to productivity improvement when considered in isolation. However, this effect becomes weaker once additional structural variables are introduced. In the full model, internet use and gross fixed capital formation emerge as the most robust predictors of output per worker, while Chinese FDI inflows lose statistical significance. This indicates that productivity growth in the Democratic Republic of the Congo is more consistently linked to domestic structural conditions than to short-term changes in annual foreign investment flows alone.

The robustness analysis further strengthens this interpretation. Chinese FDI stock is positive and significant when used instead of annual inflows, suggesting that the long-term presence of Chinese investment may matter more than year-to-year fluctuations in new inflows. In addition, mobile subscriptions also appear strongly associated with labor productivity, reinforcing the importance of digital connectivity in the

Congolese economy. By contrast, insurance variables show weaker and less stable effects once digital and capital-related variables are included in the model.

Overall, the findings suggest that Chinese FDI may support labor productivity, but its contribution is likely to be conditional on the broader domestic environment. The evidence points to a development process in which foreign investment, digital adoption, and capital formation interact rather than operate independently. Therefore, policies aimed at improving labor productivity in the Democratic Republic of the Congo should not focus only on attracting foreign investment, but also on strengthening digital infrastructure and supporting domestic capital accumulation.

Although the study provides useful empirical evidence, the findings should be interpreted with caution because the sample is relatively small and based on annual observations. For this reason, the results are better understood as evidence of association rather than strict causality. Even so, the analysis offers an important contribution by showing that the productivity effects of Chinese investment in the Democratic Republic of the Congo are likely to depend on the country's capacity to absorb and translate investment into broader structural transformation.

Several directions for future research emerge from this study. First, future work could expand the dataset by using quarterly observations or a longer time horizon in order to improve statistical power and capture more detailed dynamics in the relationship between foreign investment and productivity. Second, future studies could examine sector-level effects, especially in mining, infrastructure, manufacturing, and services, to identify whether Chinese FDI has different productivity impacts across sectors of the Congolese economy.

Third, future research could incorporate additional institutional and governance variables, such as regulatory effectiveness, education quality, financial inclusion, and infrastructure quality, in order to better understand the conditions under which Chinese FDI generates stronger productivity gains. Fourth, a comparative study across African countries could help determine whether the patterns observed in the Democratic Republic of the Congo are country-specific or part of a broader regional trend.

Finally, future research could move beyond associational analysis by applying more advanced econometric approaches, such as cointegration methods, vector error-correction models, or panel techniques, to explore long-run dynamics and possible causal channels in greater depth. Such work would help clarify whether Chinese FDI directly raises productivity or whether its effects operate mainly through complementary factors such as digital adoption, technology diffusion, and capital formation.

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