IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(2), 1308-1326.

EJ EconJournals

Education-Conditioned Foreign Direct Investment and Sustainable Development: A Complementarity Perspective

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Received: 21 October 2025 **Accepted:** 21 January 2026 **DOI:** https://doi.org/10.32479/ijeep.22830

ABSTRACT

This study examines the relationship between foreign direct investment and sustainable development from a complementarity perspective, emphasizing the conditioning role of education. While foreign direct investment is often viewed as a catalyst for development, its contribution to sustainable development remains highly heterogeneous across countries. Drawing on the absorptive capacity framework, the study argues that foreign direct investment enhances sustainable development only when host economies possess sufficiently strong educational foundations. Using panel data for 72 countries over the period 2008-2022, the analysis employs a hierarchical Bayesian modeling approach to account for unobserved cross country heterogeneity and interaction effects. Sustainable development is measured using the Sustainable Development Goals Index, capturing economic, social, and environmental dimensions. The empirical model includes foreign direct investment, education, their interaction, and key macroeconomic and institutional controls. The results show that foreign direct investment does not promote sustainable development when considered in isolation and may even exert adverse effects. In contrast, education has a robust positive association with sustainable development. Most importantly, the interaction between foreign direct investment and education is positive and statistically meaningful, particularly in middle income and low income countries.

Keywords: Foreign Direct Investment, Education, Sustainable Development, Absorptive Capacity, Hierarchical Bayesian Model
JEL Classifications: F21, F43, I25, Q01

1. INTRODUCTION

Over the past decades, foreign direct investment (FDI) has been widely regarded as a key driver of economic growth and development in host countries. From the traditional perspective, FDI not only supplements domestic capital accumulation but also facilitates technology transfer, managerial know-how spillovers, and productivity improvements, thereby contributing to long-term development outcomes (Borensztein et al., 1998; Alfaro et al., 2004). Based on this reasoning, a substantial body of research has expected FDI to play a positive role in promoting sustainable development, encompassing economic, social, and environmental dimensions.

However, an increasing body of empirical evidence accumulated in recent years suggests that the impact of FDI on sustainable development is neither automatic nor universal. Several studies indicate that FDI may even generate adverse effects, such as widening income inequality, intensifying environmental pressures, or reinforcing technological dependence in host countries when adequate foundational conditions are absent (Aitken and Harrison, 1999; Herzer and Klasen, 2008). These mixed findings have motivated an important strand of research emphasizing that the effectiveness of FDI critically depends on the internal characteristics of host economies, rather than on capital inflows per se.

Within this context, a substantial branch of the development economics literature has focused on the role of absorptive capacity as a key mechanism mediating the effects of FDI. This theoretical perspective argues that only countries with sufficient human capital, technological capability, and organizational capacity are able to effectively absorb and exploit the potential benefits of foreign investment (Borensztein et al., 1998; Durham, 2004). A growing number of empirical studies confirm that the positive effects of FDI on growth and productivity tend to materialize only when host countries reach a certain threshold of education, financial development, or institutional quality (Alfaro et al., 2010; Azman-Saini and Law, 2010).

Despite these advances, the existing literature still exhibits three important limitations. First, a substantial share of prior studies has primarily concentrated on economic growth or productivity outcomes, while the relationship between foreign direct investment and sustainable development, conceptualized as a multidimensional construct, has not yet been fully explored. Extending the analysis from growth to sustainable development requires a more nuanced approach, since short term economic gains associated with foreign direct investment do not necessarily translate into long term social and environmental improvements.

Second, although education is widely recognized as a core component of absorptive capacity, its conditioning role in the relationship between FDI and sustainable development has not been systematically examined. Many studies incorporate education merely as an independent control variable rather than explicitly modeling the interaction between FDI and education. As a result, it remains unclear whether education amplifies, mitigates, or potentially reverses the effects of FDI on sustainable development outcomes.

Third, from a methodological perspective, most existing empirical studies rely on frequentist econometric techniques, which face notable limitations when applied to short panel data with substantial cross-country heterogeneity and highly correlated interaction terms. Under such conditions, conventional estimators often suffer from parameter instability and reduced inferential reliability (Baltagi, 2008; Greene, 2012).

Motivated by these gaps, this study advances a complementarity perspective, in which FDI is conceptualized as a factor that contributes to sustainable development only when it is conditioned by the level of education in host countries. Rather than assuming that FDI and education exert independent effects, the analysis emphasizes their interaction as a central mechanism explaining heterogeneous sustainable development outcomes across countries.

From a methodological standpoint, the study employs a hierarchical Bayesian model to address the limitations of conventional approaches. This framework allows for the modeling of unobserved cross-country heterogeneity through random intercepts while implementing partial pooling to efficiently leverage information from the full sample. Moreover, the Bayesian approach enhances inferential stability in the presence of interaction terms and multicollinearity through shrinkage effects induced by prior distributions (Gelman and Hill, 2007; McElreath, 2020). These properties render hierarchical Bayesian models particularly well suited for analyzing the complex relationship between FDI, education, and sustainable development in cross-country panel settings with limited time dimensions.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Sustainable Development: Concept and Measurement

The concept of sustainable development was formally introduced into academic and policy discourse through the Brundtland Report, which defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). This definition highlights the intergenerational nature of development and underscores the need to balance short-term economic progress with long-term social and environmental objectives.

Over the past decades, sustainable development has increasingly been conceptualized as a multidimensional construct, encompassing economic, social, and environmental dimensions. This perspective has been institutionalized through the United Nations' 2030 Agenda for Sustainable Development, which articulates 17 Sustainable Development Goals (SDGs) designed to integrate economic efficiency, social equity, and environmental sustainability within a unified development framework (United Nations, 2015; Sachs, 2015). Under this framework, development outcomes are no longer evaluated solely based on income levels or growth rates, but rather on broader measures of societal well-being and environmental quality.

The multidimensional nature of sustainable development implies that economic growth alone is insufficient to guarantee sustainable outcomes in the long run. Economies experiencing rapid growth accompanied by rising inequality, environmental degradation, or declining social welfare may face significant development risks over time. This critique of growth-centered measurement has been strongly emphasized in the literature, which argues that conventional indicators such as gross domestic product fail to capture essential aspects of human well-being and sustainability (Stiglitz et al., 2009).

From a measurement perspective, the multidimensionality of sustainable development poses substantial challenges to traditional single-dimensional indicators. To address these limitations, recent studies increasingly rely on composite indices that integrate multiple development dimensions into a single metric, thereby providing a more comprehensive assessment of development performance (Stiglitz et al., 2009; UNDP, 2020). Such indices allow researchers to move beyond narrow economic indicators and better reflect the complex nature of sustainable development.

In this context, the Sustainable Development Goals Index (SDGI) has emerged as a particularly suitable tool for cross-country empirical analysis. The SDGI aggregates information from a wide range of indicators aligned with the SDGs, capturing progress across economic, social, and environmental dimensions in a standardized and internationally comparable manner (Sachs et al., 2019; Sachs et al., 2022). By summarizing multidimensional development outcomes into a single composite measure, the SDGI reduces measurement noise associated with individual indicators and facilitates both cross-country comparisons and time-series analysis.

Employing a composite measure such as the SDGI also has important implications for assessing the impact of economic drivers on sustainable development. Policies or capital flows that stimulate short-term economic activity may not necessarily improve sustainable development outcomes if they generate adverse social or environmental externalities. This consideration is particularly relevant in the context of foreign direct investment (FDI), where capital inflows may contribute to economic expansion while simultaneously exerting pressure on natural resources or reinforcing structural inequalities in the absence of adequate domestic conditions.

Overall, conceptualizing sustainable development as a multidimensional construct and employing a composite indicator such as the SDGI provide a robust conceptual and empirical foundation for this study. This approach enables a more nuanced examination of how foreign direct investment and education interact to shape long-term sustainable development outcomes, thereby setting the stage for the subsequent analysis.

2.2. Foreign Direct Investment and Sustainable Development

In the development economics literature, foreign direct investment (FDI) has long been regarded as a key driver of growth and structural transformation in host economies. From the traditional perspective, FDI not only supplements domestic capital accumulation but also facilitates technology transfer, managerial know-how spillovers, and productivity improvements, thereby contributing to long-term development outcomes (Borensztein et al., 1998; Alfaro et al., 2004). On this basis, a substantial body of research has expected FDI to play a positive role in promoting sustainable development through expanded production, job creation, and income growth.

However, an accumulating body of empirical evidence suggests that the relationship between FDI and sustainable development is neither automatic nor universal. Several studies indicate that FDI may generate adverse effects in the absence of adequate domestic conditions. In particular, FDI can exacerbate income inequality, intensify environmental pressures, or reinforce technological dependence in host countries with limited internal capacities (Aitken and Harrison, 1999; Herzer and Klasen, 2008). These findings imply that attracting FDI does not necessarily guarantee progress toward sustainable development, especially when short-term economic gains are not translated into long-term social and environmental improvements.

From an environmental perspective, some studies argue that FDI may contribute to environmental degradation through the relocation of pollution-intensive activities to countries with relatively weak environmental standards, particularly in developing economies. By contrast, other research emphasizes the potential of FDI to introduce cleaner technologies and more advanced production standards. The lack of consensus in empirical findings underscores that the environmental impact of FDI depends critically on the institutional context, regulatory capacity, and policy frameworks of host countries.

Within a multidimensional conception of sustainable development, these mixed results suggest that FDI may enhance certain development dimensions while undermining others. For example, FDI may stimulate economic growth and employment while simultaneously exerting pressure on natural resources or increasing social disparities. Consequently, assessing the impact of FDI on sustainable development requires an analytical framework capable of jointly evaluating economic, social, and environmental outcomes, rather than relying solely on traditional growth-based indicators.

A growing strand of the literature therefore emphasizes that the effectiveness of FDI is highly contingent on host-country conditions, including institutional quality, financial development, and absorptive capacity. According to this view, FDI contributes positively to sustainable development only when host economies possess sufficient capacity to absorb, adapt, and diffuse the benefits associated with foreign capital inflows. In contrast, when these foundational conditions are weak, FDI may fail to deliver the expected development benefits and may even produce unfavorable long-term consequences.

