CHAPTER I
INTRODUCTION

1.1 Problem Identification

The transition to renewable energy is a pressing global agenda to implement the 2015 Paris Agreement as well as the Sustainable Development Goals (SDGs), in particular Goals 7 and 13. While global commitments to adopt clean power are rising, low- and middle-income countries (LMICs) face greater challenges to achieve it. The countries are facing this growth in CO2 emissions at a forecasted rate of 1.5% per year because of rising population and continuing reliance on fossil fuels (IEA, 2025a). Reliance on these energy sources creates a problem for the renewable energy transition, especially in low- and middle-income countries.

Renewable energy development (RED) encompasses two main dimensions. The first dimension is renewable energy investment (REI) as an input indicator and the second dimension is renewable energy generation (REG) as an output indicator. REI reflects the financial investment in renewable energy projects, while REG shows the outcomes of these investment projects in the form of renewable capacity. Both reveal a nation's capacity to convert financial power into measurable outcomes of the clean energy, which is in keeping with the two-stage methodology in the global energy policy literature (Aydos et al., 2022).

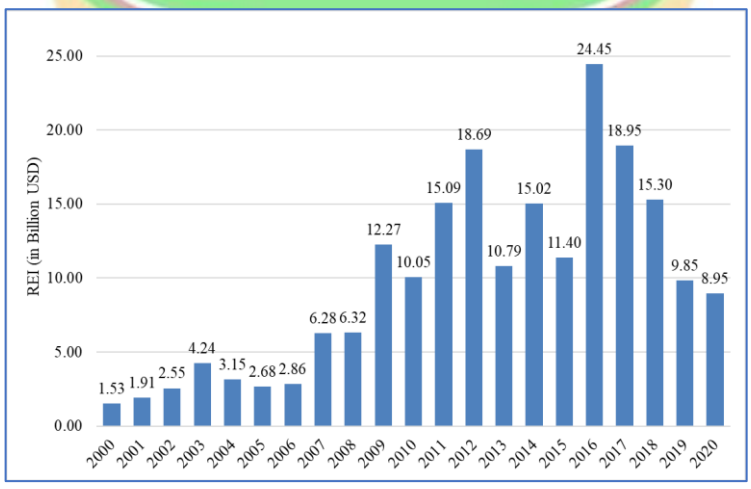

Figure 1.1 Renewable Energy Investment in LMICs, 2000–2020 (Billion USD)

Source: International Renewable Energy Agency (IRENA), 2025

Figure 1.1 depicts variations in renewable energy investments made in low- and middle-income countries (LMICs) in the period 2000–2020. The investment value surged from USD 1.53 billion in 2000 to a peak of USD 24.45 billion in 2016, but dropped drastically to around USD 8.95 billion in 2020. Furthermore, investments have continued to decline in the aftermath of the Paris Agreement. This trend suggests that despite the strengthening of global commitment to green energy in the wake of the Agreement, the fiscal capacity and financial systems in LMICs remain limited in terms of supporting long-term investment needs. The UNFCCC (2022) notes an "implementation gap" due to poor-performing financial institutions, shallow capital markets and high-risk premiums. Consequently, funding renewable energy is more expensive and less attractive than other budgetary spending priorities such as infrastructure and energy subsidies. Limited public funding and access to green financing represent significant barriers to the development of renewable energy infrastructure in low- and middle-income countries.

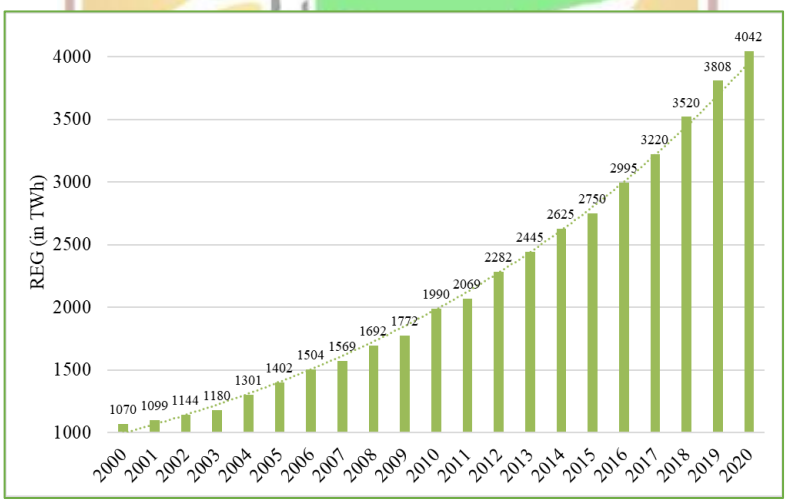

Figure 1.2 Renewable Energy Generation in LMICs, 2000–2020 (TWh)

