Chinese Economic Ties and Low-carbon Industrialization in Africa

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ABSTRACT

This working paper examines the impact of Chinese foreign direct investment (FDI) on low-carbon industrialization in Africa, within the context of China's growing economic ties with the continent. The analysis relies on a panel dataset comprising Chinese FDI into the manufacturing sectors of 34 African countries from 2003-2014, employing the Lewbel Instrumental Variable approach to address potential endogeneity issues. Findings from the study reveal that these Chinese FDI inflows increased industrial carbon emissions in Africa. Additional analysis conducted in the study shows that this adverse effect is particularly pronounced when Chinese FDI targets labor and resource-intensive manufacturing sectors. Interestingly, this effect is not observed for FDI sourced from the Organization for Economic Co-operation and Development (OECD) countries, despite its similar concentration in resource-intensive sectors. We attribute this finding to two mechanisms: the sector concentration on labor and resource-intensive manufacturing and the manufacturing processes of Chinese FDI characterized with suboptimal de facto implementation of environmental, social and governance (ESG) standards compared to the international best practices. Additional analysis underscores the potential moderating influence of recipient countries' environmental regulations, albeit statistically insignificant, highlighting the legacy

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of ineffective institutional enforcement that is prevalent on the Africa continent. Overall, the findings highlight the complex interplay between Chinese economic engagement and environmental outcomes in Africa. We discuss the policy implications, underscoring the importance of strengthening environmental governance to harness the developmental benefits of Chinese FDI while minimizing its environmental costs.

Keywords: Foreign Direct Investment; Carbon Intensive Manufacturing; Africa; China

JEL Code: F21, N60, O4, O5

INTRODUCTION

Since the establishment of the Forum on China-Africa Cooperation (FOCAC) in 2000 and the China-Africa Development Fund in 2006, China's economic ties with Africa have grown and deepened significantly. China is currently Africa's largest trading partner, and in many African countries, has become the top export destination and largest supplier of imports (Torreggiani & Andreoni, 2019; Owusu et al., 2022). China's financial involvement with Africa has also steadily increased. For instance, since 2000, China has provided over $1 trillion in development financing to developing countries, rivaling traditional multilateral development banks and Western countries (Horn et al., 2019; Humphrey & Michaelowa, 2019, Dreher et al., 2022). Moreover, since 2013, China has overtaken the US to become the world's largest bilateral provider of foreign direct investment (FDI) to Africa (Yu, 2021). However, China's deepening connections with Africa have been the subject of discussion regarding their composition, goals, nature and implications for the continent's industrial and economic development.

An evaluation of the pattern of China's FDI into Africa reveals a concentration in the energy and natural resource sectors, raising questions about China's resource-seeking intent (*Financial Times*, 2013). Furthermore, the rise of Chinese FDI in Africa has coincided with the continent's high commodity exports to China (Zafar, 2007; Garcia-Herrero & Casanova, 2017) and imports of low-cost, low-technology and labor-intensive manufactures from China (Torreggiani & Andreoni, 2019). Consequently, the potential impact of Chinese FDI on Africa's industrialization prospects, especially the transition to low-carbon industrialization, becomes an empirical question. The first objective of this working paper is to address this question by examining how the manufacturing carbon intensity in Africa is influenced by the aggregate and composition of Chinese manufacturing FDI into Africa.

However, the potential effect of Chinese FDI on low-carbon industrialization in Africa could be conditioned by important moderating factors related to the type of FDI, (i.e., sectors receiving FDI) or environmental regulations, which play a major role in determining the overall impact (Adekoya, 2022). Therefore, as the second objective, we employ an empirical approach that accounts for the moderating roles of environmental regulation and FDI type in this FDI and low-carbon industrialization nexus.

To address these questions, we compile a panel dataset comprising Chinese FDI into the manufacturing sectors of 34 African countries from 2003-2014, using deal-level FDI data from the FDI Intelligence Data developed by the Financial Times. The panel also includes information on all other FDI sources to the targeted countries, enabling us to compute the share of Chinese FDI out of the total FDI received by a country each year. We merge this dataset with data on carbon emissions from the industrial sector as a share of total fuel combustion of the same target countries and years, sourced from the World Bank World Development Indicators. Employing both a fixed effects model and an instrumental variable method to address potential endogeneity, the study offers four sets of results. First, manufacturing FDI from China increases manufacturing carbon dioxide (CO_2)

emissions in Africa. Second, this effect increases if the manufacturing FDI from China is channeled into the labor and resource-intensive manufacturing sectors. We find no significant effect when the FDI is channeled into knowledge-intensive manufacturing sectors of recipient countries in Africa. Third, the results show the important role of stronger environmental regulations in moderating the manufacturing CO_2 emissions effect of Chinese FDI to Africa, albeit statistically insignificant. More specially, the results indicate that the manufacturing CO_2 emissions of Chinese FDI are lower for countries with strong and well-functioning environmental regulations.

The study offers empirical evidence, theoretical insights and practical recommendations that contribute to our understanding of the complex relationship between FDI and sustainable industrial development. First, it contributes to the growing body of literature on the impact of FDI on inclusive green growth (Borga, 2021; Ofori et al., 2023). While previous literature generally examines FDI and its impacts on carbon emissions at the aggregate level, this working paper focuses specifically on the manufacturing FDI and carbon emissions within the same sector, controlling for different sources of FDI, thereby overcoming potential issues with aggregation bias. Consequently, this study represents the first attempt to quantify how FDI affects the carbon intensity of manufacturing production in Africa, offering insights into the prospects of low-carbon industrialization in the world's least industrialized continent.

Second, this working paper contributes to the understanding of the mechanisms behind the environmental impacts of China's FDI. We specifically examine the role of sector and environmental regulation. We also examine how Chinese FDI impacts on industrial development compares to when the FDI originates from other sources. The results show that Chinese manufacturing FDI in resource-intensive and labor-intensive sectors increases carbon emissions, whereas FDI in technology-intensive sectors does not. In contrast, FDI from countries within the Organization for Economic Co-operation and Development (OECD), despite its similar concentration in resource-intensive sectors, does not have a statistically significant impact on carbon emissions, potentially due to their higher implementation of ESG standards during the manufacturing processes. These two empirical findings indicate that both the source of FDI, which generally determines the level of adherence to clean production processes, and the sector of the FDI are important factors in determining environmental impacts. The results also show the crucial role of environmental regulation in moderating the effect although this effect we find is not significant which could be largely attributed to a lack of effective enforcement of environmental regulation or weak regulatory institutions, more broadly that plague the continent.The remainder of the working paper is organized as follows. The second section discusses the theoretical perspectives of FDI and low-carbon industrialization. The third section discusses the datasets and method, while the fourth section discusses the results. The fifth section concludes.

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LITERATURE REVIEW

Low Carbon Manufacturing and Africa's Industrialization Future

The success of Africa's industrialization prospects hinges on adeptly managing the climate transition. The global imperative to shift towards a greener economy carries profound implications for manufacturing production and trade in Africa. Despite contributing less than 4 percent to total global emissions, the region grapples with a disproportionately high level of climate risks. The interlinkage between climate change and Africa's productive capacity is underscored by its substantial reliance on commodities, rendering it economically vulnerable to climatic fluctuations. Notably, a staggering 95 percent of agriculture in Africa depends on rainfall, accentuating vulnerability due to the sector's substantial contribution to regional employment and gross domestic product (GDP) (African Development Bank, 2019). Furthermore, evolving consumer preferences in key export markets towards sustainable products present a formidable challenge.

In terms of concerns, the pushback on low-carbon industrialization policies hinges on the premise that these policies could potentially stymie Africa's industrialization aspirations. This risk arises from the constraints on export opportunities, the erection of entry barriers and the stifling of rents from value chain trade. Given that a considerable portion of Africa's exports is resource-based, predominantly derived from extractive resources like minerals and fossil fuels, policies such as the European Union's carbon border adjustment measure (CBAM) could potentially undo the gains achieved from these carbon-intensive exports (He et al, 2022). Moreover, the transition to low-carbon industrialization is a costly endeavor, characterized by labor-saving practices and necessitating substantial investments in capabilities to ensure competitiveness. Many African nations find themselves grappling with a transition lag, both in terms of infrastructure, capabilities and fiscal constraints hindering the financing of this transformative process. In this context, FDI from China assumes significant relevance, given China's ascension as the world's largest bilateral FDI investor. Amidst these challenges, the shift to low-carbon manufacturing presents a unique opportunity for Africa to invest in climate-smart manufacturing. This strategic pivot away from commodity dependence could pave the way for enhanced competitiveness, efficiency and the creation of higher value-added products.

Theoretical Perspectives: FDI and Low-carbon Industrialization

The implications of FDI on low-carbon industrialization are less straightforward. On the one hand, FDI is often associated with the deployment of advanced technologies that are inherently cleaner than those employed by domestic producers, particularly in developing recipient countries. Multinational corporations (MNCs) possess sophisticated production, cleaner and pollution-control technologies and practices which they transfer to their affiliates in developing countries. This infusion of cleaner technologies can act as a catalyst for improvements in industrial processes in the host country, as it enables the development and implementation of cleaner production methods, energy-efficient technologies and industrial waste reduction strategies, resulting in the reduction of emissions throughout the production lifecycle "Pollution Halo" effect (Gallagher & Zarsky, 2007; Demena & Afesorgbor, 2020).