Taken together, these arguments indicate that FDI should not be treated as an independent or uniformly beneficial determinant of sustainable development. Rather, its effects must be analyzed in interaction with domestic factors that shape a country's ability to transform external capital into sustainable development outcomes. This perspective naturally leads to an examination of the conditioning role of education, which constitutes a core component of absorptive capacity and a key mechanism through which FDI may be converted into inclusive and sustainable development. The next section therefore develops a complementarity framework that explicitly links FDI, education, and sustainable development.

2.3. Education, Absorptive Capacity, and the Complementarity Framework

A substantial strand of the development economics literature emphasizes the role of absorptive capacity as a central mechanism determining whether external capital inflows and technologies can be transformed into sustainable development outcomes. From this perspective, the potential benefits of foreign direct investment do not materialize automatically but depend critically on the host country's ability to absorb, adapt, and diffuse the knowledge, technologies, and managerial practices embodied in FDI (Borensztein et al., 1998; Durham, 2004).

Within the absorptive capacity framework, education is widely regarded as a core component reflecting the quality of human capital and the learning capability of an economy (Cohen and Levinthal, 1990; Benhabib and Spiegel, 1994). Education not only enhances labor productivity but also facilitates the absorption and domestic adaptation of new technologies, strengthens innovation capacity, and improves firms' ability to adjust to technological and market changes (Nelson and Phelps, 1966; Aghion, 1998). As a result, higher levels of education enable countries to better exploit the spillover effects associated with foreign direct investment, thereby improving long term development outcomes (Borensztein et al., 1998; Durham, 2004).

A growing body of empirical evidence supports the view that the positive effects of foreign direct investment on economic performance are conditional on human capital development. Borensztein et al. (1998) demonstrate that foreign direct investment promotes economic growth only in countries that have achieved a sufficiently high level of education, while Durham (2004) further confirms that absorptive capacity, proxied by education and financial development, plays a conditioning role in shaping the impact of foreign direct investment. These findings imply that education and foreign direct investment do not operate independently but interact in a manner that fundamentally influences development outcomes.

From an institutional economics perspective, the role of education extends beyond productivity enhancement and technological learning. Education contributes to the formation of skills, norms, and organizational capacities that reduce transaction costs, improve coordination, and enhance the effectiveness of economic interactions. North (1990) conceptualizes institutions as the rules of the game that structure incentives and reduce uncertainty, while Williamson (2000) emphasizes that both institutional arrangements and human capabilities are crucial for fostering innovation and long term development. In this context, education can be viewed as a foundational element that enables host economies to internalize and govern the complex processes associated with international investment and technological change.

These arguments collectively lead to a complementarity perspective in analyzing the relationship between foreign direct investment, education, and sustainable development. Under this perspective, the effect of foreign direct investment on sustainable development depends on the level of educational attainment in the host country, reflecting the central role of human capital in enhancing absorptive capacity and facilitating the diffusion of FDI related benefits (Borensztein et al., 1998; Durham, 2004; Alfaro et al., 2010). When education levels are high, foreign direct investment can be transformed into a driver of inclusive growth, improved social welfare, and environmental sustainability through the transfer of cleaner technologies and more advanced managerial practices. Conversely, in contexts characterized by low educational attainment, foreign direct investment may fail to generate the expected development benefits and may even exacerbate income inequality or environmental degradation due to limited absorptive and regulatory capacities (North, 1990; Williamson, 2000).

This complementarity perspective is particularly consistent with the conceptualization of sustainable development as a multidimensional construct encompassing economic, social, and environmental dimensions that are interdependent and subject to long term trade offs (Sachs, 2015). While foreign direct investment may generate short term economic gains, education plays a critical role in ensuring that these gains are broadly diffused, sustained over time, and aligned with broader social and environmental objectives. Accordingly, education not only exerts a direct influence on sustainable development outcomes but also conditions and amplifies the impact of foreign direct investment.

In summary, the absorptive capacity and complementarity frameworks suggest that foreign direct investment and education must be analyzed jointly rather than in isolation when examining the determinants of sustainable development. This theoretical perspective provides a clear justification for modeling the interaction between foreign direct investment and education in the empirical analysis and helps explain the substantial cross country heterogeneity observed in sustainable development outcomes.

2.4. Empirical Literature Review and Research Gaps

Over the past decade, the empirical literature on foreign direct investment has expanded beyond its traditional focus on economic growth to examine the broader implications of FDI for sustainable development understood as a multidimensional concept, closely aligned with the Sustainable Development Goals. A growing number of cross-country studies suggest that foreign direct investment can contribute positively to sustainable development by stimulating production, employment creation, and technology transfer. However, these effects are not universal and vary substantially across countries depending on host-country characteristics.

Recent empirical evidence indicates that the contribution of foreign direct investment to sustainable development is highly conditional. For example, Hamid and AlObaid (2025), using a panel of more than 56 countries over the period 2000-2022, finds that foreign direct investment improves sustainable development outcomes only in countries with adequate governance quality and institutional effectiveness. Similarly, Khan et al. (2020) provide evidence that foreign direct investment may support progress toward the Sustainable Development Goals, but its impact is strongly conditioned by domestic absorptive capacity, particularly human capital development. Their results underscore that without sufficient educational foundations, foreign direct investment is unlikely to generate sustained and inclusive development outcomes.

Similarly, Aust et al. (2020), using cross country evidence for African economies, show that foreign direct investment can support progress toward the Sustainable Development Goals, yet the strength of this contribution varies markedly across host countries, reflecting differences in domestic absorption and structural conditions. In the same spirit, Hamid (2025) documents that the development relevance of foreign direct investment is closely intertwined with governance capacity, with FDI and institutional effectiveness jointly shaping SDG related outcomes rather than FDI operating as an automatic driver. Taken together, these studies reinforce the view that foreign direct investment does not mechanically translate into sustainable development gains, but instead depends on complementary domestic foundations that determine whether external capital can be converted into broad based and sustainable progress.

Parallel to the literature on foreign direct investment, a growing body of empirical research emphasizes the role of education and human capital as fundamental drivers of sustainable development. Education contributes directly to the social and environmental dimensions of sustainability by enhancing technological awareness, strengthening innovation capacity, and fostering more resource efficient and environmentally responsible economic behavior. Through these channels, human capital development improves societies' ability to adopt cleaner technologies, optimize resource use, and internalize environmental externalities.

Within the context of foreign direct investment, education is commonly viewed as a core component of absorptive capacity, enabling host economies to internalize and manage technology and knowledge spillovers. Empirical evidence also suggests that the environmental consequences of FDI are conditional on human capital. Using Chinese provincial data, Lan et al. (2012) show that the relationship between FDI and pollution emissions depends critically on the level of human capital, with FDI being associated with lower pollution in provinces with higher human capital, but higher pollution in provinces with lower human capital. This evidence supports the view that education can mitigate adverse environmental externalities and help steer FDI toward more sustainable trajectories, although most studies still focus on single environmental indicators rather than composite measures of sustainable development.

Synthesizing these strands of empirical evidence indicates that both foreign direct investment and education are important determinants of sustainable development, yet their effects are context dependent and conditional. Although recent studies increasingly suggest that education may enable host countries to better harness the potential benefits of foreign direct investment, empirical evidence on the conditioning role of education in the relationship between foreign direct investment and multidimensional sustainable development remains fragmented and has not been systematically examined at the global level.

More specifically, the existing literature exhibits at least three notable limitations. First, most empirical studies continue to rely on single indicators or focus on individual pillars of sustainable development, while analyses employing composite measures that simultaneously capture economic, social, and environmental dimensions, such as the SDG Index, remain relatively scarce. Second, although education is widely recognized as a key component of absorptive capacity, it is typically included as an independent control variable or examined only within environmental frameworks; direct tests of the interaction between foreign direct investment and education in shaping multidimensional sustainable development outcomes are still uncommon. Third, from a methodological standpoint, the majority of existing studies rely on frequentist panel data techniques, which face well-documented limitations when dealing with short time dimensions, substantial cross-country heterogeneity, and highly correlated interaction terms, thereby raising concerns about parameter stability and inferential reliability.

Motivated by these gaps, the present study adopts a complementarity perspective, viewing the impact of foreign direct investment on sustainable development as conditional on the level of education in host countries. Methodologically, the study employs a hierarchical Bayesian framework to explicitly account for cross-country heterogeneity and to improve inferential stability in the presence of interaction effects, thereby contributing to both the empirical and methodological literature on foreign direct investment and sustainable development.

3. RESEARCH MODEL AND RESEARCH DATA

3.1. Data and Sample Selection

This study employs the Sustainable Development Index (SDGI) as the dependent variable to capture the level of sustainable development across countries. The SDGI is obtained from the Sustainable Development Report series published by the United Nations Sustainable Development Solutions Network (SDSN) in collaboration with international research institutions. The index provides a comprehensive and multidimensional assessment of countries' progress toward the United Nations Sustainable Development Goals (SDGs) by jointly reflecting economic, social, and environmental dimensions of development (Sachs et al., 2019; Sachs et al., 2022).

The empirical dataset is organized at the country-year level and covers the period from 2008 to 2022. The choice of 2008 as the starting year is motivated by both conceptual and empirical considerations. Following the global financial crisis of 2008, academic research and policy discussions increasingly questioned growth-centric development models and emphasized broader notions of welfare, resilience, and sustainability (Stiglitz et al., 2009; Sachs, 2015). Since then, sustainable development has become a central analytical framework for evaluating long-term development outcomes beyond short-term economic growth. Accordingly, the 2008-2022 period allows this study to align with the phase in which sustainable development gained prominence in global policy agendas and empirical research.

The sample includes 72 countries for which complete data are available for the SDGI and all explanatory variables used in the empirical analysis. A detailed list of countries included in the sample is reported in the Appendix. To facilitate sensitivity analysis and comparative interpretation, countries are classified into three income-based groups following the World Bank income classification, which is based on gross national income (GNI) per capita. Specifically, high-income countries are classified as high-income economies; upper-middle-income and lower-middle-income countries are grouped as middle-income economies; and low-income countries are classified as low-income economies. This income-based grouping reflects systematic differences in economic structure and development capacity across country groups and is widely applied in cross-country empirical studies.

