Threshold impact of shadow economy on sustainable development in high and low-financial development countries

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ABSTRACT

This study investigates the impact of the shadow economy on sustainable development in 54 countries (categorised as high and low financial development) from 2008 to 2021, using Bayesian regression. Utilizing a sophisticated Bayesian regression analysis, our study unearths a compelling negative relationship between the shadow economy and sustainable development within both of these groups of nations. This empirical evidence underscores the pervasive influence of the shadow economy on hindering the progress of sustainable development, irrespective of a country's financial development status. Furthermore, our research goes beyond this fundamental relationship to elucidate the presence of a crucial threshold effect in the relationship between the shadow economy and sustainable development. This threshold effect is observed at distinct levels in countries with high and low financial development, standing at 21.08% and 39.38%, respectively. This critical finding emphasises the need for tailored policy interventions that recognise and address the unique dynamics in these two countries. Drawing on these substantial insights, our paper outlines specific policy recommendations tailored to the unique circumstances of each group of countries. These recommendations are aimed at effectively regulating the shadow economy, thus facilitating the fostering of sustainable economic development. Our research contributes valuable empirical evidence and policy guidance to the ongoing discourse on the complex relationship between the shadow economy and sustainable development, offering a pathway toward more robust and effective policy frameworks for the nations under study.

1. Introduction

Economic development is commonly assessed based on criteria reflecting the quality of life for individuals, encompassing advancements in material resources, human capital, and technological progress (Deardorff, 2001). Thus, GDP (Gross Domestic Product) per capita is the primary metric for quantifying economic development. However, it is a quantitative measure that falls short of capturing the intrinsic nature of sustainable growth and the improved well-being of the populace (Aidt, 2010). Therefore, sustainable development has been increasingly prominent in recent studies, shifting the emphasis from economic development to a more comprehensive strategy encompassing environmental and social factors. This shift results from an increase in the importance of societal well-being, ecological protection, and economic advancement. As asserted by the World Commission on Environment and Development (WCED, 1987),

sustainable development entails meeting the needs of the present generation without compromising the capacity of future generations to meet their own needs. At the macro level, pursuing sustainable development necessitates incorporating three fundamental components: the Economic, Social, and Environmental dimensions. All three elements demand equitable attention and interconnectivity throughout a nation's growth (Ilic-Krstic, Ilic, & Avramović, 2018).

The nexus between the shadow economy and sustainable development has recently garnered attention from researchers but has not received comprehensive exploration. The researchers question whether the size of the informal economy has an overall impact on the economic development of countries following economic crises caused by events such as the Covid-19 epidemic or political conflicts. Indeed, since the shadow economy and the formal economy are mutually supportive in the business cycle (Bitzenis, Vlachos, & Schneider, 2016), the shadow economy acts as a buffer, absorbing a considerable portion of the decline in official output and significantly mitigating the overall impact of crisis shocks (Colombo, Onnis, & Tirelli, 2016). In the short term, it can act as a lever to boost production activities in the face of bureaucracy and corruption (Eilat & Zinnes, 2002). Moreover, informal activities can foster competition within the formal sector, compelling the government to enhance its governance, consequently improving the market and increasing financial resources (Asea, 1996).

Thus, the shadow economy is a phenomenon that exists in all economies and affects all activities, from economic to social in general (Mandroshchenko, Malkova, & Tkacheva, 2018; Özgür, Elgin, & Elveren, 2021). For this reason, it is imperative to examine the impact of the underground economy on economic growth. Understanding and addressing the issues surrounding the relationship between the shadow economy and the sustainable development of the economy should be an ongoing process, updated by the economic context. This can contribute to identifying policies that facilitate peaceful coexistence, harness its advantages, and mitigate its negative consequences (Ajide, Dada, Arnaut, & Abdulaziz Saleh Al-Faryan, 2023; Assidi, Nouira, Saafi, Abdelfattah, & Ben Mim, 2024)

Existing studies have primarily focused on specific statistical analyses rather than thoroughly investigating the relationship within the context of varying levels of financial development. The interaction between the shadow economy and financial development indicates that a robust financial system effectively mitigates the negative influence of the shadow economy on environmental degradation (Dada, Ajide, Arnaut, & Adeiza, 2023). Financial development is a significant factor influencing the scale and structure of the informal economy, as well as determining the sustainable development of a nation.

Moreover, this study seeks to reaffirm the nonlinear correlation between the informal economy and sustainable development. The primary objective is to identify the precise informal economy threshold at which sustainable development reaches its peak for high- and low-financial development nations, as highlighted by previous research (Gharleghi, 2020; Saafi, Nouira, & Assidi et al., 2024. This serves as the focal research objective of this article.

Our paper is structured as follows: (i) introduction, (ii) research overview, (iii) research model and methods, and the fourth part, (iv) the results and research discussion. Finally, the conclusion and some policy implications.

2. Literature review

2.1. Shadow economy, sustainable development and financial development

Theoretically, *the shadow economy*, also known as the underground economy, encompasses activities not officially recorded in the government's statistical system or outside

the scope of organised economic activities (Baklouti, 2019; Dreher & Schneider, 2010). It may involve illicit activities such as drug trafficking, smuggling, prostitution, gambling, and other related operations (Biswas, Reza, & Thum, 2012).

In a similar vein, as classified by Gyomai and van de Ven (2014) and specified in the OECD-IMFILO-CIS Handbook (2002), the shadow economy encompasses various aspects:

Underground production involves legal goods and services deliberately concealed from authorities to evade taxation or regulatory compliance.

Illegal production encompasses activities generating goods and services prohibited by law or performed through unauthorized procedures.

Informal sector production, wherein products are created for the market but produced by non-corporate entities, such as family businesses, unregistered units, or small-scale labour units at a certain level.