While this knowledge transfer often takes place involuntarily through MNCs' interaction with domestic firms in recipient countries, it can also occur through voluntary actions, where MNCs voluntarily share new knowledge with their domestic input suppliers to ensure more efficient production of the outsourced tasks. However, for domestic firms wanting to participate and benefit from the global production network, MNCs require these firms to have certain productive capabilities to enter and remain competitive. To satisfy these requirements, domestic firms (suppliers) are compelled to make investments to build specific capabilities for the specific activities they perform in the production network. Such investment could involve introducing new environmentally friendly production technologies, adopting a mix of innovations, engaging in skill upgrades for workers to utilize equipment and information efficiently, or even changing organizational structure, which could lead to improvements in cleaner production methods resulting in reduced emissions from industrial production (Humphrey & Schmitz, 2002; Pietrobelli & Rabellotti, 2011; Ndubuisi & Owusu, 2021, 2023).

On the other hand, challenges arise in low-income countries where fierce competition among developing nations for foreign investors (attraction of resource-seeking and pollution-intensive FDI) may result in the lowering of environmental standards for foreign investors, potentially resulting in heightened emissions and increasing pollution in weakly regulated developing countries (Zugravu-Soilita, 2017). In essence, the impact of FDI on low-carbon industrialization is an empirical question and is conditioned on the type of FDI and the regulatory quality of the recipient country, calling for a nuanced approach that takes into account the complexities in the FDI-low-carbon industrialization nexus.

The Role of Chinese FDI in Low-carbon Industrialization in Africa

Some literature has started to examine the goals and impacts of Chinese FDI in Africa. Empirical analysis of transaction-level data on registered small- and medium-sized Chinese private firms investing in Africa between 1998-2012 suggests Chinese investment is more prevalent in skill-intensive sectors in more skill-abundant countries and more concentrated in capital-intensive sectors in more capital-scarce countries, indicating an aim to leverage local comparative advantages (Chen et al. 2018). However, data on Chinese economic engagement across 50 African countries shows China's construction activities and exports negatively impact the environment and CO_2 emissions in host nations (Tawiah et al. 2021). Large infrastructure projects like roads, railways and airports generate pollution from dust, water contamination and fossil fuel use, while investments in the resource extraction industry degrade local environments. Similarly, Chen et al. (2023) find that Chinese FDI and exports to Africa had a negative relationship with green growth indicators, suggesting that China's resource extraction focus undermines sustainable development goals.

A review article by Calabrese and Tang (2022) finds that Chinese firms' major investments in African manufacturing and construction sectors have prompted views that Africa could become "the next factory of the world" (Sun, 2017). They argue that Chinese FDI into productive sectors broadly promotes structural economic transformation in Africa through industrialization and diversification. However, they raise concerns about the environmental impacts of Chinese FDI in extractives and agriculture, as well as governance issues like bribery. Adding to this, Larsen et al., (2023) note that much of the funding for Chinese outward FDI lacks policies or guidelines on low-carbon, green transformation or sustainable growth. However, they also argue that such challenges are not unique to Chinese firms operating in countries with weak regulation.

Several gaps remain in the existing literature on the empirical evidence examining the impacts of Chinese FDI on Africa's prospect for low-carbon industrialization. First, the analysis does not generally control for other sources of FDI, which could also impact the carbon emission of Africa's industries. Second, the extant literature focuses on aggregate FDI levels without disaggregating the different subsectors of manufacturing industries, yet the heterogeneous effects of industry activities may be the real driving force. Third, when analyzing carbon emission effects, the literature focuses on total country-level CO_2 emissions rather than individual sector emissions, which could introduce many sector-level endogenous factors. Our study fills these gaps in the literature and in addition, contributes to our understanding of the complex interplay between Chinese economic engagement and environmental outcomes in Africa.

RESEARCH DESIGN

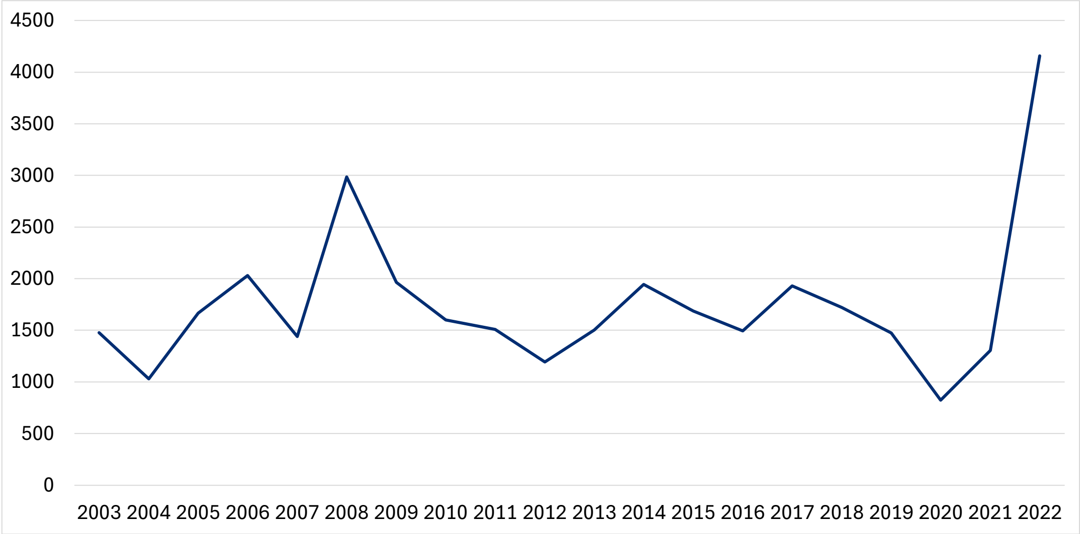
Variables and Data Sources

It is challenging to estimate the true scale of China's FDI in Africa, given that nearly 60 percent of China's outbound FDI is commissioned through offshore financial centers like Hong Kong, the British Virgin Islands and the Cayman Islands (Johns Hopkins University SAIS China-Africa Research Initiative, 2022). The most official records of China's investment in Africa can be found in the Ministry of Commerce's (MOFCOM) yearly statistical bulletin of China's FDI flows and stocks by region and sector, and this dataset has also been used by the previous literature on Chinese overseas FDI (Chen et al., 2018; Stone et al., 2021).

While the MOFCOM data on overseas FDI provides valuable insights, there are three caveats worth noting. First, MOFCOM stopped publishing its data after 2014, making it challenging to observe trends beyond that year. Second, the MOFCOM FDI data only lists the existence of a firm investing in a targeted country, but not the total value of the investment, thereby making it hard to measure the scale of FDI. Third, it lacks information on FDI from other sources to a targeted country on a yearly basis. Fortunately, the FDI Intelligence Dataset developed by the *Financial Times* allows us to break down the FDI capital investment amount by source, year and sector. The FDI Intelligence Data tracks daily greenfield investment announcements from all sources to all sectors in target countries. The reason we focus solely on greenfield FDI and exclude mergers and acquisitions (M&A) FDI is that only 1 percent of China's M&A FDI in Africa between 2000-2022 was directed to the manufacturing sector (Moses et al., 2024). Instead, Chinese M&A FDI in Africa has concentrated heavily on the mining and energy sectors, making it less relevant to our primary focus on manufacturing FDI. The data spans 2003-2022 and includes information on the total amount of capital investment. Given that the FDI Intelligence database tracks investment announcements rather than the actual operation of investments, we took additional steps to confirm the validity of the Chinese FDI information. Specifically, we double-checked the implementation status and total investment value for each of the 665 transactions in the total deal count, on a deal-by-deal basis.

Using this data, we constructed the share of Chinese FDI of the total FDI flows to targeted countries in a given year in Africa. Our empirical measure of carbon emission intensity index relies on the data on manufacturing industry CO_2 emission (percent of total fuel combustion) from the World Development Indicator (WDI). Due to missing data points for some countries and the availability of corresponding data series for the Chinese FDI data, we extracted a sample of 34 countries. See Table A1 in the Appendix for the full set of countries used in the final analysis. Figure 1 shows that the world FDI to Africa's manufacturing sector grew from $0.1 billion in 2003 to $4.2 billion in 2020. The top five African countries with the highest amount of manufacturing FDI are Egypt, Nigeria, South Africa, Morocco and Angola.

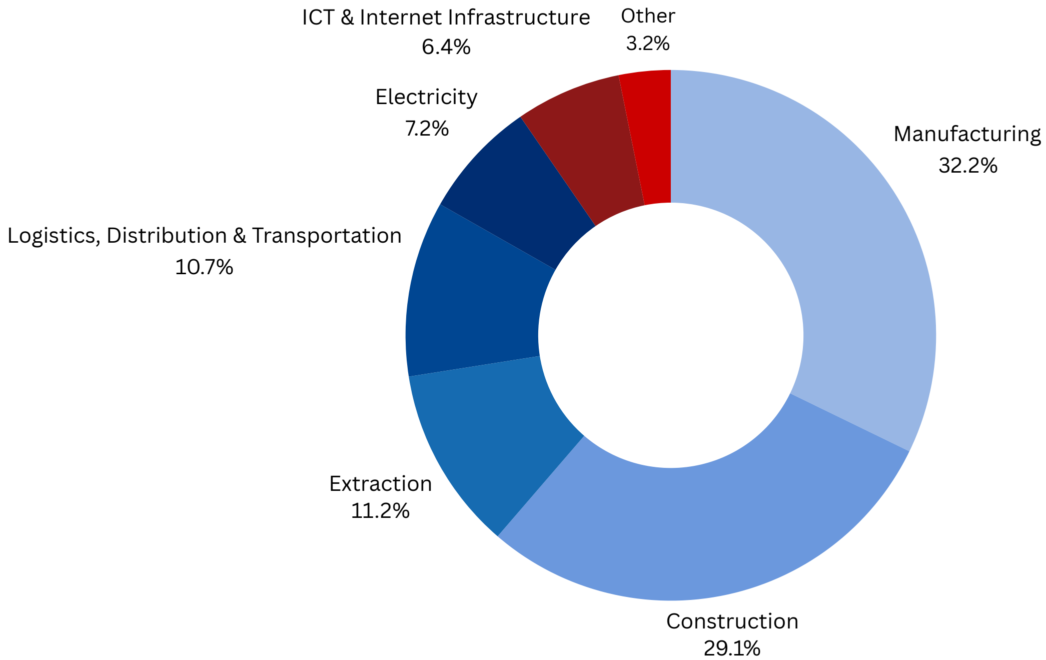
Figure 1. Annual Total FDI Inflow to Africa's Manufacturing Industry, Million USD



Source: Authors analysis using data from FDI Intelligence database.