The key explanatory variables include foreign direct investment (FDI), education (EDU), and the interaction term between FDI and education (FDI × EDU), which captures the conditional role of education in shaping the development effects of foreign capital inflows. In addition, the dataset incorporates institutional quality, measured using the Worldwide Governance Indicators (WGI) compiled by the World Bank. The WGI dataset consists of six core governance dimensions: (i) Voice and Accountability; (ii) Political Stability and Absence of Violence/Terrorism; (iii) Government Effectiveness; (iv) Regulatory Quality; (v) Rule of Law; and (vi) Control of Corruption. To ensure a parsimonious and consistent measure of institutional quality, these six indicators are aggregated using principal component analysis (PCA), a standard approach in cross-country governance research.

All macroeconomic control variables are obtained from the World Development Indicators (WDI) database of the World Bank. These include measures of trade openness, gross fixed capital formation, and population growth, which capture key structural and demographic conditions potentially associated with sustainable development outcomes.

Prior to estimation, the data undergo a standardized preprocessing procedure. Observations with missing values in key variables are excluded to maintain sample consistency. To mitigate multicollinearity and facilitate interpretation in models with interaction terms, FDI and the FDI × EDU interaction term are mean-centered (denoted by the suffix _c). This transformation also improves numerical stability in the subsequent estimation, particularly within the hierarchical Bayesian framework employed in later sections.

3.2. Econometric Model

To examine the relationship between foreign direct investment, education, and sustainable development from a complementarity perspective, this study specifies a panel data model incorporating an interaction term between FDI and education. This approach allows for a direct test of the hypothesis that the impact of FDI on sustainable development is not automatic, but rather depends on the level of human capital development in host countries.

The dependent variable in the model is the Sustainable Development Goals Index, denoted as $SDGI_{it}$, which captures the multidimensional level of sustainable development of country *i* in year *t*. Building on the theoretical framework of absorptive capacity and complementarity between FDI and education discussed in Section 2, the baseline econometric model is specified as follows:

$$SDGI_{it} = \alpha_i + \beta_1 FDI_{it} + \beta_2 EDU_{it} + \beta_3 (FDI_{it} \times EDU_{it}) + \gamma' X_{it} + \varepsilon_{it} \quad (1)$$

Where α_i represents unobserved, time-invariant country-specific characteristics; FDI_{it} denotes foreign direct investment inflows; EDU_{it} captures the level of education; $FDI_{it} \times EDU_{it}$ is the interaction term designed to capture the conditioning role of education in shaping the impact of FDI; X_{it} is a vector of control variables; and ε_{it} is the idiosyncratic error term.

In this specification, the coefficient β_3 plays a central role. A positive and statistically significant β_3 provides empirical support for the complementarity hypothesis, indicating that education amplifies the positive impact of FDI on sustainable development. Conversely, an insignificant or negative interaction coefficient suggests that education is insufficient to transform FDI inflows into sustainable development outcomes, or may even weaken the development effects of FDI in certain contexts.

3.2.1. Control variables

To isolate the effects of FDI, education, and their interaction, the model incorporates a set of control variables selected based on theoretical considerations and empirical evidence from the sustainable development and development economics literature (Table 1).

Table 1: Description of variables in the model

Variable	Definition	Expected sign	Measurement	Literature	Source
Dependent variable					
SDGI	Sustainable Development Goals Index		Composite of 17 SDG indicators	Sachs et al. (2019; 2022)	Economic and Affairs (2022)
Independent variable					
FDI	Net foreign direct investment inflows (% of GDP)	+	FDI net inflows as % of GDP	Borensztein et al. (1998); Alfaro et al. (2004)	World Bank
EDU	Education	+	Government expenditure on education (% of GDP)	Barro (1991)	World Bank
FDI×EDU	Interaction between FDI and EDU	+	Product of FDI and EDU	Borensztein et al. (1998); Durham (2004); Alfaro et al. (2010)	Author's calculation
Control variable					
WGI	Institutional quality	+	Composite index constructed from the six Worldwide Governance Indicators	North (1990); Sachs et al. (2022)	World Bank (WGI); PCA by author
TRA	Trade openness	+	Total exports+imports (% of GDP)	Frankel and Romer (1999); Yingjun et al. (2024)	World Bank
GFCF	Gross fixed capital formation	+	GFCF (% of GDP)	Barro (1991); De Long and Summers (1991)	World Bank
INF	Inflation rate	-	Annual CPI growth (%)	Bruno and Easterly (1998); Jin (2024); AlShafeey (2024)	World Bank
POP	Population growth	-	Annual population growth rate (%)	Bongaarts and O'Neill (2018)	World Bank

Source: Authors

First, institutional quality is included in the model using an aggregate indicator based on the Worldwide Governance Indicators (WGI). Institutional economics emphasizes that institutional quality determines the efficiency of resource allocation, the protection of property rights, and the effectiveness of long-term development policies (North, 1990; Williamson, 2000). Empirical studies further show that institutional quality not only directly influences sustainable development outcomes but also plays an important moderating role in shaping the effectiveness of foreign direct investment (Alfaro et al., 2010; Hamid, 2025).

Second, trade openness is introduced to control for the degree of integration into international trade. The existing literature suggests that trade openness can promote sustainable development through technology diffusion, increased competition, and improved resource efficiency; however, in the absence of appropriate environmental and social regulations, high trade openness may also intensify environmental pressure and social inequality (Grossman and Krueger, 1995; Frankel and Rose, 2005).

Third, physical capital accumulation, measured by gross fixed capital formation, is included to capture long-term investment capacity and infrastructure development. Physical capital is widely regarded as a fundamental driver of economic growth and is indirectly linked to the social and environmental dimensions of sustainable development through improvements in productive capacity and living standards (Barro, 1991; Conceição, 2020).

Fourth, population growth is incorporated to control for demographic pressures. The development literature highlights that population growth can stimulate market expansion and labor supply, while simultaneously posing challenges to natural resources, public services, and long-term sustainability (Bloom and Canning, 2008; Sachs, 2015).

Including these control variables helps mitigate potential omitted-variable bias and ensures that the estimated relationship between FDI, education, and sustainable development reflects the substantive effects of the core explanatory variables, rather than being driven by underlying macroeconomic or institutional conditions.

In summary, the econometric model developed in this study directly reflects the theoretical framework of absorptive capacity and complementarity between foreign direct investment and education, while remaining consistent with a multidimensional approach to sustainable development. This specification provides the analytical foundation for subsequent sections, which apply more advanced estimation strategies to better address cross-country heterogeneity and inferential challenges in international panel data.

3.3. Hierarchical Bayesian Model and Model Selection

While the baseline econometric model presented in Section 3.2 provides a clear framework for analyzing the conditional relationship between foreign direct investment, education, and sustainable development, the application of conventional frequentist panel data methods may encounter several limitations in a cross-country setting. In particular, international panel data are typically characterized by substantial unobserved heterogeneity across countries, relatively short time dimensions, and pronounced correlations among explanatory variables, especially when interaction terms are included. These features may lead to unstable parameter estimates and unreliable statistical inference.

To address these limitations and to enhance the robustness of the empirical results, this study adopts a hierarchical Bayesian framework and estimates three alternative model configurations with different degrees of prior informativeness. This approach allows for a systematic evaluation of how hierarchical structures and prior assumptions affect parameter stability and predictive performance.

3.3.1. Bayesian model specifications

The empirical analysis considers three Bayesian model specifications.

(i) Flat Prior Model

In the flat Bayesian model, all parameters are assigned non-informative priors, allowing the data to fully dominate posterior inference. The model is specified as:

$$SDGI_{it} = \alpha + \beta_1 FDI_{it} + \beta_2 EDU_{it} + \beta_3 (FDI_{it} \times EDU_{it}) + \gamma' Z_{it} + \quad (2)$$

with the following prior distributions:

$\alpha \sim N(0, 10^6)$, $\beta_1, \beta_2, \beta_3, \gamma_j \sim N(0, 10^6)$, $\sigma \sim$ Half-Cauchy (0,5)

This specification does not incorporate a hierarchical structure and corresponds to the assumption that all countries share a common intercept, with parameter estimates being determined entirely by the observed data.

(ii) Hierarchical Flat Model

The hierarchical flat model extends the pooled specification by introducing country-level random intercepts, thereby capturing unobserved heterogeneity in baseline sustainable development levels across countries while still allowing information to be shared with the global mean. The model is specified as:

$$SDGI_{it} = \alpha_i + \beta_1 FDI_{it} + \beta_2 EDU_{it} + \beta_3 (FDI_{it} \times EDU_{it}) + \gamma' Z_{it} + \varepsilon_{it} \quad (3)$$

Where:

$$\alpha_i \sim \mathcal{N}(\mu_\alpha, \tau_\alpha^2), \mu_\alpha \sim \mathcal{N}(0, 10^6), \tau_\alpha \sim Half-Student-t(3, 0, 2.5)$$

and:

$\sigma \sim$ Half-Cauchy (0,5).

This specification explicitly reflects the partial pooling mechanism, whereby countries with limited data are shrunk more strongly toward the global mean μ_α, while countries with richer information retain more pronounced country-specific characteristics.

(iii) Hierarchical Weakly Informative Model

The third specification maintains the hierarchical intercept structure while incorporating weakly informative priors that reflect theoretical knowledge about the relationship between institutional quality and sustainable development. Based on the institutional and development literature (North, 1990; Sachs et al., 2022), institutional quality is expected to exert a positive effect of moderate magnitude on sustainable development. Accordingly, the coefficient on institutional quality is assigned a moderately positive prior, while control variables are assigned zero-centered weakly informative priors in line with recommendations by Gelman et al. (2008), Vehtari et al. (2017), and McElreath (2020).

The model is specified as:

$$SDGI_{it} = \alpha_i + \beta_1 FDI_{it} + \beta_2 EDU_{it} + \beta_3 (FDI_{it} \times EDU_{it}) + \gamma' Z_{it} + \varepsilon_{it} \quad (4)$$

With the following prior structure:

$$\alpha_i \sim \mathcal{N}(\mu_\alpha, \tau_\alpha^2), \mu_\alpha \sim \mathcal{N}(0,1), \tau_\alpha \sim Half-Student-t(3,0,1),$$

$\beta_1, \beta_2, \beta_3 \sim N(0.5, 0.5^2)$, $\gamma_j \sim N(0,1^2)$, $\sigma \sim$ Half-Cauchy (0,2). This prior specification reflects a moderate belief that institutional quality positively affects sustainable development, while preserving sufficient flexibility and neutrality with respect to control variables. The use of weakly informative priors helps stabilize estimation, avoid extreme posterior values, and improve MCMC convergence when the data exhibit noise or mild multicollinearity.