Household final consumption production comprises activities producing goods or services consumed or capitalized by the households producing them.

Unrecorded statistical activities representing all production activities that should be accounted for in data collection programs but are missed due to deficiencies in data reporting.

Medina and Schneider (2018) utilized the Multiple Indicators Multiple Causes (MIMIC) models to estimate the scale of the shadow economy based on data derived from trade openness, unemployment, government size, financial freedom, institutional quality, corruption control, government stability, and others. While there are aspects of disagreement surrounding this method, such as the selection of variables or the sensitivity of correlation coefficients to changes in technical parameters, along with the sample of countries or the timeframe of estimation, the computational results from MIMIC have proven more reliable than other methods. Hence, it continues to be a prevalent feature in numerous studies, including our research.

Sustainable development stems from a simple perspective that economic progress and social development cannot be achieved without considering the state of the environment. Over time, in the context of uncontrolled economic growth and negative environmental and social consequences, this concept has become more complex and necessitates the integration of multiple factors.

The concept of sustainable development first emerged in the 1970s during anti-war protests and the burgeoning environmental movement. In 1972, the United Nations Environment Programme (UNEP) organized the Stockholm Conference on the Human Environment, laying the foundation for environmental protection and promoting sustainable development (Emmelin, 1972). It emphasized the need to balance economic progress, social equity, and environmental protection, preserving resources for future generations (Stockdale, 1990).

Traditionally, economic development is often referred to as sustainable progress in the quality of life-related to a nation's economy, typically quantified by increased material wealth, human resources, and technological improvement (Deardorff, 2001). Economic development is commonly measured by per capita GDP. However, this quantitative measure does not capture the sustainability or quality-of-life improvements (Aidt, 2010). Consequently, the concept of sustainable development is now more prominent in recent research as society becomes more concerned with environmental and social issues alongside economic development.

According to the World Commission on Environment and Development (WCED, 1987), sustainable development is meeting the needs of the present generation without compromising the ability of future generations to meet their needs. At a macro level, sustainable development requires at least three elements: (1) Economic, (2) Social, and (3) Environmental. These three elements must be equally considered and interconnected during a nation's growth (Ilic-Krstic et al., 2018).

This concept highlights that sustainable development is complex and multidimensional (Parris & Kates, 2003), focusing on the equilibrium and considering the three main pillars: economic, social, and environmental. These pillars play a crucial role in evaluating and measuring the progress and sustainability of a nation's development.

To measure sustainable development, numerous reputable studies and organizations around the world have developed various methods, indices, and metrics to provide a comprehensive and in-depth perspective on sustainable development.

These measurements have evolved and expanded over time. Parris and Kates (2003) highlight the diverse aspects and technical calculations involved in defining sustainable development, considering contributions from various organizations. For instance, the United Nations Commission on Sustainable Development (CSD) has 46 indices related to sustainable development, encompassing environmental, economic, social, and governance aspects. The World Economic Forum features an index for sustainable environmental development, comprising 68 indices synthesized from five categories and 20 core indices such as environmental systems, environmental stress reduction, reduced human vulnerability, social capacity and governance, and global management. From the perspective of the Global Scenario Group, these indices encompass international equity, national equity, poverty, energy use, water use, deforestation, carbon emissions, sulfur emissions, and hazardous waste. Looking forward to 2050, several challenges are posed for sustainable development, including market forces, policy reforms, and major transformations like global market competition, openness, and integration promoting global development (Sachs et al., 2019).

However, when discussing sustainable development, several fundamental indices are frequently referenced. For example, the Human Development Index (HDI), introduced by the United Nations Development Programme (UNDP) in 1990, is a multidimensional approach to measuring a country's progress. HDI assesses development based on three key factors: life expectancy, education level, and standard of living (Arinze, 1991). The Sustainable Development Goals Human Development Index (SDG-HDI) combines the HDI with other sustainability indicators, such as environmental progress and gender equality, to measure a country's progress in achieving the Sustainable Development Goals (SDGs). The Environmental Performance Index (EPI) measures how well countries achieve established environmental policy goals (Hoinaru, Buda, Borlea, Văidean, & Achim, 2020).

Financial development encompasses three key dimensions: scale, system efficiency, and system accessibility in a given country (Honohan, 2004). Levine (1999) introduced key indicators for measuring financial development, emphasising the role of financial intermediaries and markets.

Financial development positively impacts economic growth (Arestis & Demetriades, 1997) and enhances market efficiency by providing liquidity. Common indicators include depth, financial activity, and market capitalisation (Valickova, Havranek, & Horvath, 2015).

In larger urban areas, financial development supports sustainable development through capital deepening and technological innovation, while its impact is limited in smaller towns (Ahmed, Kousar et al., 2022; Gao, Yao, Fang, & He, 2022).

2.2. The relationship between shadow economy and sustainable development

Empirically, investigating the relationship between the shadow economy and sustainable development has received considerable attention from scholars with substantial empirical evidence. However, the research outcomes remain inconclusive and controversial (Hoinaru et al., 2020). The majority of studies have reported that shadow economic activity negatively affects sustainable development and democratic governance, a phenomenon commonly referred to as "greasing the wheels" (Afonso, Sá, & Leitão, 2021; Ajide et al., 2023; Baklouti, 2019; Borlea, Achim, & Miron, 2017; Demiral, 2021; Gharleghi, 2020; Hoinaru et al., 2020; Schneider, 2005; etc.). Recent studies have introduced additional factors into their investigations to substantiate further the negative relationship between the shadow economy and sustainable development. For instance, Azam (2021) included FDI, trade openness, government effectiveness, inflation rate, and population size; Ziberi and Alili (2021) considered unemployment and corruption control; Cristiane and Leonardo (2021) incorporated inflation rate, educational attainment, urban population, life expectancy, population growth, birth rate, political stability, government efficiency, institutional quality, rule of law, and democracy. Gharleghi (2020) combined trade, including total exports and imports, government spending on education, total fixed capital formation, foreign direct investment, institutional quality, population growth rate, and GDP per capita. The majority of these research findings have consistently supported the existence of a negative relationship between the shadow economy and sustainable economic development.