Figure 2 shows that the manufacturing sector attracts the most Chinese investment in Africa. By the end of 2022, 32.2 percent of Chinese FDI stock in Africa was concentrated in the manufacturing sector, followed by 29.1 percent in construction, 11.2 percent in extraction, 10.7 percent in logistics, distribution and transportation, 7.2 percent in electricity, and 6.4 percent in ICT and internet infrastructure. The significant share of the manufacturing sector in China's FDI to Africa makes it pertinent to study the general environmental impacts of Chinese manufacturing FDI on the continent.

Figure 2. Chinese FDI to Africa, by Sector, 2003-2022

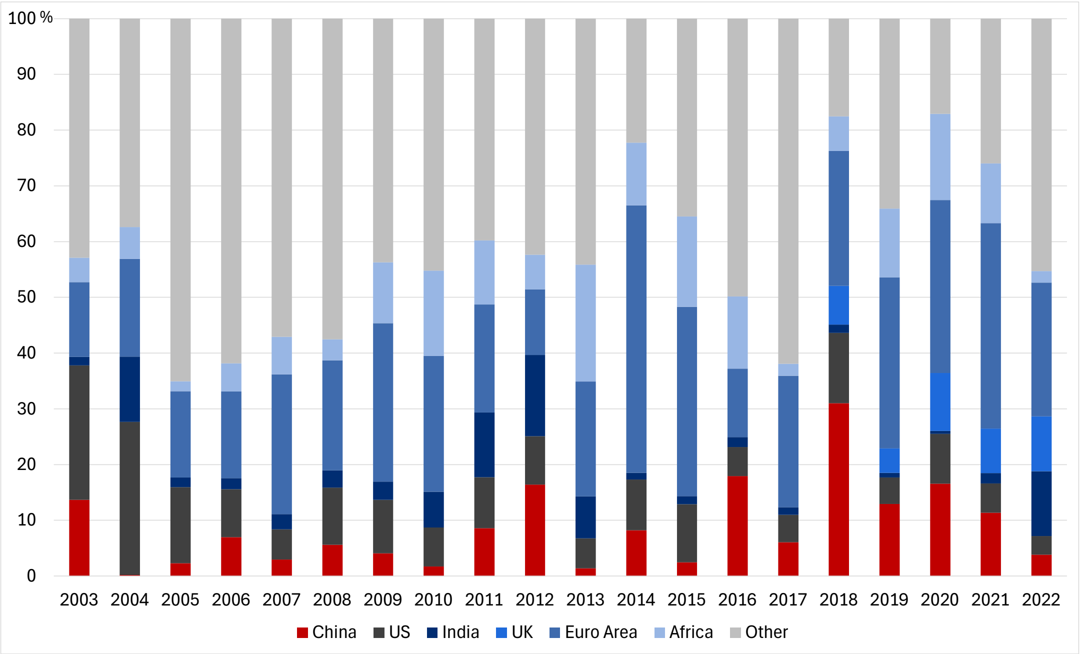


Source: Authors analysis using data from FDI Intelligence database.

Figure 3 presents a dynamic landscape of annual FDI inflows to Africa's manufacturing industry, expressed as percentages from various sources over two decades. Since around 2012, China has emerged as the most significant source of bilateral FDI to Africa's manufacturing industry. This is particularly evident in 2018, when China's contribution peaked at 31 percent. However, this trend experienced a sharp reversal in 2022, with China's share dropping to 4 percent. This decline can be attributed to two major factors. Firstly, the looming sovereign debt crisis in the region, with China being the single biggest bilateral official lender, likely made investors cautious. Secondly, the global COVID-19 pandemic has had widespread economic impacts, disrupting investment flows worldwide. These factors combined have led to a significant reduction in FDI from China to Africa's manufacturing industry in 2022.

Despite these challenges, the data underscores the pivotal role China plays in Africa's manufacturing sector. The US has maintained a relatively stable presence, often contributing around 10 percent, with a high of 27 percent in 2004. India's share has seen sporadic peaks, such as 15 percent in 2012, while the United Kingdom's involvement only became notable from 2018 onwards. The Euro area has been a consistent contributor, particularly in 2014 when it accounted for nearly half of the FDI at 48 percent. Interestingly, Africa's self-investment peaked in 2013 at 21 percent, reflecting a growing internal market.

Figure 3. Annual FDI Inflow to Africa's Manufacturing Industry, by Sources, Percent

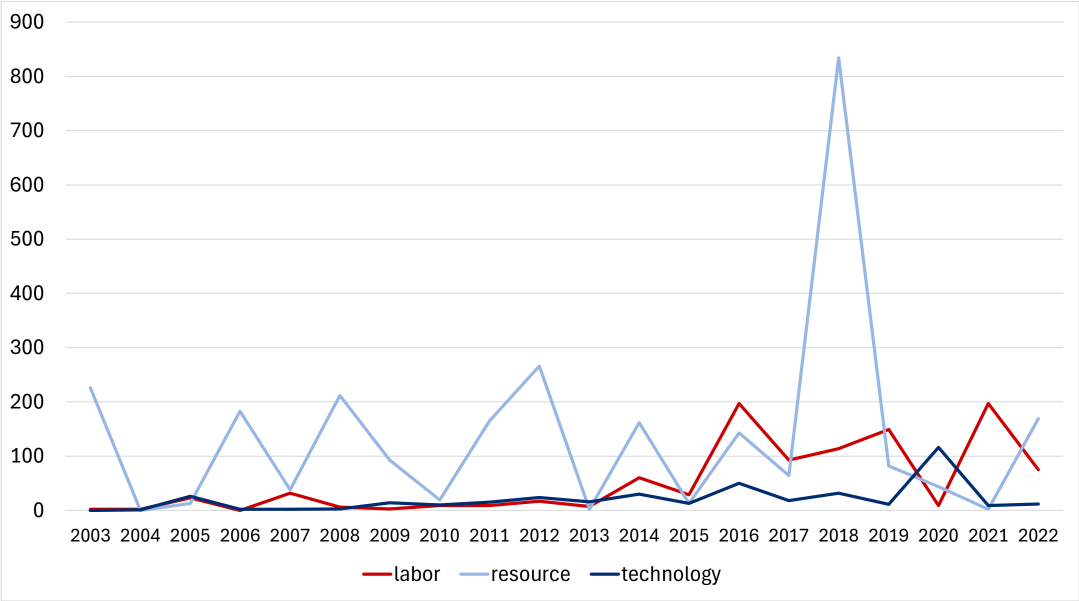


Source: Authors analysis using data from FDI Intelligence database.

Figure 4 presents the annual Chinese FDI inflow to Africa's manufacturing sector, categorized by sector characteristics and denominated in million USD. The sectors are divided into labor-intensive, resource-intensive and technology-intensive. The increase in investment in the labor-intensive sector, particularly noticeable in 2016, coincides with discussions on the prospect of industrial policy and structural transformation in Africa. This is particularly relevant in the cases of Ethiopia and Rwanda, where there has been a significant focus on labor-intensive manufacturing as a driver of economic growth. The resource-intensive sector has traditionally attracted the highest amount of

FDI. However, since 2015, there has been a shift with the labor-intensive and technology-intensive sectors gradually overtaking the resource-intensive sector. This could be due to the commodity price slump since late 2014, which made resource-intensive investments less attractive. The exception to this trend is the unusual spike in resource-intensive investment in 2018. The technology sector sees its highest investment in 2020.