3.3.2. Hamiltonian Monte Carlo estimation

To estimate the parameters of the hierarchical Bayesian models, the study employs the Hamiltonian Monte Carlo (HMC) algorithm, an advanced variant of the Metropolis-Hastings family within the Markov Chain Monte Carlo (MCMC) framework. HMC is designed to explore high-dimensional parameter spaces more efficiently than conventional random-walk algorithms.

HMC simulates the motion of a particle in the parameter space according to the principles of Hamiltonian mechanics, where the potential energy corresponds to the negative log-posterior density and the kinetic energy is associated with an auxiliary momentum variable. The Hamiltonian is defined as:

$$H(\theta, p) = U(\theta) + K(p) = -\log P(\theta y) + \frac{1}{2} p^\top M^{-1} p \quad (5)$$

Where θ denotes the parameter vector, p is the momentum variable, and M is the mass matrix.

Because the Hamiltonian equations cannot be solved analytically, HMC relies on the leapfrog algorithm to approximate the Hamiltonian trajectory using a step size ϵ. After simulating the trajectory for L leapfrog steps, the proposed state is accepted or rejected according to the Metropolis criterion, ensuring detailed balance and convergence to the target posterior distribution.

By simulating directed trajectories that approximately conserve energy, HMC enables the sampler to move efficiently through the parameter space, substantially reducing autocorrelation, accelerating convergence, and improving sampling efficiency in models with a large number of parameters (Neal, 2011; Betancourt, 2017).

3.3.3. Convergence diagnostics and model selection

To ensure the reliability of posterior inference, the study evaluates standard Markov Chain Monte Carlo convergence diagnostics, including the effective sample size and related sampling efficiency indicators. These diagnostics confirm that the posterior draws are sufficient to support stable and reliable inference across all estimated Bayesian specifications.

In addition to convergence diagnostics, model adequacy and predictive performance are assessed using leave one out cross validation. Unlike conventional goodness of fit measures that rely on in sample performance, leave one out cross validation evaluates models based on their out of sample predictive accuracy. This property makes it particularly suitable for comparing Bayesian models with different levels of complexity and hierarchical structure.

Model comparison is conducted using the expected log predictive density obtained from leave one out cross validation. Higher values of the expected log predictive density indicate superior out of sample predictive performance. The analysis shows that both hierarchical specifications substantially outperform the flat prior model, highlighting the importance of explicitly accounting for unobserved country level heterogeneity in cross country panel data.

Between the two hierarchical specifications, the standard hierarchical model achieves the highest expected log predictive density and exhibits stable Pareto k diagnostics. Although the hierarchical weakly informative model delivers very similar predictive accuracy, its performance is marginally lower and is accompanied by a minor diagnostic warning. Accordingly, based on the combined evidence from predictive accuracy and diagnostic reliability, the hierarchical model is selected as the preferred specification for substantive interpretation and policy discussion in subsequent sections.

4. RESEARCH RESULTS AND DISCUSSION

4.1. Analysis on the full sample

Table 2 reports the descriptive statistics of the variables used in the analysis, covering 1,080 country-year observations over the

Table 2: Descriptive statistics of variables in the model

Variable	Count	Mean	Standard	Min	25%	50%	75%	Max	Skew	Kurtosis
WGI	1080	0.604	0.235	0.164	0.403	0.609	0.799	1	0.048	−1.228
FDI	1080	3.311	4.65	−32.547	1.286	2.601	4.468	36.803	1.276	15.682
TRA	1080	39.961	26.867	4.549	23.861	32.297	50.828	228.994	2.664	11.775
EDU	1080	4.441	1.544	0.864	3.295	4.348	5.428	9.51	0.371	−0.188
GFCF	1080	22.963	6.094	5.656	19.08	22.469	25.782	52.418	0.905	1.844
INF	1080	4.288	5.586	−3.233	1.201	2.758	5.59	72.309	4.354	35.93
REM	1080	2.975	4.755	0	0.265	1.039	3.474	33.612	2.876	9.415
POP	1080	1.073	1.303	−4.17	0.143	0.896	1.992	6.569	0.296	0.391
SDGI	1080	68.903	10.411	45.161	61.144	71.588	77.342	86.509	−0.538	−0.851

Source: Authors

study period. The Sustainable Development Goals Index (SDGI) exhibits a mean value of approximately 68.9 points, with a standard deviation of 10.4, indicating substantial cross-country variation in sustainable development performance. The distribution of SDGI is relatively balanced, with a slightly negative skewness and low kurtosis, suggesting the absence of severe distributional asymmetry or extreme observations.

Regarding the main explanatory variables, foreign direct investment (FDI) records an average value of 3.31% of GDP, but displays considerable dispersion across countries, as reflected by a large standard deviation (4.65) and a wide range spanning from -32.55% to 36.80% of GDP. This pattern highlights pronounced heterogeneity in both the scale and volatility of FDI inflows across national economies. In contrast, education (EDU), measured by government expenditure on education as a share of GDP, has an average value of approximately 4.44% of GDP, with moderate variability and a relatively symmetric distribution, indicating that education levels are more stable than FDI within the sample.

Institutional quality (WGI) shows a mean value of 0.60 and a fairly balanced distribution, reflecting cross-country differences in governance capacity. Trade openness (TRA) has an average level close to 40% of GDP but exhibits a pronounced right-skewed distribution, implying that a subset of countries is characterized by exceptionally high degrees of trade integration. Gross fixed capital formation (GFCF) averages around 23% of GDP and displays a relatively stable distribution. Among the remaining macroeconomic control variables, inflation (INF) and remittances (REM) are strongly right-skewed with high kurtosis, indicating the presence of extreme observations in certain countries and periods, whereas population growth (POP) has a low mean value and a relatively balanced distribution. Overall, the descriptive statistics reveal substantial heterogeneity across countries, particularly for macroeconomic variables such as FDI, trade openness, and inflation, thereby underscoring the need for empirical approaches capable of accommodating cross-country heterogeneity and non-uniform data distributions in subsequent analyses.

Prior to model estimation, the data are preprocessed to ensure numerical stability and facilitate the interpretation of regression coefficients, especially in the presence of interaction terms. Specifically, foreign direct investment (FDI) is mean-centered by subtracting its sample mean before constructing the interaction term with education. This transformation serves two primary purposes: (i) reducing mechanical multicollinearity between FDI and the interaction term FDI × EDU, and (ii) allowing the estimated coefficients to be interpreted at the average level of FDI in the sample, rather than at an FDI value of zero, which carries limited economic meaning in a cross-country context.

In contrast, education (EDU) is not mean-centered and is retained in its original scale. This treatment reflects the theoretical role of education in the model as a foundational factor and a conditioning variable, which determines the capacity of host countries to absorb and transform FDI inflows into sustainable development outcomes. Preserving EDU in its original scale maintains its economic and policy relevance and allows for a direct interpretation of the amplifying role of education in shaping the impact of FDI through the interaction term. Moreover, the descriptive statistics indicate that EDU exhibits a relatively balanced distribution without severe skewness or extreme outliers; therefore, mean-centering this variable is not necessary from a numerical stability perspective and could potentially reduce the clarity of its economic interpretation in a policy-oriented analysis.

The correlation matrix indicates that SDGI exhibits relatively strong positive correlations with institutional quality (WGI) and education (EDU), highlighting the foundational role of institutional capacity and human capital in promoting sustainable development (Figure 1). In contrast, SDGI is negatively correlated with population growth (POP) and inflation (INF), suggesting that demographic pressure and macroeconomic instability may hinder the long-term sustainability of development outcomes.

With respect to the explanatory variables, although FDI has been mean-centered prior to constructing the interaction term, the correlation between FDI_c and the interaction variable EDU × FDI_c remains relatively high. This pattern is a well-documented feature of models incorporating interaction terms, as interaction variables inherently share information with their constituent components, even after mean-centering (Aiken et al., 1991; Brambor et al., 2006). Consequently, a high correlation between interaction terms and their underlying variables does not mechanically imply severe multicollinearity, but it may increase the variance of coefficient estimates and lead to unstable inference in conventional linear regression frameworks.

In this context, the hierarchical Bayesian approach is particularly appropriate when multicollinearity arises from interaction effects, where explanatory variables remain highly correlated even after centering. Rather than excluding variables or applying mechanical corrective procedures, hierarchical Bayesian models allow for regularization of regression coefficients through prior distributions, thereby reducing posterior variance induced by multicollinearity and mitigating the estimation instability commonly observed in traditional linear regression models. Through Bayesian shrinkage, coefficient estimates are stabilized within plausible ranges without distorting the theoretical structure of the model or discarding economically meaningful information embedded in the interaction term (Gelman et al., 2013; Pesaran and Smith, 2019; McElreath, 2020).

Overall, the correlation matrix provides important descriptive insights into the relationships among the variables employed in the model and further supports the suitability of adopting a hierarchical Bayesian framework to address inferential challenges arising from high correlations between interaction terms and their component variables in subsequent empirical analysis.