Furthermore, various studies have documented that the shadow economy affects economic development and has implications for several other aspects of socio-economic life because economic development is intertwined with environmental and societal dimensions. As discussed earlier, financial development is also a multidimensional factor influencing sustainable development. Therefore, it is essential to incorporate Financial Development as a variable in examining the relationship between the shadow economy and sustainable development.

The research conducted by Torgler and Schneider (2009) revealed that the shadow economy is detrimental to financial development and economic growth as it encourages tax evasion and avoidance. Simultaneously, when the shadow economy negatively impacts sustainable economic development and growth, it leads to disruptions in economic growth, thereby jeopardizing sustainable development (Caurkubule & Rubanovskis, 2014). In addition to the significant negative impact of the scale of the shadow economy on economic growth (Younas, Qureshi, & Al-Faryan, 2022), Özgür et al. (2021) also concluded that an increase in the scale of the informal sector is correlated with a decrease in per capita GDP and acts as a barrier to sustainable development. This is because the scale of the shadow economy exhibits an inverse relationship with indicators such as school enrollment rates, life expectancy, educational attainment, and access to clean water. In reality, the scale of the shadow economy is increasing irrespective of the level of development. This situation has resulted in regulatory violations, reduced tax revenue, increased inequality, corruption, budget deficits, and public debt. Gharleghi (2020) found a negative relationship between the shadow economy, economic development, and democracy, especially in countries rich in natural resources, where a larger informal economy is associated with less effective economic activity, accompanied by corruption and inequality.

Dada et al. (2023) have still examined the influence of the underground economy on environmental sustainability and affirmed the causal relationship between the shadow economy, financial development, urbanization, and ecological issues. Specifically, a robust financial system can significantly mitigate the adverse effects of the shadow economy on environmental degradation.

Applying the threshold model proposed by Gharleghi (2020) revealed new insights regarding the threshold relationship between the shadow economy and financial development. The research indicates that a significant and negative threshold relationship between the shadow economy and financial development exists only for countries with a per capita income of USD 33,600. A deeper analysis reveals a positive interaction between financial development and economic growth, highlighting the importance of prioritizing the development of financial markets in developing countries. Efforts to reduce the scale of the informal economy should be emphasized only after reaching a certain level of development. Moreover, Saafi et al. (2023) conducted an experimental study that provided evidence supporting the existence of threshold effects of the shadow economy on economic, social, and environmental aspects of sustainable development in both global and sub-samples of developed and developing countries. Furthermore, the global and developing country samples show that the shadow economy will disrupt the three pillars of sustainable development only when its scale exceeds a certain threshold. In contrast, the impact is negative even for low-level informal activities. Therefore, the shadow economy and sustainable development relationship are nonlinear (Saafi et al., 2023).

In summary, despite important findings, there is no consensus in the literature regarding the relationship between the shadow economy and sustainability, particularly in financial development and especially in studies on the threshold of this nonlinear relationship. In light of these research gaps, we undertake this study to explore the threshold of the shadow economy with sustainable development rather than mere economic growth while considering countries' financial development. This study aims to explore additional thresholds of the shadow economy with variables other than those considered by Gharleghi (2020), Saafi et al. (2023). To achieve this, we use Bayesian regression, which offers distinct advantages over Gharleghi's (2020) threshold regression, to detect and complement the current findings regarding the relationship between the shadow economy, corruption, and sustainable growth in different financial development contexts across countries with high and low levels of financial development.

3. Model and methodology

In this section, we outline the econometric methodology, regression model and data sources that we employ to test the nonlinear threshold impact of the shadow economy on sustainable development.

3.1. Model

Building upon the groundwork established by prior research (Gharleghi, 2020; Nguyen, Bui, Thai, Nguyen, & Nguyen, 2022), our model endeavours to pinpoint the threshold of the shadow economy concerning sustainable development, all while considering the significance of financial development. To accomplish this, we outline the role of financial development as follows:

$$SDGI_{i,t} = \alpha_1 SE_{squared_{i,t}} + \alpha_2 SE_{i,t} + \alpha_3 CPI_{i,t} + \alpha_4 FDI_{i,t} + \alpha_5 TAX_{i,t} + \alpha_6 INF_{i,t} + \alpha_7 EXP_{i,t} + \alpha_8 POP_{i,t} + \alpha_9 REM_{i,t} + \alpha_{10} FIX_{i,t} + \alpha_{11} TRA_{i,t} + \alpha_{12} UN_{i,t} + \alpha_{13} SCH_{i,t} + \alpha_{14} RQ_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where:

$SDGI_{i,t}$: Represents the sustainable development index of country i in year t.

$SE_{i,t}, SE_{squared_{i,t}}$: the shadow economy and the squared value of the shadow economy of country i in year t.

$CPI_{i,t}$; $FDI_{i,t}$; $TAX_{i,t}$; $INF_{i,t}$;$EXP_{i,t}$; $POP_{i,t}$; $REM_{i,t}$; $FIX_{i,t}$;$TRA_{i,t}$; $UN_{i,t}$; $SCH_{i,t}$; $RQ_{i,t}$: The control variables, encompass the following factors: corruption index, foreign direct investment, tax revenue, inflation rate, total budget expenditure, population growth rate, remittances, total fixed capital formation, trade openness, unemployment rate, secondary education enrollment, and institutional quality (refer to Table 1 below describes the variables, their expected signs, and the references and sources for data collection used in the model (1)).