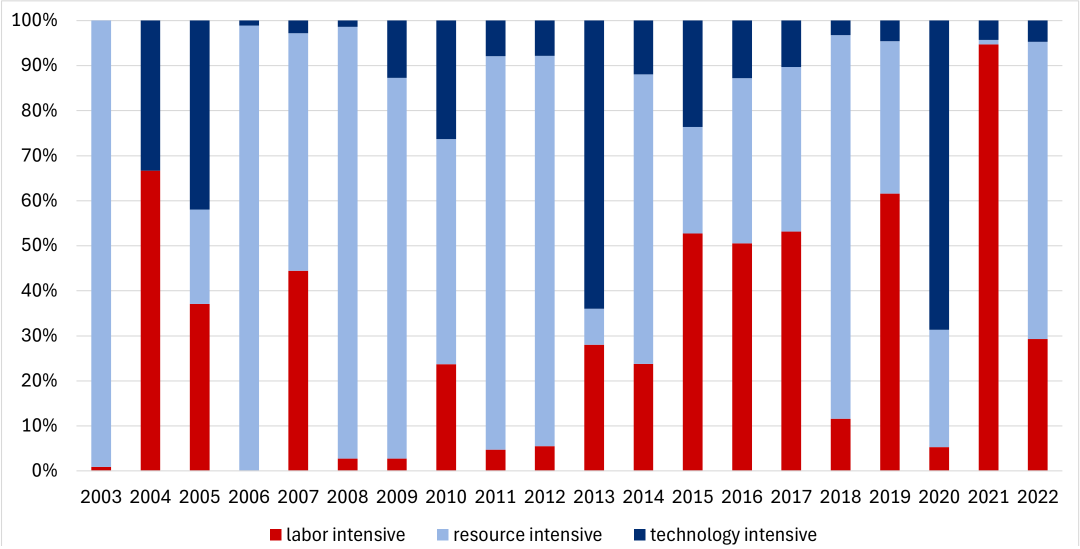
Figure 4. Annual Chinese FDI Inflow to Africa's Manufacturing Sector, Million USD



Source: Authors analysis using data from FDI Intelligence database.

Figure 5 enriches the insights gleaned from Figure 4 by showcasing the proportional distribution of China's manufacturing FDI across different sector characteristics over the years. Despite its historical dominance, the resource-intensive sector has experienced a gradual decline in its share since 2015. In contrast, the labor-intensive and technology-intensive sectors have seen their shares increase, mirroring China's strategic emphasis on these sectors. This shift is particularly pronounced in 2021 when the labor-intensive sector accounted for a substantial 95 percent of the FDI. The technology-intensive sector, which witnessed its peak absolute investment in 2020 according to Figure 4, also demonstrated a significant relative surge in its share in the same year as per Figure 5. This trend underscores the escalating significance of the telecommunications technology sector in China's FDI strategy in Africa, with Huawei and ZTE emerging as the leading players. However, the resource-intensive sector still experienced intermittent spikes, such as in 2018, indicating its continued relevance to Chinese investors.

Figure 5. Annual Chinese FDI Inflow to Africa's Manufacturing Sector, Percent



Source: Authors' analysis using data from FDI Intelligence database.

Figures A1 and A2 in the Appendix provide a comprehensive view of the annual OECD countries' FDI inflows to Africa's manufacturing sector by sector characteristics, both in absolute amounts (million USD) and as a share of total manufacturing FDI. The resource-intensive sector has traditionally been the primary recipient of FDI, with a notable peak in 2022 at $2.11 billion. The labor-intensive sector saw a significant increase in 2008, reaching $466 million, which aligns with a broader focus on labor-intensive manufacturing for economic growth. The technology-intensive sector experienced its highest investment in 2020, amounting to $163 million, reflecting a growing interest in technology-driven development.

In terms of FDI share by sector, the resource-intensive sector consistently held the majority share, especially in 2022 with 85 percent of the total FDI. The labor-intensive sector had a substantial share in 2008 at 39 percent, indicating a strategic shift towards labor-intensive investments during that period. The technology-intensive sector saw an increase in its share over time, peaking at 26 percent in 2020, suggesting an evolving focus on technological advancements within the manufacturing industry. These trends highlight the shifting priorities of OECD countries in their investment strategies in Africa, with a clear emphasis on resource-intensive sectors, while also recognizing the potential of labor and technology sectors in driving future economic development.

While FDI in manufacturing from both OECD countries and China are concentrated in resource and labor-intensive sectors, the literature suggests elevated ESG risks related to China's manufacturing investment in Africa. This results in higher risks to biodiversity and Indigenous lands, as Chinese firms adhere only to the lowest ESG requirements set by local regulations, rather than China's own Green BRI Guidelines or international best practices (Springer et al., 2023). Moreover, Chinese firms in the Global South tend to approach ESG standards differently compared to firms in more advanced economies. The primary drivers for Chinese firms are managing economic and political risks to their operations, rather than ethical considerations, despite the Chinese government's increasing incorporation of ESG into its regulatory frameworks (Morris, 2023). Private Chinese firms focus more on profitability and stability, using ESG as a risk management tool to respond to local community demands (Ibid). In contrast, empirical research has found that OECD countries' FDI could have a positive long-term impact on the environment due to technological innovation and improved standards (Pazienza, 2019). This suggests that even in the same labor-intensive or resource-intensive sectors, Chinese firms' de-facto implementation of ESG standards may be lower than OECD investors.

Model Specification and Estimation Strategy

To empirically analyze the effect of Chinese FDI on the carbon intensity of manufacturing in Africa, the following regression models are estimated.

$$ManCo2_{it} = \beta_0 + \beta_1 Chineses\ FDI_{it} + \beta_2 C'_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where $ManCo2$ is the share of industry CO2 $Chinese\ FDI$ is foreign direct investment from China to the manufacturing Africa. The subscript i refers to country and t is the time period, while γ_i captures country fixed effects, δ_t is the period fixed effect and ε_{it} is the idiosyncratic error term. C'_{it} is a vector of control variables. To minimize potential omitted variable bias, however, it is also important that we control for other important variables in our empirical specification. Guided by the existing related literature (Xu & Lin, 2015; Raheem & Ogebe, 2016; Nathaniel & Adeleye, 2021), our baseline empirical specification controls for GDP per capita and its quadratic form and total population. More specifically, we use GDP per capita and its quadratic form to capture and test the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis is an idea first conceptualized in Grossman and Krueger´s (1993) seminal paper on the potential impacts of the North American Free Trade Agreement (NAFTA). The concept postulates that environmental damage increases in the early stages of growth but diminishes once nations reach higher levels of income (Selden and Song, 1994; Grossman and Krueger, 1995; Stern, 2004) for more on the growth and environment nexus. We also control for the share of industry value added share of GDP to capture the composition effect. The choice of manufacturing value added share is guided by the existing literature that establishes a strong positive association between industrial activities and CO2 emissions (Grossman & Krueger,1993). Total population is used to capture the effect of population growth which extant studies suggest has a detrimental effect on manufacturing CO2 emissions due to among other things, high demand for industrial products arising from population growth emissions (Kaufman et al., 2007; Jiang et al., 2013). We also include a measure of environmental regulation. We rely on a self-constructed index, defined as the sum of environmental treaties that a country has joined. Original data used to compute this index is sourced from United Nations Department of Economic and Social Affairs environmental statistics[1] (UNDESA). To isolate the effect of environmental regulation from broader country regulatory institutional quality, we also control for regulatory quality using the regulatory quality index from the World Governance Indicator. We run a baseline regression for the full sample of countries and separately for the split samples of the three manufacturing sectors, namely labor-intensive, resource-intensive and knowledge-intensive manufacturing sectors.

We first estimate Equation 1 under two assumptions: first, isolating time-invariant unobservable characteristics by incorporating country-specific fixed effects to capture them; second, capturing year-based shocks or events constant across countries through time-fixed effects. To ensure result robustness, we employ an instrumental variable (IV) technique, relaxing these assumptions to address potential endogeneity issues arising from omitted variable bias and simultaneity bias. We utilize Lewbel's (2012) IV approach, identifying endogenous variables in the absence of good

[1] To compute this index, we proceeded in three steps. First, we computed an index comprising the sum of each country envromental treaties. Second, we normalized the index to have a minimum of zero and a maximum of one. Third, we extracted the sample of African countries.

external instruments by leveraging heteroskedasticity present in the model to generate instrument sets (Baum et al., 2013). Contrary to the conventional IV approach requiring an external instrument for appropriate endogenous variable identification, the Lewbel (2012) IV approach identifies regressors uncorrelated with the product of heteroskedasticity errors, a feature present in many models with error correlations due to an unobserved common factor (Baum et al., 2013, p.13). However, this method also allows the inclusion of external instruments, recommended by Baum and Lewbel (2019) for enhancing IV estimator efficiency when available. In our analysis, we employ IV-Heteroskedasticity results with and without external instruments, using two instruments.

Firstly, we use the average Chinese FDI share to other African countries as an instrument. The choice of this instrument is inspired by the trade literature (Autor et al., 2013, Bloom et al., 2016), aiming to capture variation in the share of Chinese FDI driven by changes in supply conditions in foreign, but similar, countries not influenced by domestic industry-specific shocks potentially endogenous to carbon emissions. The method we employ to compute this index is as defined in Equation 2.

$$Average\ Chinese\ FDI_{it} = \frac{Chinese\ FDI_t - Chinese\ FDI_{it}}{n-1} \quad \dots (2)$$

Where n is the total number of countries in the sample, $Chinese\ FDI_t$ is the sum of Chinese FDI across the African countries in the sample in period t and $Chinese\ FDI_{it}$ is country-time-specific Chinese FDI. By substituting the latter from the total FDI, we generate an instrument that varies across country and time. Moving on, the second instrument we employ is a predicted value of Chinese FDI from a gravity model as an instrument. The choice of this instrument is also inspired by the trade literature that uses predicted trade flows as an instrument (Frankel & Romer, 1999; Blanchard & Olney, 2017; Feyrer, 2019), aiming to exploit exogenous changes in the country characteristics to identify the effects of FDI. More formally, the equation that guides this analysis is expressed in Equation 3.

$$Chinese\ FDI_{ijt} = f\left(X_{it},\ Z_{ijt}, \mu_{ijt}\right) \dots (3)$$

Where $Chinese\ FDI_{ijt} \in$ {includes total Chinese FDI, labor-intensive Chinese FDI, resource-intensive Chinese FDI and knowledge-intensive Chinese FDI} j indexes China, X_{it} is a vector of variables that vary only across African countries (e.g., landlocked, and land mass), while Z_{ijt} is a vector of variables that vary across country-pair (e.g., diplomatic disagreement, distance, World Trade Organization (WTO) membership, the difference in cost of starting a business, and institutional and preference similarity)[2]. The computation of the predicted Chinese FDI from a gravity model involves three inclusive steps: estimating Chinese FDI flow using the gravity model, predicting Chinese FDI flows from the post-gravity model estimation and aggregating predicted flows across FDI recipient countries to derive country-specific time-varying predicted Chinese FDI flows for each African country. We then use the latter as instruments in the Lewbel IV regression approach. Our identification assumption is that the predicted Chinese FDI flow values are uncontaminated by endogeneity concerns, allowing for causal inferences about the effect of Chinese FDI on the outcome variables. Table A3 in the Appendix shows the gravity result. Four factors are important determinants of Chinese FDI in Africa, including land mass, membership in the WTO, bilateral distance and differences in the cost of starting a business. Importantly, land mass and WTO membership serve as pull factors, while differences in the cost of doing business and bilateral distance serve as push factors.