Table 3 reports the posterior statistical indices of the three Bayesian model specifications estimated in this study, including the Flat model, the Hierarchical model with uninformative priors, and the Hierarchical Informative model. The reported statistics comprise the posterior mean (mean), standard deviation (sd), 90% highest

Figure 1: Correlation matrix

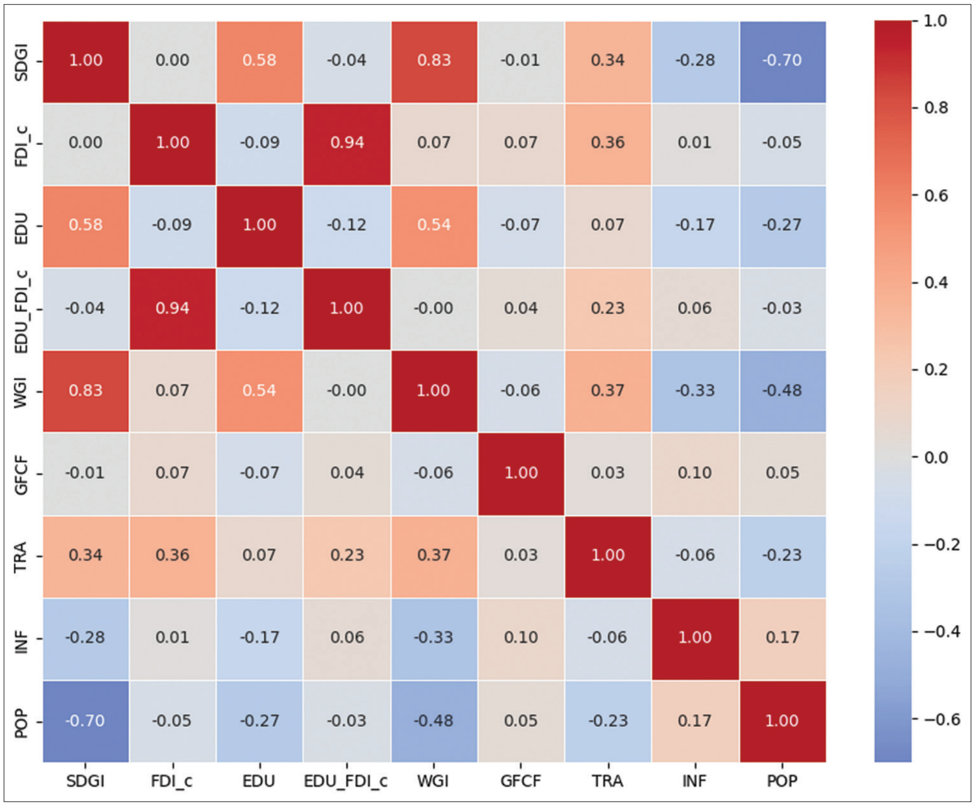


Table 3: Posterior inference results

Variable	Flat model								
	Mean	Standard deviation	hdi_5%	hdi_95%	mcse_mean	mcse_sd	ess_bulk	ess_tail	$\hat{r}$
Intercept	48.047	0.746	46.812	49.260	0.008	0.006	7937	8638	1
FDI_c	−1.958	0.399	−2.612	−1.300	0.005	0.004	7565	8436	1
EDU	1.387	0.098	1.229	1.548	0.001	0.001	12732	7942	1
EDU_FDI_c	0.266	0.080	0.140	0.405	0.001	0.001	7746	8099	1
WGI	22.980	0.763	21.690	24.205	0.007	0.006	10630	8928	1
GFCF	0.121	0.021	0.087	0.155	0.000	0.000	10019	8777	1
TRA	0.035	0.006	0.025	0.044	0.000	0.000	11997	9341	1
INF	−0.017	0.024	−0.057	0.023	0.000	0.000	13346	8969	1
POP	−3.046	0.112	−3.228	−2.860	0.001	0.001	11805	7907	1
Sigma	4.168	0.088	4.022	4.312	0.001	0.001	17003	8749	1
Hierarchical Model									
FDI_c	−0.709	0.236	−1.105	−0.332	0.004	0.003	3057	4504	1
EDU	0.533	0.094	0.388	0.694	0.002	0.001	1757	3628	1
EDU_FDI_c	0.072	0.043	0.001	0.142	0.001	0	3263	4950	1
WGI	9.529	1.756	6.851	12.543	0.083	0.042	447	880	1.01
GFCF	0.073	0.018	0.043	0.103	0	0	1737	3807	1
TRA	0.047	0.009	0.033	0.062	0	0	1444	3359	1
INF	−0.045	0.013	−0.066	−0.024	0	0	5364	6659	1
POP	−0.709	0.102	−0.873	−0.541	0.002	0.001	3153	4322	1
Sigma	1.735	0.04	1.67	1.8	0.001	0	2831	5060	1
Hierarchical Informative									
FDI_c	−0.709	0.239	−1.097	−0.313	0.004	0.003	4350	5829	1
EDU	0.538	0.094	0.391	0.696	0.003	0.001	1335	4186	1
EDU_FDI_c	0.071	0.044	0	0.144	0.001	0	4551	5823	1
WGI	10.579	1.822	7.833	13.714	0.095	0.049	357	881	1.01
GFCF	0.072	0.018	0.042	0.101	0	0	2065	4253	1
TRA	0.048	0.009	0.033	0.063	0	0	1392	3467	1
INF	−0.045	0.013	−0.065	−0.023	0	0	6870	7909	1
POP	−0.721	0.103	−0.893	−0.554	0.002	0.001	2698	4320	1
Sigma	1.74	0.041	1.673	1.807	0.001	0	3523	5545	1

Source: Authors

density interval (HDI 5-95%), Monte Carlo error (mcse_mean, mcse_sd), effective sample size (ess_bulk, ess_tail), and the convergence diagnostic $\hat{r}$.

Overall, the MCMC chains of all three models exhibit good convergence, as indicated by $\hat{r}$ values close to 1 for all parameters. This confirms that the sampling process has reached a stable stationary distribution and that posterior parameters can be reliably inferred. In addition, the Monte Carlo errors are uniformly small, mostly below 0.01, reflecting high precision in estimating posterior means and variances.

In terms of effective sample size, the Flat model displays substantially higher ess_bulk and ess_tail values, indicating high sampling efficiency and low chain dependence under the pooled specification. By contrast, the two hierarchical models yield lower effective sample sizes due to the increased complexity of the posterior distribution induced by the hierarchical structure. Nevertheless, the ESS values remain within an acceptable range for posterior inference when considered alongside stable $\hat{r}$ diagnostics. Notably, the Hierarchical Informative model tends to achieve higher average effective sample sizes than the uninformative hierarchical specification for key variables, reflecting the information borrowing effect of weakly informative priors, which stabilizes estimation in the presence of correlated predictors and short time dimensions.

Taken together, the posterior diagnostics indicate that all three models converge well and yield reliable inference. While the Flat model achieves higher effective sample sizes, the hierarchical specifications, particularly the Hierarchical Informative model, provide more conservative and stable estimates under conditions of cross country heterogeneity and uneven statistical signals.

While Table 3 focuses on effect magnitudes and associated uncertainty, Table 4 complements this analysis by examining the posterior probability of coefficients having the expected directional effects.

Table 4 reports the posterior probabilities P (β > 0) for each explanatory variable across the three Bayesian specifications, Flat, Hierarchical, and Hierarchical Informative. The results reveal a high degree of consistency across models for most core explanatory and control variables.

Table 4: Posterior probability P (β > 0) across Bayesian models

Variable	→ SDGI	Bayes model (%)		
		Flat	Flat hierarchical	Hierarchical informative
FDI_c	→ SDGI	0.00	0.21	0.13
EDU	→ SDGI	100	100	100
EDU_FDI_c	→ SDGI	99.95	95.6	95.0
WGI	→ SDGI	100	100	100
GFCF	→ SDGI	100	100	100
TRA	→ SDGI	100	100	100
INF	→ SDGI	24.7	0.0	0.0
POP	→ SDGI	0.0	0.0	0.0

Source: Authors

Specifically, education (EDU), institutional quality (WGI), gross fixed capital formation (GFCF), and trade openness (TRA) all exhibit posterior probabilities at or near 100% for positive effects on SDGI across all model specifications, confirming the robust and stable contribution of these factors to sustainable development outcomes. Importantly, the interaction term EDU multiplied by FDI_c also demonstrates very high posterior probabilities, approaching 100% in the Flat model and around 95% in the hierarchical specifications, providing strong probabilistic support for the hypothesis that education enhances the absorptive capacity through which FDI contributes to sustainable development.

By contrast, FDI_c displays posterior probabilities close to 0% for a positive effect in all three models, indicating that FDI inflows, when considered in isolation, do not promote sustainable development outcomes. For inflation (INF), the posterior probability of a positive effect appears only weakly in the Flat model and declines to nearly zero in the hierarchical specifications, suggesting that the negative impact of inflation becomes more consistent once unobserved country level heterogeneity is accounted for. Similarly, population growth (POP) shows posterior probabilities of zero for positive effects across all specifications, indicating a highly stable negative association with SDGI.

Overall, Table 4 reinforces the conclusions drawn from Table 3 by providing a clear probabilistic perspective. While FDI alone does not foster sustainable development, education plays a critical conditioning role, enabling host countries to transform foreign investment inflows into more favorable sustainable development outcomes.

Table 5 reports the out of sample predictive performance of the three Bayesian model specifications, including the Flat, Hierarchical, and Hierarchical Informative models, evaluated using leave one out cross validation. The reported statistics include the expected log predictive density, its standard error, the effective number of parameters, and the Pareto k diagnostics.

The results show that both hierarchical specifications substantially outperform the Flat model in terms of predictive accuracy. The Hierarchical model achieves the highest expected log predictive density with a value of minus 2170.199, followed closely by the Hierarchical Informative model with a value of minus 2173.911. In contrast, the Flat model performs considerably worse, with an expected log predictive density of minus 3082.245. These results indicate that explicitly accounting for unobserved country level heterogeneity leads to a marked improvement in out of sample predictive performance.

As expected, the hierarchical models exhibit greater model complexity, as reflected by higher values of the effective number of parameters, which are approximately 81, compared with about 12.5 for the Flat specification. With respect to diagnostic reliability, the leave one out cross validation results are highly stable across all models. All observations in the Flat and Hierarchical models display Pareto $k \leq 0.7$. The Hierarchical Informative model contains one observation in the moderate range where $k > 0.7$ but ≤ 1. No observations exceed the critical threshold where k >

1. Overall, the Pareto k diagnostics confirm that the leave one out cross validation estimates are reliable and suitable for model comparison.

Table 6 summarizes the Bayesian model comparison based on leave one out cross validation and posterior model weights computed using the stacking approach. The results clearly identify the Hierarchical model as the preferred specification, as it ranks first and achieves the highest expected log predictive density of −2170.2. This model receives a posterior model weight of one, indicating dominant support from the data.

The Hierarchical Informative model ranks second, with an expected log predictive density of −2173.91 and an expected log predictive density difference of 3.71 relative to the best performing model. Although this difference remains small in magnitude and well within the associated standard error, the stacking procedure assigns a negligible posterior weight to this specification. This outcome reflects the presence of a minor Pareto k warning, which reduces its contribution in the model averaging framework.

By contrast, the Flat model exhibits substantially weaker predictive performance, with an expected log predictive density of −3082.25 and an expected log predictive density difference exceeding 900 units relative to the Hierarchical model. Despite its lower effective number of parameters, the Flat specification shows limited generalizability when unobserved cross country heterogeneity is ignored.

Taken together, the leave one out cross validation results and posterior model weights consistently indicate that the Hierarchical model provides the most reliable and robust representation of the data. Accordingly, this specification is selected as the preferred model for subsequent inference and discussion.