$\varepsilon_{i,t}$: residual.

Table 1

Description of variables

Variables	Description	Expectation sign	Research	Data Source
Dependent variable				
SDGI	Sustainable development (index)		Economic and Affairs (2022)	SDGI
Independent variables				
SE	Shadow Economy (% GDP)	-	Demiral (2021); Borlea et al. (2017); Baklouti (2019); Hoinaru et al. (2020); Nguyen and Duong (2021)	Medina and Schneider (2022)
SE_squared	Shadow Economy squared	+/-	Wu and Schneider (2019)	Medina and Schneider (2022)
Control variables				
CPI	Corruption Perceptions Index	-	Nguyen and Duong (2021); Demiral (2021); Borlea et al. (2017); Baklouti (2019); Gründler and Potrafke (2019); Nasir, Wibowo, and Yansyah (2021); Hoinaru et al. (2020)	Transparency International Organization
FDI	Foreign Direct Investment (% GDP)	+	Demiral (2021); Baklouti (2019); Ziberi and Alili (2021); Nasir et al. (2021) Gharleghi (2020); Nguyen and Duong (2021)	WB/IFM
TAX	Tax revenue (% GDP)	+	Nguyen and Duong (2021); Demiral (2021)	WB/IFM
INF	Inflation rate (%)	-	Nguyen and Duong (2021); Cristiane and Leonardo (2021); Azam (2021), Zhuo, O, Muhammad, and Khan (2020)	WB/IFM

Variables	Description	Expectation sign	Research	Data Source
EXP	Total Government Spending (% GDP)	+	Nguyen and Duong (2021); Demiral (2021); Özgür et al. (2021); Nasir et al. (2021)	WB/IFM
POP	Population growth rate (%)	+	Gharleghi (2020); Cristiane and Leonardo (2021); Azam (2021); Ziberi and Alili (2021); Nasir et al. (2021)	WB/IFM
REM	Remittance (% GDP)	+	Demiral (2021); Azam (2021); Ziberi and Alili (2021)	WB/IFM
FIX	Gross fixed capital formation (% of GDP)	+	Gharleghi (2020)	WB/IFM
TRA	Trade openness (% GDP)	+	Nguyen and Duong (2021); Özgür et al. (2021); d'Agostino, Dunne, and Pieroni (2016)	WB/IFM
UN	Unemployment, total (% of the total labour force) (modeled ILO estimate)	−	Baklouti (2019); Özgür et al. (2021)	WB/IFM
SCH	School enrollment, secondary (% gross)	+	Baklouti (2019)	WB/IFM
RQ	Regulatory Quality	+	Gharleghi (2020); Cristiane and Leonardo (2021); Zhuo et al. (2020); d'Agostino et al. (2016)	World development indicators

Source: Authors

3.2. Sample and data

A cross-country database encompassing 54 countries was utilized from 2008 to 2021. This article aims to establish the thresholds for the size of the shadow economy about sustainable development across these 54 countries, stratified by various levels of financial development. Consequently, based on the average Financial Development (FD) index calculated for all countries worldwide during the study period, we partitioned the data into two distinct samples: one group comprises 27 countries with an FD index exceeding the global average, while the other group encompasses 27 countries with an FD index below the global average (Tran, 2023).

Basic statistics of the variables have also been segregated into two clusters, as illustrated in the two tables below:

Table 2

Summary statistics for the samples of high FD countries

Variable	Obs	Mean	Std. dev.	Min	Max
SDGI	378	76.92712	5.188588	58.5	86.48
CPI	378	68.63492	18.25487	21	95
SE	378	17.12257	10.3563	4.8	50.74343
FDI	378	9.999435	31.63905	-41.651	279.3473
TAX	378	21.34634	6.037226	7.903518	46.04608
INF	378	1.909647	2.061969	-4.4781	15.53441
EXP	378	19.55439	3.873822	10.5707	27.935
POP	378	0.773545	0.706669	-1.85372	3.931356
REM	378	0.687595	0.795183	0	3.406834
FIX	378	21.70636	4.407387	10.68721	54.30437
TRA	378	103.866	72.74645	23.38376	388.1204
UN	378	7.566119	5.27287	0.25	33.559
SCH	378	111.1037	17.93858	79.21977	163.9347
RQ	378	1.266254	0.599475	-0.55995	2.086641

Source: Authors' processing

Table 3

Summary statistics for the samples of low FD countries

Variable	Obs	Mean	Std. dev.	Min	Max
SDGI	378	70.46823	6.768435	47.86	80.63
CPI	378	43.53968	13.88126	18	93
SE	378	32.28252	12.3225	12.15	68.91331
FDI	378	4.776046	8.975421	-40.0866	109.0253
TAX	378	17.14342	4.210644	7.68011	27.45394
INF	378	4.116705	3.939302	-1.79965	27.95567
EXP	378	14.92134	4.156165	4.806798	24.01632
POP	378	0.399913	1.046984	-3.74238	3.284764
REM	378	6.015146	5.99186	0.158016	31.18195
FIX	378	23.37984	5.4606	14.7531	48.41233
TRA	378	94.82848	39.90015	32.9756	189.804
UN	378	7.586653	4.575535	0.14	21.206
SCH	378	92.92437	19.40351	33.73199	142.4966
RQ	378	0.336381	0.558464	-0.67663	1.695029