[2] Institutional similarlity is defined as the rule of law difference btween an African country and China. Preference difference is defined as the per capita gdp difference btween an African country and China. Cost of starting a business is defined as the difference between the averaged cost of starting a business in an African country and China.

RESULTS AND DISCUSSION

Full sample

Table 1 shows the regression results for the full sample. Columns 1 and 2 report the Panel fixed effects results, while columns 3-6 report the IV estimation results. Across all columns, the findings consistently show that an increase in FDI from China to Africa leads to higher manufacturing CO2 emissions. Focusing on column 1, the result shows that, on average, a 1 percent increase in FDI from China increases manufacturing CO2 emissions by 0.017-0.019 percent across African countries. This effect is statistically significant at the 1 percent level. The results remain robust to the inclusion of control variables and after addressing potential endogeneity concerns (columns 3-6).

On the one hand, the result aligns with patterns observed in other studies, which suggest the adverse environmental impacts of Chinese investment in BRI countries (Tawiah et al., 2021; Yang et al., 2021; Chen et al., 2023), or increase local energy consumption (Yang & Ni, 2022; Shinwari et al., 2024). This is particularly pronounced in those lower income countries, where environmental and social regulation tend to be laxer (Mahadevan & Sun, 2020). This 'race to the bottom' mentality aims to attract more investment and create jobs, but at the cost of environmental protection (Springer et al., 2023). On the other hand, the result also contradicts some studies that find Chinese FDI reduces CO2 emissions across all BRI countries and sectors (Su et al., 2022). However, it is important to note that our sample is limited to the manufacturing sector emissions in some of the world's poorest countries with the least developed institutional regulations. In this context, the technological innovation of Chinese manufacturing investment may not be the highest. Previous literature has documented that within the manufacturing sector, Chinese FDI in these countries tends to concentrate in light manufacturing industries, such as low-skilled apparel and footwear production and other resource intensive manufacturing industries such as in minerals, metals and oil and gas (Brautigam & Tang, 2011). As a result, the emissions-reducing effects of technological transfer through FDI observed by other literature may be quite small in the manufacturing sector in these countries.

Turning to the control variables, the estimated coefficients have the expected signs, although some are statistically insignificant at conventional significance levels. The estimated coefficient of environmental regulation remains negative albeit statistically insignificant across the columns. While the result is statistically insignificant, the consistently negative effect across the column highlights a systematic impact which in this case highlights the potential effect of stringent environmental regulation to reduce CO2 emissions. In this case, ineffective implementation of the regulation could be indicted for the unobserved insignificant impact. The estimated coefficient of GDP per capita in levels is positive, while the squared term is negative, indicating an *inverted-U* curve relationship between manufacturing CO2 emissions and income level: manufacturing CO2 emissions increase in the early stages of growth but diminish once countries reach higher levels of income. The result, therefore, joins studies such as Grossman and Krueger (1995) and Stern (2004) in providing empirical support for the EKC hypothesis. The positive estimated coefficient of the industry share in GDP is consistent with extant studies suggesting that while industrialization is an important source of economic growth, it could also increase manufacturing CO2 emissions. The estimated coefficient of regulatory quality (measure of institution) is significant and consistent with the literature. Finally, the estimated coefficient of total population is consistent with the literature arguing that an increase in population leads to increased manufacturing CO2 emissions due to, among other things, high demand for industrial products arising from the population growth. This could also arise from high rates of land conversion and habitat loss, which can decrease biodiversity and alter species interactions, negatively impacting the environment (Kaufman et al., 2007; Jiang et al., 2013). The results are robust to the inclusion of FDI shares coming from other FDI partners and

Table 1. Chinese FDI and Manufacturing CO2

	PEM		IV-Estimation			
	(1)	(2)	(3)	(4)	(5)	(6)
Chinese FDI (log)	0.020***	0.019***	0.019**	0.017**	0.019***	0.017**
	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)	(0.007)
Environmental regulation		-0.076	-0.075	-0.316	-0.076	-0.316
		(0.297)	(0.276)	(0.243)	(0.276)	(0.243)
GDP pc (log)		1.291	1.286	1.635*	1.289	1.638*
		(0.965)	(0.906)	(0.858)	(0.902)	(0.854)
GDP pc squared		-0.077	-0.077	-0.092	-0.077	-0.092
		(0.068)	(0.064)	(0.060)	(0.063)	(0.060)
Population (log)		0.814	0.816*	0.786	0.815*	0.785
		(0.533)	(0.493)	(0.481)	(0.494)	(0.481)
Regulatory quality		-0.154*	-0.154*	-0.176**	-0.154*	-0.176**
		(0.092)	(0.085)	(0.082)	(0.085)	(0.082)
Industry (% GDP)		0.009**	0.009**	0.009**	0.009**	0.009**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	2.377***	-17.591**	-16.663**	-17.759**	-16.666**	-17.763**
	(0.066)	(8.422)	(7.472)	(7.311)	(7.472)	(7.310)
Observations	338	335	335	326	335	326
R-squared	0.885	0.889	0.889	0.900	0.889	0.900
Country Effect	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES
Hansen J stat			44	45	45	45
Hansen J stat p-val			0.16	0.06	0.18	0.06

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors' elaboration based on described data.

Note: Columns 1-2 report panel fixed effect regression, while columns 3-6 report Lewbel-IV-regression. Column 3 shows the result without external instruments, while columns 4-6 show the result with external instruments. The external instrument is predicted Chinese FDI in column 4 and average Chinese FDI inflows in column 5. Column 6 shows the result when both external instruments are jointly employed.

countries such as the European Union (EU), the US and India reported in Table A4 in the Appendix. In all the columns, the results show that Chinese FDI and FDI coming from non-OECD countries to Africa significantly increase manufacturing CO2 emissions. Conversely, we do not find any evidence suggesting that FDI coming from the OECD and other regions or countries such as the EU, US or India significantly increases manufacturing CO2 emissions. Given that Figures 1A and 2A show that FDI from OECD countries to Africa's manufacturing industry have patterns similar to their Chinese counterparts, the issue may not solely stem from patterns of FDI flows, but from the actual operation process of these investment projects. Previous literature has suggested that Chinese FDI tends to adhere to the minimum ESG standards in host countries (Voituriez et al., 2019; Springer et al., 2023). While the Chinese government has recently enacted more stringent domestic regulations on the environmental standards of BRI projects, with "green, clean" objectives (Coenen et al., 2021), it may take some time before these new regulations take full effect. Moreover, it is questionable whether the Chinese government has the capacity to effectively oversee the operations of the thousands of FDI projects overseas. This suggests that the underlying issue may be rooted implementation of ESG standards that guides the actual operational processes of these manufacturing investment projects in FDI recipient countries.

Accounting for the Role of Sector

A second major contribution of this study is to examine whether Chinese FDI's impact on manufacturing CO2 in Africa varies depending on the sector receiving the FDI. To address this, we categorize Chinese FDI into three sectors: labor-intensive, resource-intensive and knowledge-intensive manufacturing[1]. FDI in knowledge-intensive sectors, such as technology, research and development, typically drive the adoption of advanced and cleaner technologies. These sectors prioritize efficiency and innovation, leading to reduced emissions and pollution. Consequently, we anticipate a positive environmental impact from these types of FDI. Conversely, FDI in labor-intensive or resource-intensive sectors may overlook environmental concerns, focusing instead on maximizing production and minimizing costs. Without stringent environmental regulations, this can result in higher emissions and pollution. Additionally, competition among developing nations for FDI in these sectors may lead to a 'race to the bottom' in environmental standards. Thus, the sector receiving FDI plays a significant role in shaping the environmental implications of Chinese manufacturing FDI flows in Africa.

We examine whether the effect of Chinese FDI on manufacturing CO2 in Africa varies based on the sector receiving the FDI. The findings of this exercise are reported in Table 2, where columns 1-2 depict panel fixed effect results, and columns 3-6 display IV results utilizing the two external instruments as previously defined. Overall, the results indicate that the effect of Chinese FDI on manufacturing CO2 emissions depends on the FDI composition. Chinese manufacturing FDI that is more resource-seeking and labor-intensive significantly increases manufacturing CO2 emissions. Conversely, Chinese manufacturing FDI that is more knowledge-intensive does not significantly affect manufacturing carbon intensity.

[3] Classification seen in Table A2 in the Appendix.