Table 7 reports the posterior estimates of the Hierarchical Flat model, which is selected as the preferred specification based on the LOO-CV comparison. In addition to the regression coefficients at the observation level, the table also presents group level parameters, including the global intercept mean $\bar{\alpha}$ and the standard deviation of country specific intercepts σ_{α}. These parameters capture the average baseline level of sustainable development across the full sample and the extent of unobserved heterogeneity across countries in the Sustainable Development Goals Index, after controlling for the explanatory variables included in the model.

The results indicate that the posterior mean of $\bar{\alpha}$ is approximately 56.60, with a relatively narrow highest density interval, suggesting that the average baseline level of SDGI is precisely identified once observable covariates are taken into account. At the same time, σ^{α} is estimated at 6.73, revealing substantial cross country variation in baseline SDGI, even among countries with similar levels of FDI, education, institutional quality, and other control variables. This finding implies that unobserved factors such as historical trajectories, social structures, governance capacity, and long term policy paths continue to play an important role in shaping countries' initial sustainable development levels. Consequently, assuming a common intercept across all countries, as in conventional pooled models, may lead to biased inference and an incomplete understanding of the underlying dynamics of sustainable development (Baltagi, 2008; Gelman et al., 2013).

Table 5: Out-of-sample predictive performance and diagnostic statistics based on leave-one-out cross-validation (LOO-CV)

Model	elpd_loo	SE (elpd_loo)	p_loo	Pareto k≤0.7	Pareto k (0.7-1)	Pareto k>1
Hierarchical Model	−2170.199	22.632	80.764	1080	0	0
Hierarchical Informative	−2173.911	22.721	80.829	1079	1	0
Flat	−3082.245	27.249	12.540	1080	0	0

Source: Authors

Table 6: Model comparison based on LOO-CV and posterior model weights

Model	Rank	elpd_loo	p_loo	elpd_diff	Weight	se	dse	Warning
Hierarchical Model	1	−2170.2	80.7639	0	1	22.63237	0	False
Hierarchical Informative	2	−2173.91	80.82853	3.711901	3.99E-08	22.72122	0.709395	True
Flat	3	−3082.25	12.53976	912.0461	0	27.2495	30.92441	False

Source: Authors

Table 7: Posterior summary - hierarchical model

Variable	→SDGI	Posterior mean	Standard deviation	hdi_5%	hdi_95%	P(β>0) (%)
alpha_bar		56.595	1.4299	54.3273	59.0266	
sigma_alpha		6.7253	0.6084	5.7076	7.6968	
FDI_c	→ SDGI	−0.6986	0.2382	−1.0922	−0.3166	0.10
EDU	→ SDGI	0.538	0.0933	0.3786	0.6861	100.00
EDU_FDI_c	→ SDGI	0.0699	0.0436	−0.0008	0.1422	94.60
WGI	→ SDGI	9.7168	1.7679	6.8262	12.6928	100.00
GFCF	→ SDGI	0.0726	0.0184	0.0418	0.1027	100.00
TRA	→ SDGI	0.048	0.0089	0.0338	0.0634	100.00
INF	→ SDGI	−0.0454	0.0132	−0.0671	−0.0241	0.00
POP	→ SDGI	−0.7073	0.1016	−0.8755	−0.5421	0.00
sigma		1.736	0.0407	1.67	1.8035	

Source: Authors

Turning to the regression coefficients, FDI exhibits a negative effect on SDGI at the average level of education, indicating that FDI does not automatically promote sustainable development in contexts where domestic absorptive conditions remain limited. By contrast, education shows a strong and stable positive association with SDGI, underscoring the foundational role of human capital in advancing sustainable development outcomes.

Crucially, even after accounting for the substantial baseline heterogeneity across countries through the hierarchical structure, the estimation results continue to provide consistent evidence of a complementarity mechanism between education and FDI. Specifically, the interaction term between education and FDI carries a positive sign with a high posterior probability, indicating that the effect of FDI on sustainable development becomes more favorable in countries with stronger educational foundations. This result suggests that the education FDI complementarity does not merely reflect pre-existing cross country differences, but rather represents a structural relationship that persists even after unobserved country specific characteristics are tightly controlled for.

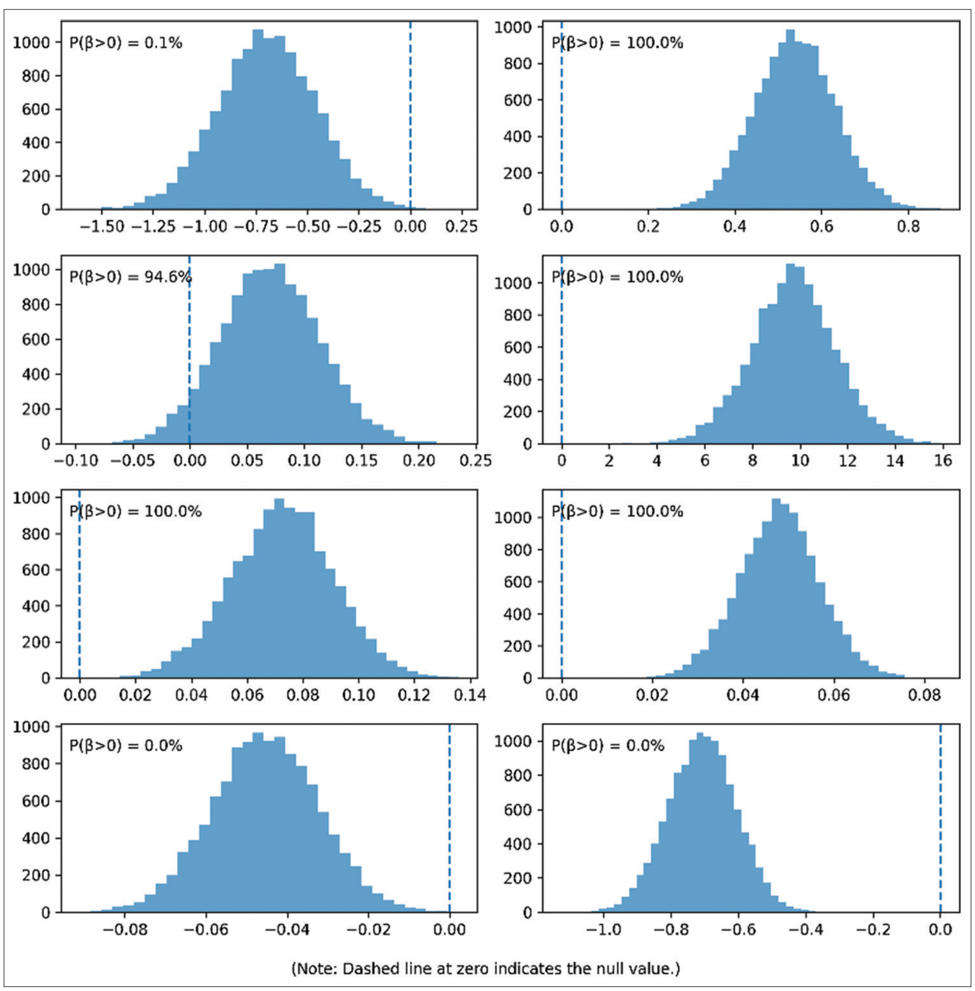
These findings extend earlier work on absorptive capacity, which has largely focused on economic growth outcomes (Borensztein et al., 1998; Durham, 2004), to a multidimensional sustainable development framework. In this broader context, education emerges not only as an independent determinant of sustainable development, but also as a key factor shaping how FDI is transformed into long term development outcomes. Figure 2 visually reinforces these conclusions by illustrating the posterior distributions of the main coefficients, with particular emphasis on the conditioning role of education in determining the impact of FDI on SDGI.

4.2. Analysis by Country Groups

To further elucidate the heterogeneity in the relationship between foreign direct investment, education, and sustainable development across countries at different stages of development, this study proceeds by estimating the hierarchical Bayesian model separately for each country group based on the World Bank income classification. This approach allows for an explicit assessment of whether the complementarity mechanism between FDI and education varies with income levels, while also providing more granular evidence on structural differences in the drivers of sustainable development across country groups.

Table 8 reports the posterior estimates from the hierarchical Bayesian model for three country groups, including high income, middle income, and low income economies. The table presents

Figure 2: Posterior distributions - hierarchical informative model



Source: Authors

Table 8: Posterior summary - hierarchical model

Variable	→ SDGI	Posterior Mean	Standard deviation	hdi_5%	hdi_95%	(β>0) (%)
High-income countries						
alpha_bar		71.734	2.626	67.585	76.223	
sigma_alpha		5.974	0.838	4.572	7.263	
FDI_c	→ SDGI	−0.541	0.354	−1.089	0.061	5.9
EDU	→ SDGI	0.339	0.133	0.123	0.558	99.4
EDU_FDI_c	→ SDGI	0.08	0.06	−0.021	0.175	90.9
WGI	→ SDGI	0.439	2.762	−4.394	4.781	56.4
GFCF	→ SDGI	−0.017	0.031	−0.065	0.035	28.3
TRA	→ SDGI	0.076	0.01	0.06	0.093	100.0
INF	→ SDGI	−0.034	0.024	−0.071	0.008	8.2
POP	→ SDGI	−0.119	0.08	−0.255	0.007	6.6
Sigma		1.188	0.043	1.116	1.258	
Middle-income countries						
alpha_bar		63.094	2.077	59.675	66.472	
sigma_alpha		5.344	0.79	4.11	6.564	
FDI_c	→ SDGI	−2.387	0.38	−3.026	−1.769	0.0
EDU	→ SDGI	0.322	0.158	0.07	0.589	97.8
EDU_FDI_c	→ SDGI	0.402	0.09	0.259	0.555	100.0
WGI	→ SDGI	7.453	2.577	3.134	11.604	99.8
GFCF	→ SDGI	0.057	0.029	0.012	0.105	97.5
TRA	→ SDGI	−0.015	0.015	−0.041	0.008	16.0
INF	→ SDGI	−0.051	0.018	−0.081	−0.023	0.2
POP	→ SDGI	−2.016	0.287	−2.473	−1.528	0.0
Sigma		1.899	0.073	1.774	2.011	
Low-income countries						
alpha_bar		50.843	2.136	47.565	54.618	
sigma_alpha		3.161	0.877	1.899	4.414	
FDI_c	→ SDGI	−3.339	0.615	−4.324	−2.287	0
EDU	→ SDGI	0.971	0.166	0.693	1.235	100
EDU_FDI_c	→ SDGI	1.019	0.215	0.672	1.384	100
WGI	→ SDGI	1.102	2.561	−2.822	5.546	67
GFCF	→ SDGI	0.163	0.04	0.095	0.225	100
TRA	→ SDGI	0.04	0.034	−0.013	0.098	88
INF	→ SDGI	−0.104	0.037	−0.163	−0.044	0.3
POP	→ SDGI	−2.111	0.485	−2.89	−1.298	0.0
Sigma		1.937	0.143	1.699	2.162	

Source: Authors

the posterior mean, posterior standard deviation, the 90% highest density interval (HDI 5–95%), and the posterior probability that each coefficient is positive, P (β > 0), for all covariates included in the model.