Source: Authors' processing

3.3. Methodology

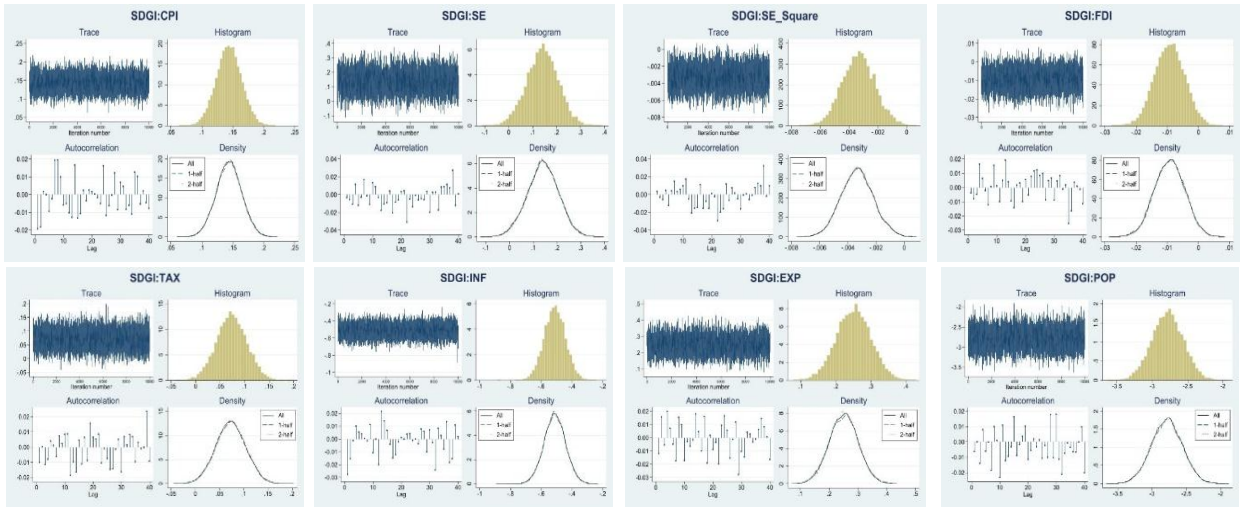
The Bayesian regression method emerges as a well-suited choice for our study, effectively addressing limitations often encountered with traditional frequentist approaches, as highlighted by Allenby (1990); Berger and Sellke (1987). One primary advantage of the Bayesian methodology is its ability to bypass the requirement for repeatedly sampled data, a frequently deemed unsuitable restriction, particularly in social sciences. Furthermore, Bayesian panel data regression incorporates fixed and random effects, enabling the integration of prior information into our analysis and proficiently addressing unobserved heterogeneity, a common occurrence in empirical research.

A fundamental distinction between the Bayesian and frequentist frameworks revolves around treating fixed quantities and applying probability theory to parameter uncertainty. The frequentist paradigm centers on the probability of observed data given fixed parameters, with inference about hypothetical datasets that could have been observed. Conversely, Bayesian inference pertains to the specific set of N observations, focusing on the probability distribution of parameters given this observed data. This distinction holds significant implications: the frequentist approach yields point estimates and occasional standard errors based on long-run estimator properties but does not facilitate probability statements about parameters. In contrast, Bayesian inference employs probability theory to describe parameter uncertainty, yielding a posterior probability distribution across all possible parameter values conditional on the model and observed data. This affords the capacity to make probabilistic statements about parameters, including the probability that parameter values fall within specified intervals (Muth, Oravecz, & Gabry, 2018).

These advantages make Bayesian panel data regression a powerful tool for analyzing panel data, accommodating unobserved factors that may influence dependent and explanatory variables. While Bayesian methods may entail greater computational demands than other techniques, recent strides in computer science have considerably alleviated this concern. Modern, fast computers allow for efficient computations, making Bayesian treatment accessible across various applications (Bishop & Tipping, 2003). In fact, Winter, Ryan, Zondervan-zwijnenburg, and Depaoli (2017) conducted a comprehensive assessment spanning 15 years, revealing a nearly fivefold increase in the use of Bayesian methods in experimental studies from 2010 to 2015. This trend underscores the growing acceptance and adoption of Bayesian approaches within the scientific community (Duong, Le, Nguyen, & Nguyen, 2022; Nguyen & Duong, 2022; Tran, 2023).

4. Results and discussions

Below are Figures 1 and 2, summarising the diagnostic convergence plots for the two groups of countries with high FD and low FD, respectively.