Table 2. Chinese FDI and Manufacturing CO2, Accounting for the Role of Sector Receiving FDI

	PEM		IV-Estimation			
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A					
Labor intensive Chinese FDI (log)	0.022**	0.018*	0.020**	0.018*	0.018**	0.016*
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Constant	2.404***	-18.120**	-17.211**	-18.261**	-17.182**	-18.237**
	(0.061)	(8.527)	(7.545)	(7.366)	(7.554)	(7.374)
Observations	338	335	335	326	335	326
R-squared	0.884	0.888	0.888	0.899	0.888	0.899
Control	NO	YES	YES	YES	YES	YES
Country Effect	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES
Hansen J stat			44	45	45	46
Hansen J stat p-val			0.12	0.17	0.12	0.15
	Panel B					
Resource intensive Chinese FDI (log)	0.015*	0.012	0.016**	0.012	0.014*	0.010
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Constant	2.412***	-17.985**	-17.089**	-18.125**	-17.065**	-18.109**
	(0.065)	(8.573)	(7.585)	(7.411)	(7.591)	(7.417)
Observations	338	335	335	326	335	326
R-squared	0.883	0.887	0.887	0.898	0.887	0.898
Control	NO	YES	YES	YES	YES	YES
Country Effect	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES
Hansen J stat			44	45	45	46
Hansen J stat p-val			0.69	0.78	0.63	0.65
	Panel C					
Knowledge intensive Chinese FDI (log)	0.007	0.008	0.008	0.010	0.008	0.010
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)
Constant	2.418***	-17.927**	-17.000**	-18.147**	-16.993**	-18.152**
	(0.060)	(8.593)	(7.610)	(7.416)	(7.614)	(7.416)
Observations	338	335	335	326	335	326
R-squared	0.882	0.887	0.887	0.899	0.887	0.899
Control	NO	YES	YES	YES	YES	YES

	PEM		IV-Estimation			
	(1)	(2)	(3)	(4)	(5)	(6)
Country Effect	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES
Hansen J stat			44	45	45	46
Hansen J stat p-val			0.26	0.33	0.29	0.36

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Source: Authors' elaboration based on described data.

Note: Columns 1-2 report panel fixed effect regression, while columns 3-6 report Lewbel-IV-regression. Column 3 shows the result without external instruments, while columns 4-6 show the result with external instruments. The external instrument is predicted Chinese FDI in column 4 and average Chinese FDI inflows in column 5. Column 6 shows the result when both external instruments are jointly employed.

Accounting for the Role of Environmental Regulation

The current findings indicate a negative environmental impact of Chinese manufacturing FDI in Africa. It further suggests the effect is not significant when the FDI from China is channeled into the knowledge-intensive manufacturing of recipient countries in Africa. This sub-section delves deeper into whether this relationship is contingent upon other country characteristics. Building on discussions from previous sections, we examine the role of environmental regulation in moderating this effect within the recipient African countries of FDI. To achieve this, we augment Equation 1 with an interaction term comprising the Chinese FDI variable and the country characteristic of environmental regulatory quality.

$$ManCo2_{it} = \beta_0 + \beta_1 Chinese\ FDI_{it} + \beta_2 \mathbb{Z}_{i,t} + \beta_3 (Chinese\ FDI_{i,t} \times \mathbb{Z}_{i,t}) + \beta_4 C'_{it} + \gamma_i + \delta_t + \varepsilon_{it} \qquad (4)$$

where all variables are as defined in Equation 1, $\mathbb{Z}_{i,t}$ is a country characteristic of interest (environmental regulatory quality), and $FDI_{i,t} \times \mathbb{Z}_{i,t}$ is an interaction term comprising FDI and environmental regulatory quality. The total effect of FDI on manufacturing CO2 emissions in Equation 4 is captured by $\beta_1 + \beta_3 \mathbb{Z}_{i,t}$. Here, we are more interested in the differential manufacturing CO2 emissions effect of Chinese FDI given the level of quality of a recipient country's environmental regulatory system. This is given by the parameter β_3. Hence, β_3 is the key parameter of interest in Equation 4. In line with the discussion in the previous sections, $\beta_3 < 0$ is expected in the case of an interaction term comprising Chinese FDI and environmental quality, implying that the manufacturing CO2 emissions effect of Chinese FDI decreases with the quality of a country's environmental regulatory system.

Table 3 reports the regression results for this analysis. Columns 1 and 2 report the panel fixed effect results, while columns 3-5 report the IV estimation results. Across the columns, the estimated coefficient of the interaction variable is negative, highlighting a systematic impact of environmental regulation in shaping the nature of the relation between FDI and manufacturing CO2. The insignificant result thus may be highlighting the ineffective implementation of environmental regulation across the African continent. In this case, effective implementation of environmental regulation in the region may hold a promise in counteracting the adverse environmental effect of Chinese FDI in Africa. See for instance studies by Neves et al. (2020), Zhang et al. (2020) and Yirong (2022), which highlight the significance of strong institutions in moderating the environmental effect FDI.

Table 3. Chinese FDI and Manufacturing CO2, Accounting for the Role Environmental Regulation

	PEM		IV-Estimation		
	(1)	(2)	(3)	(4)	(5)
Chinese FDI (log)	0.043	0.047	0.024	0.042	0.024
	(0.052)	(0.048)	(0.047)	(0.049)	(0.047)
Environmental Regulation	-0.055	-0.052	-0.308	-0.055	-0.308
	(0.302)	(0.279)	(0.247)	(0.279)	(0.247)
Chinese FDI (log) × Environmental Regulation	-0.029	-0.034	-0.009	-0.028	-0.009
	(0.061)	(0.056)	(0.055)	(0.057)	(0.055)
GDP pc (log)	1.284	1.289	1.634*	1.282	1.634*
	(0.958)	(0.886)	(0.844)	(0.888)	(0.844)
GDP pc squared	-0.076	-0.076	-0.092	-0.076	-0.092
	(0.067)	(0.062)	(0.059)	(0.062)	(0.059)
Population (log)	0.788	0.782	0.777	0.789	0.777
	(0.530)	(0.489)	(0.482)	(0.489)	(0.482)
Regulatory quality	-0.156*	-0.157*	-0.176**	-0.156*	-0.176**
	(0.092)	(0.086)	(0.083)	(0.086)	(0.083)
Industry (% GDP)	0.009**	0.009**	0.009**	0.009**	0.009**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	-17.176**	-16.200**	-17.632**	-16.279**	-17.632**
	(8.363)	(7.384)	(7.286)	(7.389)	(7.286)
Observations	335	335	326	335	326
R-squared	0.889	0.889	0.900	0.889	0.900
Control	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Hansen J stat		13	13	13	13
Hansen J stat p-value		14	09	15	07

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10.

Source: Authors' elaboration based on described data.

Note: Columns 1 report panel fixed effect regression, while columns 3-5 report Lewbel-IV-regression. Column 2 shows the result without external instrument, while Columns 3-4 show the result with external instruments. The external instrument is predicted Chinese FDI in column 4 and average Chinese FDI inflows in column 5. Column 5 shows the result when both external instruments are jointly employed. Note that we also endogeneize the environmental regulation variable as well as its interaction with Chinese FDI in the IV models.

Extended Analysis:
FDI and Low-carbon Manufacturing Value Chains Integration

In an extended analysis, we examine the effect of Chinese FDI on carbon intensity of manufacturing value chain integration. Integration into the global value chain (GVC) has in recent years received attention from governments, scholars, development agencies and international organizations as an easier route to boost industrialization of developing countries and ultimately, unlock their long-awaited economic transformation (World Bank, 2020; Abreha et al., 2021, Ndubuisi & Owusu 2021). Africa's GVC integration has been impressive over recent years. The EU, China, India and the US have generally been Africa's strongest partners in manufacturing GVC trade. Overall GVC trade with these key trading partners increased during 1995-2015. However, the region's integration with the EU and the US with regard to sourcing intermediate goods has declined while it has risen substantially with China (Abreha et al., 2021), suggesting an important shift in global trade and the need to re-orient Africa's trade and industrialization strategies toward Asia while improving the utilization of preferential trade agreements with the US and EU. However, Africa's high integration in GVC with China and other partner countries is in tasks that are predominantly dominated by activities in low-skilled tasks in light manufacturing and exports of primary products and basic inputs such as extraction and the export of raw materials—crude oil, natural gas and minerals (Abreha et al., 2020). As part of the objectives of this working paper, we additionally examine the effect of Chinese development finance and FDI on low-carbon value chain integration in Africa.

To compute the carbon intensity of value chain integration, we use the Eora MRIO I-O database. The database comprises a set of input-output tables and carbon footprint of trade integration data covering 187 countries from 1990-2015, providing the largest coverage of countries (including developing countries) in an I-O database. The database is widely used (see Ndubuisi & Owusu, 2021, 2022, 2023; World Bank WDR, 2020; Amendolagine et al., 2019). The reliability and accuracy of the Eora database are discussed in detail in Lenzen et al. (2013) where it compares very well with comparator databases such as the Global Trade Analysis Project (GTAP) database, OECD–WTO data and the World Input-Output Database (WIOD) database (UNCTAD, 2013).