Source: International Energy Agency (IEA), 2025

Renewable energy generation (REG) in low- and middle-income countries (LMICs) increased steadily from 2000 to 2020, while investments fluctuated. As can be seen from Figure 1.2, total REG rose sharply from 1,070 TWh in 2000 to 4,042 TWh in 2020. The surge since the mid-2010s occurs against a backdrop of falling technology costs for solar and wind, and increased policy support after the

Paris Agreement (Bilbao et al., 2024). Nevertheless, the gap in the levels of investment and generation shows that a rise in clean energy output is not necessarily matched by an equal rise in financing. These indicate the financial restraints and the success of public financing in low or middle-income nations.

The World Bank (2023) stated that the lack of adequate infrastructure and finance have been identified as the key constraints on accelerating the energy transition in LMICs. The high upfront cost of green energy infrastructure, limited access to private capital, and weak financial sector capacity are severely restricting the transition in LMICs. Low- and middle-income countries represent only about ten percent of total international debt issuance with most of this concentrated in a few upper-middle-income countries (World Bank, 2023). As a consequence, these constraints create divergence between funding needs and development of renewable energy in LMICs.

Table 1.1 Global Public Debt, 2000 – 2023 (% of GDP, weighted averages)

	2000s	2004	2010s	2019	2020	2021	2022	2023
World	66.8	69.9	80.9	84.7	100.0	95.2	91.8	93.8
Advanced Economies	75.8	77.1	104.5	105.1	123.7	117.4	112.3	112.0
Emerging Market Economies	40.5	43.7	44.1	55.4	65.5	64.5	64.7	69.0
China	26.9	26.4	44.3	60.4	70.1	71.8	77.1	84.3
Others	44.2	48.4	43.7	51.7	61.4	57.9	54.5	57.1
Low-Income Developing Countries	45.7	51.0	34.7	42.4	48.0	47.5	47.9	50.3

Source: IMF Global Debt Database, 2024

As the financing gap for clean energy transition continues to increase, a growing number of countries are turning to public debt for funding green infrastructure projects (Kushawaha & Jain, 2025). Despite this, many low- and middle-income countries find their debt at such high levels that they have limited fiscal space (Ahuja & Kumar, 2025). According to IMF data (see Figure 1.3), total global public debt was around USD 93 trillion (94% of global GDP). That burden has been mounting over the years as long-term trends show that debt levels in developing economies have steadily increased. In decades, emerging markets increased from 40.5% of GDP in 2000 to 69% of GDP in 2023. Further in low-income countries peaked at 51% in 2004 and has remained above 47% since 2020.

The rising number of debts limits the capacity of the governments to reach out to the long-term objectives but forces them more on debt repayments than spending on investments like infrastructure and renewable energy.

How debt is managed is also crucial due to this pressure. Public debt has the potential to act as a catalyst for long-term development (Baret & Menuet, 2024; Kushawaha & Jain, 2025). The UN ESCAP (2023) highlights that stable and productive debt allocation can support development. Moreover, the fiscal space may shrink and fiscal sustainability may become jeopardized as a result of weak fiscal governance and inefficient use of debt (Durand et al., 2021). The effectiveness of public debt is also determined by some other macroeconomic factors like development of financial market, capability of financial institution, growth of population and per capita income (Kushawaha & Jain, 2025). Therefore, managing debt must be done effectively to enhance fiscal sustainability and also allow inclusive and sustainable energy transition.