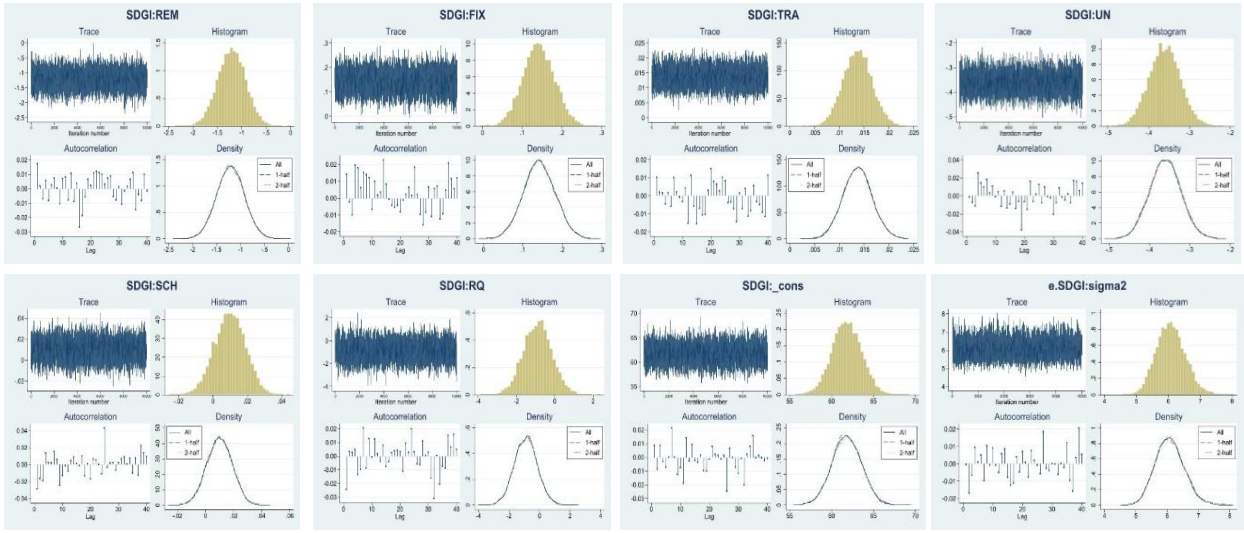


Figure 1. Diagnostic convergence plot with high FD

Source: Authors' processing

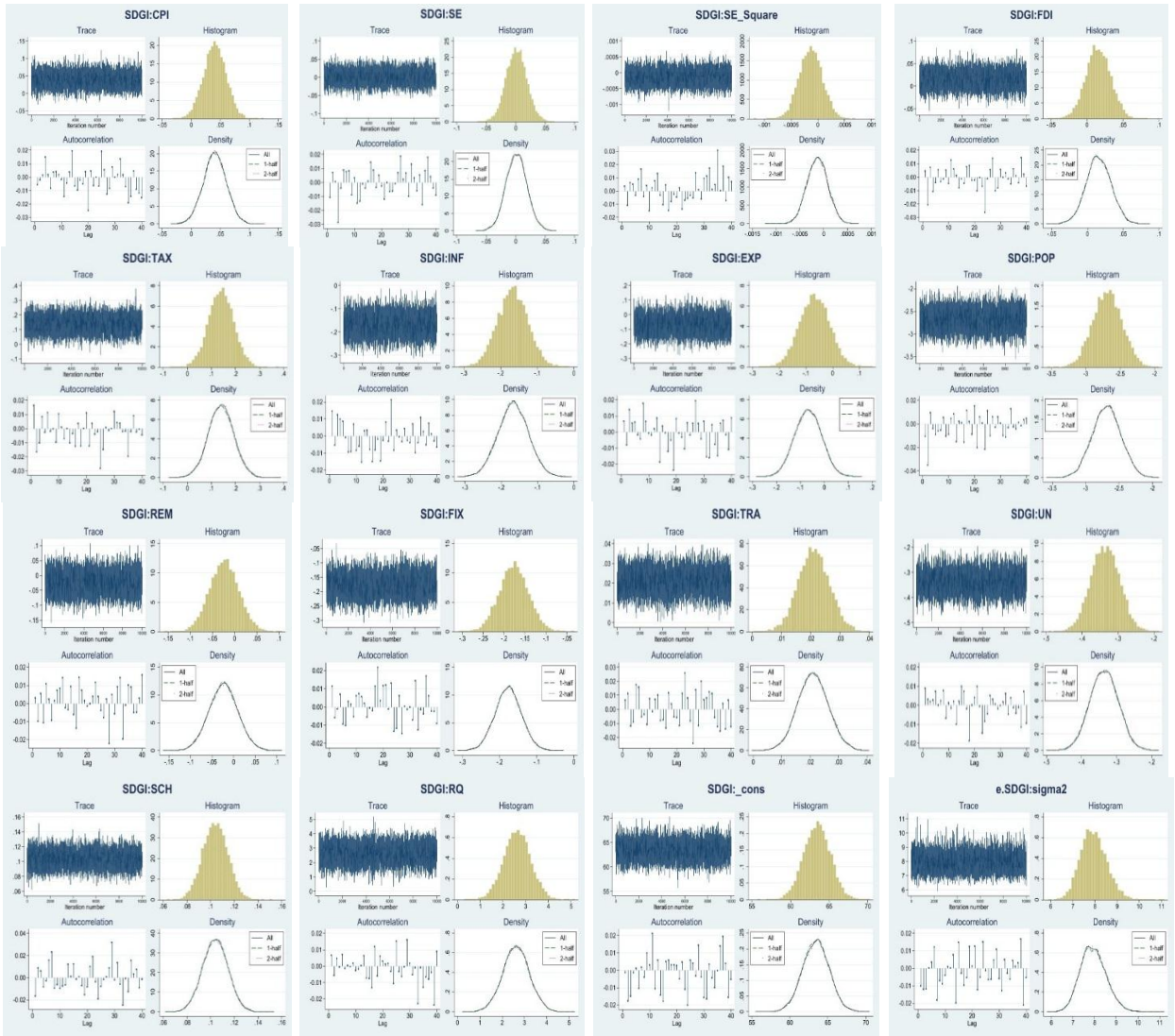


Figure 2. Diagnostic convergence plot with low FD

Source: Authors' processing

Figures 1 and 2 illustrate that all parameter trace plots within the model exhibit reasonable behaviour, with trace and autocorrelation plots indicating low levels of autocorrelation. These plots consistently demonstrate a normal distribution pattern. Furthermore, the charts display strong mixing, as evidenced by autocorrelation coefficients hovering around 0.02, signifying alignment with the simulated distribution density and capturing all relevant lags effectively. In sum, these results affirm the appropriateness of the model, with all lags falling within the effective range.

Table 4 provides a concise summary of our baseline estimation results for two distinct specifications. One column presents the estimates for countries with high levels of financial development, while the adjacent column presents the results for countries with low financial development, respectively.