Following recent developments in the empirical GVC literature (see Wang et al., 2013; Koopman et al., 2014; Foster-McGregor et al., 2015; Montalbano et al., 2018; Ndubuisi & Owusu, 2021, 2022, 2023), we use the dataset to compute three carbon intensity of manufacturing value chain integration indicators that are used in the analysis. The carbon intensity of manufacturing value chain (GVC) integration of a country in the cross-national trade of intermediate goods is defined as:

$$GVC\,Participation_{it} = \left(\frac{FVA_{it}}{TE_{it}}\right) + \left(\frac{DVX_{it}}{TE_{it}}\right) \tag{5}$$

From Equation 5, while TE_{it} is the gross export of country i at period t, $\frac{FVA_{it}}{TE_{it}}$ captures the extent of a country's backward participation and is measured as the share of foreign value-added used in a country's export adjusted for the carbon footprint of that integration and $\frac{DVX_{it}}{TE_{it}}$ captures the extent of a country's forward participation and is measured as the share of a country's domestic value-added that enters as inputs in the exports of other countries adjusted for the carbon footprint of that integration. Summing up the two components gives the aggregate GVC integration indicator (carbon intensity of manufacturing value chain integration) with higher values indicating more carbon intensity of value chain integration.

Linking this to the Chinese FDI data, we examine the effect of Chinese FDI on low-carbon manufacturing value chain integration. The results of this exercise are reported in Table A5 in the

Appendix. The results largely show that Chinese FDI significantly reduces the carbon footprint of Africa's manufacturing value chain integration but strongly through the forward value chain integration, a result that is consistent with (Shi etal., 2022).

Extended Analysis: Loans and Low-carbon Manufacturing and Value Chains Integration

We also examine the effect of Chinese loans on manufacturing CO2 emissions. Chinese development finance to Africa is sourced from African Debt Database (ADD) developed by the Kiel Institute for the World Economy, which provides comprehensive information on all external borrowing by African governments each year. This allows us to calculate the percentage of a debtor country's total loans that come from Chinese sources. In addition to the FDI flow from private business owners, the Chinese state also actively provides capital to support investment in Africa, utilizing equity investment instruments like the China-Africa Fund, which had $10 billion in available funds specifically focusing on investing in Africa as of 2022 (Moses et al., 2022). There are also non-equity instruments, such as the Africa Growing Together Fund established in 2014 with capital of $2 billion for joint loans from the African Development Bank and the People's Bank of China. The China-Portuguese Speaking Countries Cooperation and Development Fund also has investments in the African continent (Springer et al., 2023).

The rationale for separately analyzing the impacts of Chinese FDI and development finance is that the latter reflects more of the incentives and objectives of the Chinese government. Development finance primarily originates from policy banks or state-owned commercial banks, whereas FDI is more driven by private capital, focusing on profit maximization rather than upholding ESG standards. This contrast between official and private economic engagement could test whether China's development finance institutions' recent shifts towards zero-emission and a green BRI have been as effective as claimed. By analyzing both FDI and development finance from China on carbon emissions in the manufacturing sector, we gain a holistic view of the impacts of China's economic engagement in the prospect of low-carbon manufacturing in Africa. The results of this exercise are reported in Table A6 in the Appendix. The results are identical to those of Chinese FDI reported in Table 1.

CONCLUSIONS AND POLICY IMPLICATIONS

China has emerged as Africa's largest trading partner, the biggest bilateral provider of development finance, and a major source of FDI to Africa's manufacturing industry. This working paper examined the effects of Chinese manufacturing FDI on low-carbon manufacturing in Africa, addressing inquiries regarding China's economic engagement and its broader effects on the continent's low-carbon structural transformation.

Employing empirical analysis, we utilized a panel dataset comprising Chinese FDI into the manufacturing sectors of 34 African countries from 2003-2014, coupled with data on carbon emissions from manufacturing industries. Our analysis reveals that Chinese FDI in manufacturing contributes to an increase in CO_2 emissions within Africa's manufacturing sector. This effect is particularly pronounced when Chinese FDI targets labor- and resource-intensive manufacturing sectors, yet we find no significant effect when the FDI is channeled to the knowledge-intensive sectors. We argue that besides sector concentration, this adverse effect stems from the less stringent implementation of ESG standards during the manufacturing process. Moreover, our findings demonstrate that stronger environmental regulations in recipient countries can moderate the impact of Chinese FDI on manufacturing CO_2 emissions, underscoring the crucial role of regulatory frameworks. The findings suggest a nuanced relationship between Chinese economic engagement and environmental outcomes in Africa, emphasizing the necessity for sustainable development strategies and robust regulatory frameworks to effectively address environmental challenges.

From these findings, several policy recommendations emerge. First, there is an urgent need to bolster environmental regulation. African governments and policymakers must prioritize enhancing environmental regulations to ensure strict adherence to environmental standards by industries, especially those receiving Chinese FDI. This entails establishing and enforcing emissions limits, promoting the adoption of cleaner production technologies and implementing effective monitoring and enforcement mechanisms. Second, our findings advocate for the promotion of sustainable financing on the continent. It is imperative to encourage Chinese investors and other foreign investors to prioritize investments in environmentally sustainable projects and industries. This can be achieved through incentives like tax breaks or subsidies for investments in green industrial sectors, leveraging existing comparative advantages and pre-existing capabilities, and gradually transitioning to new productive and innovative green industries over the long term.

Lastly, our results underscore the importance of investment-promoting policies that facilitates technology transfer and capacity-building initiatives through FDI. These efforts should empower African countries to adopt and implement low-carbon manufacturing practices, supporting domestic manufacturing firms in integrating low-carbon manufacturing innovations and technologies to enhance resource efficiency in their production processes in line with the objectives of green industrial policy.

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APPENDIX

Table A1. Country List in Sample

Country Name	Country Code
Algeria	DZA
Angola	AGO
Benin	BEN
Botswana	BWA
Cameroon	CMR
Democratic Republic of Congo	COD
Republic of Congo	COG
Cote d'Ivoire	CIV
Egypt	EGY
Equatorial Guinea	GNQ
Eritrea	ERI
Eswatini	SWZ
Ethiopia	ETH
Gabon	GAB
Ghana	GHA
Kenya	KEN
Libya	LBY
Madagascar	MDG
Mauritius	MUS
Morocco	MAR
Mozambique	MOZ
Niger	NER
Nigeria	NGA
Rwanda	RWA
Senegal	SEN
South Africa	ZAF
South Sudan	SSD
Sudan	SDN
Tanzania	TZA

Togo	TGO
Tunisia	TUN
Uganda	UGA
Zambia	ZMB
Zimbabwe	ZWE

Source: Authors' elaboration based on described data.

Table A2. Industry Classification based on Activities

Industry sectors	Classification
Beverages	Labor-intensive
Building & Construction Materials	Labor-intensive
Consumer Electronics	Labor-intensive
Consumer Products	Labor-intensive
Food & Beverage	Labor-intensive
Food & Tobacco	Labor-intensive
Hotels & Tourism	Labor-intensive
Leisure & Entertainment	Labor-intensive
Non-Automotive Transport OEM	Labor-intensive
Paper, Printing & Packaging	Labor-intensive
Real Estate	Labor-intensive
Textiles	Labor-intensive
Transportation	Labor-intensive
Warehousing & Storage	Labor-intensive
Alternative/Renewable energy	Resource-intensive
Ceramics & Glass	Resource-intensive
Chemicals	Resource-intensive
Coal, Oil and Natural Gas	Resource-intensive
Metals	Resource-intensive
Minerals	Resource-intensive
Plastics	Resource-intensive
Renewable energy	Resource-intensive
Rubber	Resource-intensive

Industry sectors	Classification
Wood Products	Resource-intensive
Aerospace	Technology-intensive
Automotive Components	Technology-intensive
Automotive OEM	Technology-intensive
Biotechnology	Technology-intensive
Business Machines & Equipment	Technology-intensive
Business services	Technology-intensive
Communications	Technology-intensive
Electronic Components	Technology-intensive
Engines & Turbines	Technology-intensive
Financial Services	Technology-intensive
Healthcare	Technology-intensive
Industrial Machinery, Equipment & Tools	Technology-intensive
Medical Devices	Technology-intensive
Pharmaceuticals	Technology-intensive
Semiconductors	Technology-intensive
Software & IT services	Technology-intensive
Space & Defense	Technology-intensive

Source: Authors' elaboration based on described data.

Table A3. Determinants of FDI

	Total Chinese FDI	Resource Intensive Chinese FDI	Labor Intensive Chinese FDI	Knowledge Intensive Chinese FDI
	(1)	(2)	(3)	(4)
Institution Similarity	0.215	0.124	0.229	0.192
	(0.302)	(0.210)	(0.223)	(0.246)
Distance (log)	-2.462***	-1.294*	-1.489**	-0.862
	(0.895)	(0.773)	(0.737)	(0.770)
Area (log)	0.545***	0.278***	0.308***	0.294***
	(0.058)	(0.045)	(0.042)	(0.046)
Land locked	-0.080	-0.206	-0.095	0.076
	(0.257)	(0.173)	(0.170)	(0.221)
WTO	1.219***	0.737**	0.546*	0.668**
	(0.391)	(0.297)	(0.300)	(0.331)
Diplomatic Disagreement	0.329	-0.138	-0.138	0.542
	(0.425)	(0.300)	(0.300)	(0.380)
Cost of business startup	-0.208*	-0.151	-0.068	-0.116
	(0.122)	(0.094)	(0.093)	(0.101)
Preference	-0.001	0.001	0.013	-0.011
	(0.021)	(0.015)	(0.015)	(0.016)
Constant	16.465**	8.878	9.954	4.873
	(8.128)	(6.896)	(6.535)	(6.926)
Observations	593	593	593	593
R-squared	0.214	0.152	0.119	0.132

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Source: Authors' elaboration based on described data.
Note: the outcome variables are logged by adding a constant.