The estimation results reveal pronounced structural heterogeneity across income groups. First, the global intercept, $\bar{\alpha}$, exhibits a clear downward gradient with respect to countries' income levels. Specifically, high income countries display the highest baseline level of sustainable development, with a posterior mean SDGI of 71.734, followed by middle income countries at 63.094, and low income countries at 50.843. The 90% highest density intervals (HDI 5–95%) of $\bar{\alpha}$ are relatively narrow across all three groups, indicating that baseline SDGI levels by income group are well identified and stable within the hierarchical Bayesian framework.

At the same time, the standard deviation of country specific intercepts, σ_α, indicates that unobserved cross country heterogeneity remains substantial across all income groups. However, σ_α is notably lower for low income countries (3.161) than for high income (5.974) and middle income countries (5.344). This pattern suggests that baseline SDGI levels among low income countries are relatively more homogeneous, albeit at a lower level, whereas high income and middle income countries exhibit greater dispersion in their sustainable development trajectories, even after controlling for observable covariates in the model.

With respect to residual uncertainty, captured by the error term σ, high income countries exhibit the lowest posterior mean value (1.188), while middle income and low income countries display substantially higher values of 1.899 and 1.937, respectively. This finding implies that sustainable development outcomes in middle income and low income countries are more strongly influenced by factors outside the model, including macroeconomic shocks, institutional volatility, or other difficult to observe structural characteristics, thereby increasing unexplained variation relative to high income countries.

Turning to the direct effect of foreign direct investment, the coefficient on FDI_c is negative across all three income groups, though its magnitude and certainty vary considerably. In high income countries, FDI_c has a posterior mean of −0.541, with a 90% HDI ranging from −1.089 to 0.061 and a posterior probability of a positive effect of only 5.9%, indicating a relatively weak and statistically uncertain negative association. In contrast, the effect becomes substantially more pronounced in middle income countries, where FDI_c declines to −2.387, with the entire 90% HDI lying below zero [−3.026; −1.769] and P (β > 0) = 0. This pattern intensifies further in low income countries, where *FDIc* reaches −3.339, with a 90% HDI of [−4.324; −2.287] and again P (β > 0) = 0. Taken together, these results indicate that foreign direct investment, when considered in isolation, does not promote sustainable development and may even undermine it, particularly in lower income contexts.

Crucially, the central insight of the results lies in the interaction between foreign direct investment and education, EDU_FDI_c, which captures the proposed complementarity mechanism. In high income countries, the interaction term is positive, with a posterior mean of 0.08, although its 90% HDI still marginally overlaps zero [−0.021; 0.175], despite a relatively high posterior probability of a positive effect, P (β > 0) = 90.9%. By contrast, in middle income countries, the interaction coefficient rises sharply to 0.402, with the entire 90% HDI located above zero [0.259; 0.555] and P (β > 0) = 100%. The effect is even more pronounced in low income countries, where the interaction term reaches 1.019, with a 90% HDI of [0.672; 1.384] and P (β > 0) = 100%. These findings provide compelling evidence that education plays a decisive complementary role in transforming foreign direct investment into a driver of sustainable development, and that this role becomes increasingly important as countries' income levels decline.

Beyond its moderating function, education also exhibits a strong and positive direct effect on sustainable development across all income groups. Notably, the magnitude of this effect is largest in low income countries, with a posterior mean of 0.971, substantially exceeding the corresponding estimates for high income (0.339) and middle income countries (0.322). This result suggests that the marginal returns to educational investment in terms of sustainable development outcomes are particularly high in less developed economies, where improvements in human capital can generate broad spillover effects across economic, social, and environmental dimensions.

Overall, the group specific results provide consistent and robust support for the complementarity perspective advanced in this study. Foreign direct investment is not an autonomous driver of sustainable development and, in contexts characterized by limited absorptive capacity, may even be associated with adverse outcomes. Only when combined with sufficiently strong educational foundations, especially in middle income and low income countries, can foreign direct investment be effectively transformed into a source of sustainable and long term development gains.

5. SENSITIVITY AND ROBUSTNESS ANALYSES

This section provides additional evidence on the reliability and stability of the main findings through a combination of sensitivity analysis and robustness checks. Specifically, we first examine the sensitivity of the results to sample composition by implementing a Leave-One-Group-Out (LOGO) design, in which one income group is excluded at a time and the model is re-estimated on the remaining two groups. We then assess robustness by comparing the hierarchical Bayesian estimates with results obtained from conventional panel data estimation approaches. This two-step strategy allows us to disentangle sensitivity to sample structure from robustness to alternative estimation frameworks.

5.1. Sensitivity Analysis Using Leave-One-Group-Out

The results of the sensitivity analysis based on the Leave One Group Out design indicate that the core conclusions of the study are largely stable and not driven by any specific income group. When each income group is sequentially excluded and the model is re estimated on the remaining two groups, the signs and posterior significance of the key variables, particularly foreign direct investment, education, and their interaction, remain broadly consistent.

Specifically, across all three LOGO specifications, the coefficient on FDI_c remains negative, with a posterior probability for a positive effect that is close to zero. In LOGO_1, the posterior mean of FDI_c is −1.673, with a 90% highest density interval entirely below zero, ranging from −2.188 to −1.173, and a posterior probability P(β > 0) equal to 0%. This negative effect becomes even more pronounced in LOGO_2, where the posterior mean declines to −2.597, with a 90% highest density interval of −3.065 to −2.134 and again a zero probability of a positive effect. Even in LOGO_3, where the magnitude of the coefficient is smaller at −0.691, the 90% highest density interval remains fully negative, from −1.096 to −0.297, and the posterior probability of a positive effect is only 0.16%. Taken together, these results suggest that the adverse stand alone effect of foreign direct investment on sustainable development is a structural feature of the data rather than an artifact driven by the presence of any particular income group.

Education exhibits a consistently positive and robust direct effect on sustainable development across all LOGO configurations. The posterior mean of the EDU coefficient ranges from 0.314 in LOGO_3 to 0.666 in LOGO_2, with 90% highest density intervals entirely located above zero and posterior probabilities for a positive effect close to or equal to 100%. This finding reinforces the role of education as a fundamental driver of sustainable development, even under substantial changes in sample composition.

More importantly, the interaction term between education and foreign direct investment, EDU_FDI_c, continues to display a positive sign with high posterior certainty across the LOGO analyses. In LOGO_1, the posterior mean of the interaction term is 0.284, with a 90% highest density interval from 0.154 to 0.419 and a posterior probability P (β > 0) of 99.99%. In LOGO_2, this complementarity effect becomes even stronger, with a posterior mean of 0.431, a 90% highest density interval from 0.348 to 0.514, and a posterior probability of 100%. Even in LOGO_3, where the magnitude of the interaction coefficient is smaller at 0.070, the posterior probability for a positive effect remains high at 94.84%. These results indicate that the complementarity mechanism between education and foreign direct investment is not sensitive to the exclusion of any single income group and reflects a systematic relationship in the data.

Regarding the control variables, institutional quality measured by WGI maintains a positive association with sustainable development across all LOGO specifications, with particularly strong posterior support in LOGO_3, where the posterior mean reaches 9.824 and the posterior probability for a positive effect equals 100%. Physical capital accumulation measured by gross fixed capital formation shows a stable positive effect in LOGO_1 and LOGO_2, while becoming less precisely estimated in LOGO_3, suggesting that its contribution may depend to some extent on sample composition. By contrast, inflation and population growth consistently exhibit negative effects across all LOGO configurations, with 90% highest density intervals entirely below zero and posterior probabilities for positive effects close to zero, indicating a stable adverse association with sustainable development.

Overall, the LOGO sensitivity analysis provides strong evidence that the main findings of the study are not sensitive to the exclusion of any particular income group. In particular, the negative stand alone effect of foreign direct investment, the positive direct effect of education, and the complementary role of education in conditioning the impact of foreign direct investment on sustainable development remain robust across alternative sample compositions. These results strengthen the credibility of the empirical conclusions and suggest that the relationship between foreign direct investment, education, and sustainable development reflects a structural mechanism rather than a sample specific outcome.

5.2. Robustness Checks via Comparison with Conventional Panel Estimators

Table 9 presents a comparison between the hierarchical Bayesian model employed in this study and several conventional panel data estimation methods, including pooled ordinary least squares, random effects, fixed effects, first difference estimation, and two stage least squares. The purpose of this comparison is to assess the robustness of the empirical findings with respect to alternative estimation strategies and to examine whether the main conclusions are sensitive to methodological choices.

With respect to the direct effect of foreign direct investment, the coefficient on FDI_c is negative in most estimation approaches. Specifically, FDI_c is negative and statistically significant at the 5% level in the pooled ordinary least squares, random effects, and two stage least squares models, while it is only marginally significant in the fixed effects specification and becomes statistically insignificant in the first difference model. In the hierarchical Bayesian framework, FDI_c also exhibits a negative posterior mean of −0.699, with a posterior probability of a positive effect of only 0.10%. The consistency of the negative sign across most estimation methods indicates that foreign direct investment, when considered in isolation, does not act as an autonomous driver of sustainable development.

Education shows a generally positive and statistically significant effect on sustainable development in the pooled ordinary least squares, random effects, first difference, and two stage least squares models, with estimated coefficients close to 1.30. However, in the fixed effects specification, the coefficient on education becomes statistically insignificant, reflecting a well known limitation of fixed effects models in short panel settings, where most of the variation in education occurs across countries rather than over time. By contrast, the hierarchical Bayesian model yields a stable and positive posterior mean of 0.538 for education, with a posterior probability of a positive effect equal to 100%, underscoring the persistent and foundational role of education in shaping sustainable development outcomes.