Table 4

Regression results for two groups of countries with high and low FD

	SDGI (high FD)			**SDGI (low FD)**		
	Mean	Std.dev.	MCSE	Mean	Std.dev.	MCSE
SE	0.140808	0.06621	0.000662	0.281168	0.074535	7.45E-04
SE Square	-0.00334	0.001154	0.000012	-0.00357	0.000934	9.30E-06
FDI	-0.00924	0.004877	0.000049	0.008412	0.017547	0.000175
CPI	0.143897	0.020563	1.98E-04	0.042569	0.019458	0.000195
TAX	0.073277	0.030875	0.000309	0.14769	0.051579	0.000508
INF	-0.51164	0.069117	0.000661	-0.1693	0.041339	0.000406
EXP	0.250759	0.049504	0.000497	-0.07158	0.056443	0.000564
POP	-2.78286	0.224694	0.002247	-2.52776	0.218732	0.002187
REM	-1.20972	0.283648	0.002885	-0.06388	0.034667	0.000347
FIX	0.141729	0.040189	0.000408	-0.14159	0.03605	0.00036
TRA	0.013682	0.002901	0.000029	0.030119	0.005952	0.00006
UN	-0.36098	0.038378	0.000384	-0.30209	0.040243	0.000402
SCH	0.009914	0.008979	0.000085	0.113744	0.010924	0.000109
RQ	-0.89647	0.747628	0.007292	2.326136	0.589011	0.00589
_cons	61.81665	1.75944	0.017594	55.76869	2.718082	0.027762
e.SDGI						
sigma2	6.086288	0.456819	0.004568	7.858314	0.596311	0.005963
var	3.831781	99.09774	2.50267	2.357067	94.93936	2.92222

Source: Authors' processing

Table 5

Bayesian posterior interval test

	Mean	Std. dev.	MCSE		Mean	Std. dev.	MCSE
High FD				**Low FD**			
{SDGI:SE_Square} < 0	.998	0.04355	.0004355	{SDGI:SE_Square} < 0	1	0	0
{SDGI:SE} > 0	.9818	0.13368	.0013368	{SDGI:SE} > 0	1	0	0
{SDGI:FDI} < 0	.9718	0.16555	.0016376	{SDGI:FDI} > 0	.6858	0.46422	.0046422
{SDGI:INF} < 0	1	0	0	{SDGI:INF} < 0	.9999	0.01000	.0001
{SDGI:POP} < 0	1	0	0	{SDGI:POP} < 0	1	0	0
{SDGI:REM} < 0	1	0	0	{SDGI:REM} < 0	.968	0.17601	.0017925
{SDGI:UN} < 0	1	0	0	{SDGI:UN} < 0	1	0	0
{SDGI:RQ} < 0	.886	0.3167	.0031673	{SDGI:RQ} > 0	1	0	0
{SDGI:CPI} > 0	1	0	0	{SDGI:CPI} > 0	.986	0.11750	.001175
{SDGI:TAX} > 0	.991	0.09340	.000947	{SDGI:TAX} > 0	.9975	0.04994	.0004994
{SDGI:EXP} > 0	1	0	0	{SDGI:EXP} < 0	.897	0.3039	.0030397
{SDGI:FIX} > 0	.9999	0.0100	.0001	{SDGI:FIX} < 0	1	0	0
{SDGI:TRA} > 0	1	0	0	{SDGI:TRA} > 0	1	0	0
{SDGI:SCH} > 0	.860	0.34617	.0034158	{SDGI:SCH} > 0	1	0	0

Source: Authors' processing

The Bayesian method was implemented using the Metropolis-Hastings algorithm, conducting 10,000 regression model simulations. Each simulation yielded a set of regression coefficients, resulting in the regression result table presenting the mean values of these coefficients alongside their standard deviations (Std. Dev) and Monte Carlo Standard Errors (MCSE). Notably, the MCSE values for all parameters are notably small, in line with findings by Flegal, Haran, and Jones (2008). In this context, smaller MCSE values signify a more stable MCMC chain. It is important to highlight that MCSE values below 6.5% of the standard deviation are considered acceptable, with values below 5% considered optimal.

The variable SE positively impacts SDGI with a posterior probability of 0.9818 for countries with high FD and 01 for countries with low FD. This suggests that the informal economy supports the sustainable development of nations, in line with the findings of Nguyen and Duong (2021). According to the "grease the wheels" perspective, the informal economy is pivotal in mitigating high unemployment rates and providing credit to individuals who lack access to formal credit sources (Zaman & Goschin, 2015). The informal sector contributes to social capital, stimulates the local economy, generates employment opportunities, and facilitates the necessary economic transformation towards sustainability (Ruzek, 2015).

Both groups of countries exhibit negative coefficients for the variable SE_Squared, in contrast to SE, indicating the presence of a point where SDGI attains its maximum value. Supported by the Bayesian posterior interval test results in Table 5, the regression coefficient of SE_Squared carries a negative sign with a posterior probability of 99.8%. This implies that the informal economy contributes positively to sustainable development, but surpassing a certain threshold leads to a decline in SDGI, aligning with the initial hypothesis of Wu and Schneider (2019). Specifically,

for countries with high FD, the estimated threshold value is 0.140808/(20.00334) = 21.079041%, and for countries with low FD, it is 0.281168/(20.00357) = 39.38095%.

These research findings corroborate the study's hypothesis and align with the findings of Gharleghi (2020): the impact of the shadow economy and corruption on sustainable development varies among countries. Specifically, for countries with a GDP per capita above $33,600, a negative relationship between the informal economy and financial development emerges. Conversely, for countries with a GDP per capita below $33,600, the informal economy's and corruption's impact on sustainable development is reversed. Our research results also concur with empirical findings in the study by Saafi et al. (2023), where the threshold of the shadow economy below 13.38% of GDP has a positive impact on economic growth. The shadow economy also influences the Human Development Index in a U-shaped pattern; beyond the limit point of 39.7% of GDP, the scale of the shadow economy negatively affects human development. As for the Environmental Development Index, the threshold is 38.40% of GDP; beyond this level, the environment is adversely impacted.