Table A4: Chinese and Other Sources of FDI and Manufacturing CO_2

VARIABLES	(1)	(2)
Chinese FDI (log)	0.019**	0.023***
	(0.007)	(0.008)
Environmental regulation	-0.055	-0.044
	(0.304)	(0.342)
U.S. FDI share	0.051	
	(0.100)	
EU FDI Share	0.082	
	(0.122)	
India FDI Share	-0.024	
	(0.103)	
Africa FDI Share	-0.083	
	(0.072)	
Other FDI Share	0.048	
	(0.060)	
GDP pc (log)	1.374	1.691
	(0.997)	(1.441)
GDP pc squared	-0.084	-0.080
	(0.070)	(0.092)
Population (log)	0.759	-0.067
	(0.538)	(0.622)
Industry (% GDP)	0.009**	0.006
	(0.004)	(0.006)
Regulatory quality	-0.138	-0.153*
	(0.097)	(0.086)
OECD FDI Share		0.012
		(0.015)
NonOECD FDI Share		0.018**
		(0.008)
Constant	-16.852**	-5.244
	(8.557)	(10.354)
Observations	335	228
R-squared	0.890	0.873
Country Effect	YES	YES
Year Effect	YES	YES

Source: Authors' elaboration based on described data.

Table A5: Chinese FDI and Carbon Footprint of Value Chain Integration

	(1) IGVCCO2 Total Value Chain Integration	(2) IGVCCO2 Total Value Chain Integration	(3) IFVACO2 Backward Value Chain Integration	(4) IFVACO2 Backward Value Chain Integration	(5) IDVXCO2 Forward Value Chain Integration	(6) IDVXCO2 Forward Value Chain Integration
Chinese FDI share	-0.035	-0.379*	-0.014	-0.319	-0.032	-0.456**
	(0.216)	(0.201)	(0.227)	(0.216)	(0.229)	(0.207)
U.S. FDI Share	-0.010		0.000		-0.030	
	(0.114)		(0.098)		(0.131)	
EU FDI Share	-0.000		-0.027		0.057	
	(0.067)		(0.071)		(0.077)	
India FDI Share	0.169		0.176		0.211*	
	(0.179)		(0.239)		(0.116)	
Africa FDI Share	0.079		0.054		0.129	
	(0.083)		(0.091)		(0.105)	
Other FDI Share	0.055		0.006		0.104	
	(0.075)		(0.078)		(0.088)	
GDP pc (log)	0.552	0.923	0.957	1.470	2.339	0.926
	(1.193)	(1.644)	(1.074)	(1.612)	(2.107)	(2.578)
GDP pc squared	-0.004	-0.050	-0.064	-0.120	-0.096	-0.031
	(0.083)	(0.101)	(0.070)	(0.091)	(0.133)	(0.156)
Population (log)	-0.776	0.029	-1.860**	-1.383**	-0.885	0.104
	(0.813)	(0.638)	(0.816)	(0.647)	(0.851)	(0.694)
Industry (% GDP)	0.012*	0.020**	0.011	0.0213**	0.012*	0.015**
	(0.007)	(0.008)	(0.006)	(0.009)	(0.007)	(0.006)
Regulatory Quality	0.041	0.060	0.248**	0.192**	-0.223	-0.114
	(0.120)	(0.084)	(0.104)	(0.076)	(0.167)	(0.126)
OECD FDI Share		-0.025*		-0.0141		-0.058**
		(0.014)		(0.015)		(0.026)
Non-OECD FDI Share		-0.014*		-0.016*		-0.019*
		(0.008)		(0.009)		(0.010)
constant	10.020	-4.257	28.360**	19.060*	2.944	-7.070
	(13.140)	(10.550)	(13.500)	(11.110)	(14.050)	(12.020)
Observation	332	237	332	237	332	237
R-squared	0.965	0.976	0.963	0.977	0.947	0.957
Country Effect	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES

Standard errors in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

Source: Authors' elaboration based on described data.

Note: Columns 1-6 report panel fixed effect regression.

Table A6: Chinese Loans and Manufacturing CO2

	(1)	(2)	(3)	(4)
Chinese Loan share	0.041	0.007	0.292***	0.244**
	(0.057)	(0.063)	(0.109)	(0.101)
GDP pc (log)		1.525	1.619*	1.596*
		(0.973)	(0.963)	(0.913)
GDP pc squared		-0.088	-0.096	-0.098
		(0.069)	(0.068)	(0.060)
Population (log)		0.700	0.868	0.883*
		(0.559)	(0.578)	(0.480)
Industry (% GDP)		0.009**	0.010**	0.010***
		(0.004)	(0.004)	(0.003)
Regulatory Quality		-0.157*	-0.187**	-0.169*
		(0.092)	(0.090)	(0.102)
OECD Loan Share			0.345***	0.369***
			(0.111)	(0.099)
Non-OECD Loan Share			0.420***	0.467***
			(0.143)	(0.148)
Environmental Regulation				-0.051
				(0.066)
Chinese Loan share* Environmental Regulation				0.260**
				(0.104)
constant	2.426***	-16.77*	-19.97**	-19.90**
	(0.061)	(8.832)	(9.213)	(8.201)
Observation	338	335	335	335
R-squared	0.882	0.886	0.891	0.894
Country Effect	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES

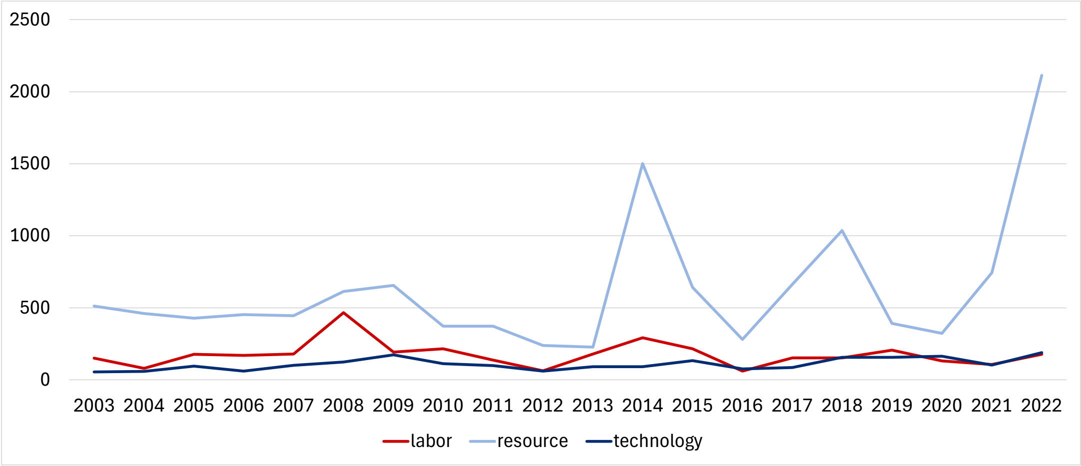
Standard errors in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01

Source: Authors' elaboration based on described data.

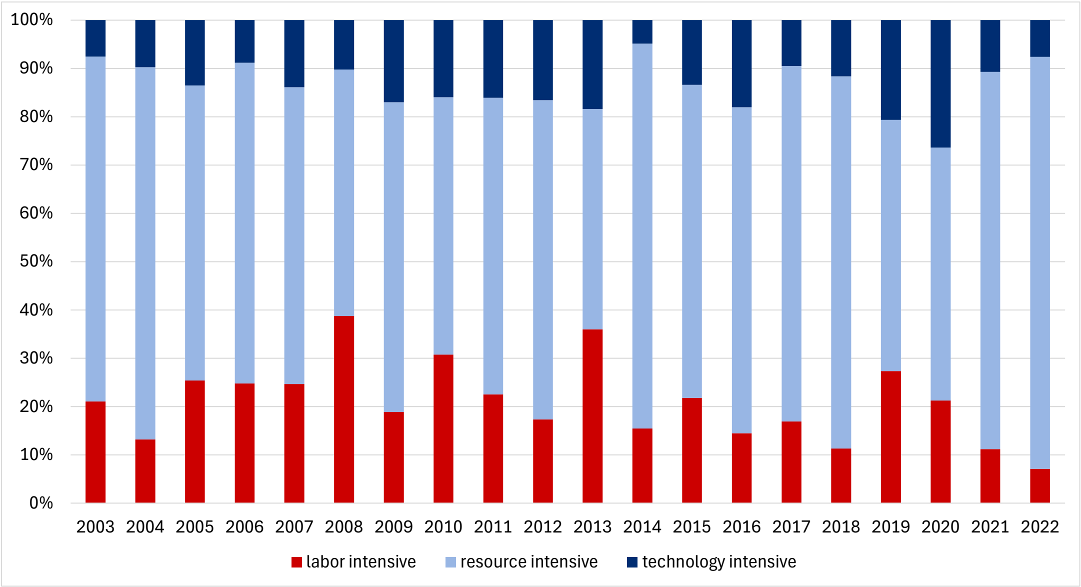
Note: Columns 1-4 report panel fixed effect regression.

Figure A1. Annual OECD Countries' FDI Inflows to Africa's Manufacturing Sector, Million USD



Source: Authors' elaboration using data from FDI Intelligence database.

Figure A2. Annual OECD Countries' FDI Inflows to Africa's Manufacturing Sector, Percent



Source: Authors' elaboration using data from FDI Intelligence database.

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