The interaction term between foreign direct investment and education, EDU_FDI_c, reveals substantial heterogeneity across estimation methods. In the pooled ordinary least squares and random effects models, the interaction coefficient is positive but only marginally significant. In the fixed effects and first difference specifications, the interaction term becomes statistically insignificant and even changes sign, reflecting estimation instability arising from multicollinearity and limited within country variation. In contrast, the interaction term is positive and statistically significant in the two stage least squares model, and remains positive in the hierarchical Bayesian model with a posterior probability of 94.6%. These results suggest that the complementarity mechanism between education and foreign direct investment is more clearly identified in estimation frameworks that are better equipped to address endogeneity and parameter instability.

Regarding the control variables, institutional quality, physical capital accumulation, and trade openness generally exhibit positive and statistically significant effects in the pooled ordinary least squares, random effects, and two stage least squares models, but their effects become weaker or insignificant in the fixed effects and first difference specifications. The hierarchical Bayesian model consistently assigns high posterior probabilities to positive effects for these variables, highlighting the stabilizing role of partial

Table 9: Comparison of hierarchical Bayesian estimates with conventional panel data estimators

Variables	OLS		REM		FEM		FD		IV2SLS		BAYES	
	Coefficient	P>|t|	Coefficient	P>|t|	Coefficient	P>|t|	Coefficient	P>|t|	Coefficient	P>|t|	Mean	P (β>0) (%)
FDI_c	−1.876**	0.031	−1.166*	0.051	−0.654*	0.064	0.011	0.873	−3.371**	0.004	−0.699	0.10
EDU	1.304***	0.000	1.448***	0.000	0.319	0.246	0.121***	0.005	1.301***	0.000	0.538	100
EDU_FDI_c	0.251*	0.080	0.128	0.188	0.067	0.241	−0.006	0.614	0.549**	0.016	0.07	94.60
WGI	23.143**	0.000	46.317**	0.000	−0.875	0.882	−0.505	0.619	23.413**	0.000	9.717	100
GFCF	0.102	0.144	0.239***	0.000	0.052	0.186	0.000	0.969	0.116***	0.000	0.073	100
TRA	0.032**	0.028	0.151***	0.000	0.024	0.317	0.007	0.129	0.036***	0.000	0.048	100
INF	−0.020	0.730	−0.043	0.252	−0.044**	0.034	−0.005	0.115	−0.011	0.731	−0.045	0.00
POP	−3.083**	0.000	−0.885**	0.005	−0.521**	0.029	0.027	0.156	−3.092**	0.000	−0.707	0.00

Source: Authors

pooling in the presence of unobserved cross country heterogeneity. In contrast, inflation and population growth predominantly display negative effects across estimation methods, and the Bayesian results further reinforce the adverse association of these variables with sustainable development.

Overall, the comparison across estimation approaches indicates that the main empirical conclusions of the study are robust to alternative methodologies. In particular, the negative standalone effect of foreign direct investment and the complementary role of education in conditioning the impact of foreign direct investment on sustainable development remain qualitatively consistent across models. However, conventional panel estimators, especially fixed effects and first difference models, exhibit considerable instability when interaction terms and unobserved heterogeneity are present. By contrast, the hierarchical Bayesian framework delivers more stable estimates and more coherent economic interpretations, thereby strengthening the credibility of the empirical findings.

6. CONCLUSION AND IMPLICATIONS

6.1. Conclusion

This study examines the relationship between foreign direct investment, education, and sustainable development from a complementarity perspective, in which the impact of foreign direct investment on sustainable development is assumed to be conditional on the absorptive capacity of host countries, particularly their educational foundations. Using panel data for 72 countries over the period 2008-2022 and adopting a hierarchical Bayesian framework, the analysis explicitly accounts for unobserved cross country heterogeneity while improving inferential stability in the presence of interaction terms and correlated explanatory variables.

The empirical results yield several important findings. First, foreign direct investment cannot be regarded as an autonomous driver of sustainable development. Across most model specifications, the direct effect of foreign direct investment on the sustainable development index is negative or statistically insignificant, indicating that capital inflows alone do not necessarily translate into improvements in long term sustainable development outcomes. In certain contexts, foreign direct investment may even be associated with adverse effects when domestic absorptive conditions remain limited. This finding reinforces the view that foreign direct investment can generate environmental, social, or structural challenges in host economies that lack sufficient internal capacity.

Second, education plays a consistently positive and foundational role in promoting sustainable development. The coefficient on education is positive with very high posterior probability across all model specifications, highlighting that investment in education contributes not only to economic performance but also to broader social and environmental dimensions of development. Notably, the magnitude of the education effect tends to be stronger in low income and middle income countries, suggesting that the marginal returns of educational investment for sustainable development are particularly high in less developed economies.

More importantly, the results provide robust evidence of a complementarity mechanism between foreign direct investment and education. The interaction term between foreign direct investment and education is positive with high posterior probability in most specifications and becomes especially pronounced in the income group analysis. These findings indicate that education constitutes a critical conditioning factor that enables host countries to transform foreign direct investment into sustainable development gains. When educational foundations are weak, foreign direct investment is unlikely to yield favorable sustainable outcomes and may even exacerbate existing vulnerabilities. By contrast, when education levels are sufficiently high, foreign direct investment can exert a positive influence through technology spillovers, managerial upgrading, and the diffusion of more sustainable production practices.

Third, the income group analysis and sensitivity checks confirm that the complementarity mechanism is not driven by any specific subset of countries. The interaction effect between foreign direct investment and education becomes stronger as income levels decline, implying that developing and low income economies stand to benefit the most from foreign direct investment when accompanied by substantial investments in education and absorptive capacity. The Leave One Group Out sensitivity analysis and comparisons with conventional panel estimators further support the robustness and stability of the main findings.

Taken together, this study contributes to the existing literature in three main ways. First, it shifts the analytical focus from economic growth to sustainable development measured as a multidimensional outcome. Second, it explicitly identifies the conditioning role of education in shaping the impact of foreign direct investment on sustainable development through a complementarity framework. Third, it illustrates the advantages of hierarchical Bayesian methods in cross country panel analysis, particularly in settings characterized by substantial heterogeneity and interaction effects.

6.2. Policy Implications

The empirical findings of this study offer several important policy implications. First, host countries should not treat foreign direct investment attraction as an end in itself within sustainable development strategies. Prioritizing the volume of foreign capital inflows without strengthening domestic foundations may lead to unintended consequences and undermine the quality of long term development. Foreign direct investment policies should therefore be embedded within a broader development framework that emphasizes investment quality, sectoral composition, and the potential for positive spillovers.

Second, education should be regarded as a central pillar in strategies aimed at harnessing the benefits of foreign direct investment. Policies that increase educational expenditure, improve education quality, and align education systems with labor market and technological needs can significantly enhance absorptive capacity. Under such conditions, foreign direct investment is more likely to contribute not only to short term economic gains but also to innovation, productivity growth, and improved social and environmental outcomes.

Third, for low income and middle income countries, policy coordination between foreign direct investment attraction and educational development is particularly critical. The results indicate that these countries face the greatest risks from foreign direct investment in the absence of absorptive capacity, but also possess the greatest potential gains when educational foundations are strengthened. Development strategies should therefore avoid fragmented policy approaches and instead adopt integrated frameworks in which foreign direct investment, education, and institutional development are jointly designed to support long term sustainable development objectives.

Finally, from a methodological perspective, the findings suggest that policymakers and researchers should exercise caution when interpreting results derived from conventional linear panel models in highly heterogeneous cross country contexts. More flexible approaches such as hierarchical Bayesian models can better capture cross country differences and provide a more reliable empirical basis for policy design and evaluation in the field of sustainable development.

6.3. Limitations and Directions for Future Research

Despite providing consistent empirical evidence on the complementary role of foreign direct investment and education in promoting sustainable development, this study is subject to several limitations that warrant careful consideration. Acknowledging these limitations not only helps to contextualize the findings but also points to promising avenues for future research.

First, the study employs a composite sustainable development index as the dependent variable in order to capture economic, social, and environmental dimensions simultaneously. While this approach allows for a comprehensive assessment of sustainable development and avoids the limitations of single dimensional indicators, the use of a composite index may obscure heterogeneous effects across individual pillars. Future research could disaggregate sustainable development into its economic, social, and environmental components or employ specific indicators such as carbon emissions, income inequality, or social welfare measures to better identify the underlying transmission mechanisms.

Second, education is measured using government expenditure on education as a share of gross domestic product, which reflects public investment priorities but does not fully capture education quality, skill composition, or the alignment between human capital and the technological requirements of foreign direct investment projects. Subsequent studies could incorporate alternative or complementary measures, including average years of schooling, education quality indices, or indicators of vocational training and workforce skills, to provide a more nuanced assessment of human capital and absorptive capacity.

Third, although the hierarchical Bayesian framework effectively accounts for unobserved cross country heterogeneity and improves estimation stability in short panel settings, the analysis does not explicitly model dynamic or lagged effects. In practice, the benefits of foreign direct investment and educational investment often materialize over longer time horizons. Future research could extend the framework to dynamic specifications, incorporate longer lag structures, or employ Bayesian dynamic panel models to examine medium and long term effects.

Fourth, the study focuses on the complementarity between foreign direct investment and education, while other conditioning factors such as institutional quality, financial development, industrial structure, and environmental regulation are treated as control variables. Although this choice maintains model parsimony and clarity, future research could explore multidimensional complementarity mechanisms, including interactions between foreign direct investment, education, and institutions, or between foreign direct investment and environmental policy frameworks, to better reflect the complexity of sustainable development processes.

Finally, the empirical analysis is based on a sample of 72 countries over the period 2008-2022, constrained by data availability and comparability requirements. While this sample is sufficiently broad to support global level inference, future studies could expand the temporal or spatial scope as data availability improves, or complement quantitative analysis with country specific or regional case studies to enrich the interpretation of the results.

In summary, these limitations do not undermine the core contributions of the study but rather highlight opportunities for further research. By incorporating more detailed indicators, dynamic modeling approaches, and richer institutional contexts, future work can deepen our understanding of how foreign direct investment and education jointly shape sustainable development trajectories over the long term. This research is funded by University of Finance – Marketing.

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