The valuable insights garnered from our novel discoveries, alongside the findings of previous studies on thresholds, can significantly contribute to national governance and management in pursuing sustainable development in the future.

Regardless of the level of financial development in the two groups of countries, the Corruption Perception Index (CPI) exerts a positive influence on sustainable development. The probability for countries with high financial development is 01, while for countries with low financial development, it is 0.986. These results further support the "grease the wheels" theory proposed by Jiang and Nie (2014); Hoinaru et al. (2020).

In addition to SE and CPI, factors associated with TAX, TRA, and SCH positively affect a country's sustainable development, with probabilities of 0.991 and 0.9975. This suggests that increasing tax revenues contribute to the sustainability of a country's development, which aligns with findings by Nguyen and Duong (2021). Tax revenue is a primary source of budget funding for public expenditures and can stimulate economic growth. It also reflects the growth of the private sector, leading to higher tax revenues due to increased income levels. Trade openness and improvements in primary education also drive sustainable economic growth (Tahir & Azid, 2015).

Another group of factors includes INF, POP, REM, and UN, which negatively impact sustainable development in both countries, with very high probabilities, mostly 01 or 0.999 for both datasets.

Reducing inflation contributes to a stable macroeconomic environment, supporting sustainable economic development. Conversely, a rising population rate hinders sustainable growth, while remittances harm economic growth sustainability. An increase in unemployment rates leads to inefficient labour utilization, burdening welfare and insurance systems, reducing budget revenue, and increasing budget deficits (Özgür et al., 2021; Nguyen & Duong, 2021).

Meanwhile, FDI and RQ have varying impacts on countries depending on their levels of economic development. For countries with low economic development (low FD), both FDI and RQ exhibit positive effects, although FDI's influence has a probability of 0.6858, while RQ's influence has a higher probability of 0.9718. This underscores the importance of FDI as a resource for sustainable growth in low-FD countries, driving advancements in science, technology, and processes, resulting in increased economic productivity and efficiency. However, there is evidence of an inverse U-shaped relationship between the income level of countries and the impact of FDI on growth (Tamar & Luca, 2019). Findings from Okada and Samreth (2014); Nguyen and Duong (2021) further support this inequality in the benefits of FDI across countries.

Regulatory Quality (RQ) is crucial to a country's governance. A strong governance system enhances competitiveness, controls the informal economy, and improves citizens' quality of life. It fosters sustainable growth, especially in low-FD countries (Zhuo et al., 2020), and is positively associated with long-term domestic growth (Azam, 2021).

Finally, like FDI and RQ, the two factors related to Government Expenditure and Total Fixed Capital (EXP and FIX, respectively) exhibit complex interactions with a country's economic development. They positively affect economic growth in countries with low FD and negatively in countries with high FD. The size of government expenditure significantly impacts economic growth, especially in countries with low FD, as highlighted by Nasir et al. (2021).

5. Conclusion and implications

Extending Bayesian regression techniques, this study examines whether the size of the shadow economy has a threshold effect on a country's sustainable growth, within the context of financial development, considering two groups of countries with high and low financial development indexes. The empirical findings reveal that the shadow economy positively influences sustainable development in both groups of countries, with the threshold size being 21.079041% for high FD countries and 39.38095% for low FD countries.

From a policy perspective, it is crucial to consider the following recommendations:

For low financial development countries:

Addressing Sustainable Development Challenges: Focus primarily on resolving the multifaceted challenges related to sustainable development. This should encompass initiatives to curb population growth, effectively managing social welfare concerns and ensuring the population's well-being for the long term.

Attracting High-Quality Foreign Direct Investment (FDI): Dedicate efforts to attract Foreign Direct Investment (FDI), emphasising enhancing the investment environment and infrastructure. The goal is to create an environment conducive to attracting high-quality FDI, which can significantly contribute to addressing employment challenges and fostering economic growth.

Promoting Sustainable Technological Learning: Foster an environment that encourages technological and management learning without causing adverse environmental impacts. Invest in sustainable technology and innovation that can drive economic growth while maintaining a commitment to environmental responsibility.

Governance Enhancement: Strive to enhance the quality of governance, with a specific focus on promoting financial inclusion. This includes improving access to financial products and services for underserved populations and ensuring everyone has equal opportunities to participate in the financial system.

Development of Robust Financial Markets: Strengthen mainstream finance by improving the quality of existing financial services and facilitating the development of vibrant financial markets. This entails creating a conducive regulatory environment and providing opportunities for financial institutions to thrive.

Education Policy Emphasis: Give increased attention to public education policies to improve literacy rates and create a high-quality, adaptable workforce for the future. Education is a cornerstone for sustainable development, and investing in it can yield long-term economic benefits.

By incorporating these edited strategies, low-financial development countries can better address their unique challenges and pave the way for sustained economic growth and development.

For high financial development countries:

Foreign Investment Strategy: Reevaluate the emphasis on attracting foreign investment and consider reducing such efforts.

Government Expenditure Enhancement: Augment government expenditure to bolster sustainable economic growth.

Investment in Fixed Capital: Allocate resources toward fixed capital formation to reinforce economic stability and foster growth.

Population Control Measures: Implement strategies for population management to sustain a stable labour force and mitigate unemployment rates for enduring economic prosperity.

Combating the Informal Economy and Corruption: Develop and implement measures to mitigate the prevalence of the informal economy and corruption, ensuring a positive economic impact.

These recommendations are tailored to the specific needs and characteristics of countries with different levels of financial development. They can serve as valuable guidelines for policymakers striving to promote sustainable development in their nations.

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Declaration of Interest statement.

The authors report that there are no competing interests to declare.

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