Previous studies on public debt and energy from renewables have yielded contrary findings. A few pieces of research state that debt has a positive impact on the green energy development (Florea et al., 2021; Kushawaha & Jain, 2025; Qamruzzaman, 2022). Other studies find the impact negative or insignificant to debt sustainability risks (Auteri et al., 2024; Sadiq et al., 2024). The mixed findings here indicate that public debt may have a nonlinear relationship with renewable energy development. At low levels, public debt can enhance renewable energy development. But after a certain level, increasing debt hinders investment and generation of renewable energy through crowding out and fiscal risks. In addition, public debt impacts the investment and generation stages of renewable energy development differently due to variations in adjustment speed and maturity.

Even though this non-linear relationship explains partly the mixed evidence of the literature, it does not fully clarify why public debt is more useful in some countries than others. This variety signals the existence of conditioning mechanisms that determines public debt's effectiveness. In these circumstances, the development of the financial sector, which consists of financial institutions (FI) and financial markets (FM), plays a key role in offsetting the negative effects of public

debt on renewable energy development (Kushawaha & Jain, 2025). A well-functioning financial sector can enhance credit allocation, reduce financing costs, and facilitate access to long-term green finance, thereby mitigating the adverse effects of high debt levels (Kushawaha & Jain, 2024, 2025). On the other hand, weak financial institutions and shallow financial markets can increase fiscal risks and limit the productive use of public debt (Anton & Nucu, 2020; Qin et al., 2023). Hence, this study will comprehend the moderating influence of financial sector development on the association of public debt and renewable energy development.

Furthermore, there is a significant gap in the literature regarding the potential issue of spatial dependence in the role of public debt on renewable energy development. The goal of this study is to fill the gap by using a spatial approach to provide a better understanding. Most prior research has examined the direct effect of national debt in driving green energy investment, but fewer studies have considered the indirect influence (spatial spillover effects) in analyzing this relationship. Spillover effects are defined as the indirect influence of changes in a neighboring country's public debt on a local country's development in renewable energy. Interregional linkages drive these spatial effects through trade, technology diffusion, capital inflows, and economic, political, and social factors (Otieno, 2024). Furthermore, economic and environmental issues usually have spatial dependence (Lv & Li, 2021). Therefore, a spatial approach is used to achieve better estimation results and reduce potential bias because this method account for spatial dependence compared to using conventional methods (Anselin, 1988).

Based on the above discussion, this study aims to analyze the relationship between public debt and renewable energy development in 69 low- and middle-income countries over the period 2000 to 2020 using the Spatial Durbin Model (SDM) approach. This method allows for testing the direct (domestic), indirect (spillover), and total effects of public debt on renewable energy development. Furthermore, this study examines the moderating role of the financial sector in shaping the relationship between public debt and renewable energy development. This study will make empirical and methodological contributions to the literature on the green economy and public finance by emphasizing the importance of the

spatial dimension for understanding the dynamics of sustainable energy transitions in low- and middle-income countries.

1.2 Problem Formulation

Based on the background and limitations identified in previous studies, the research questions are as follows:

1. How does public debt directly affect renewable energy investment (REI) and renewable energy generation (REG) in low- and middle-income countries?
2. Does public debt generate spatial spillover (indirect) effects on renewable energy investment (REI) and renewable energy generation (REG) across countries?
3. How do financial markets (FM) and financial institutions (FI) moderate the effect of public debt on renewable energy investment (REI) and renewable energy generation (REG) in LMICs?

1.3 Research Objectives

Based on the problem formulation above, the objectives of this study are:

1. Analyze the direct effect of public debt on renewable energy investment (REI) and renewable energy generation (REG) in low- and middle-income countries (LMICs).
2. Examine whether public debt generates spatial spillover effects on renewable energy investment (REI) and renewable energy generation (REG) across countries.
3. Investigate the moderating role of financial markets and financial institutions in shaping the nexus between public debt and renewable energy investment (REI) and renewable energy generation (REG) in LMICs.

1.4 Research Benefits

1.4.1 Theoretical Contribution

This research contributes to the field of public finance and energy economics. It examines the public debt-renewable energy relationship using a nonlinear and spatial econometric methodology in low- and middle-income countries (LMICs). In contrast to previous linear and nonspatial approaches in this field, the current study shows that public debt has a heterogeneous impact on the investment and generation dimensions of renewable energy, influenced by spillover effects between countries. As such, this research contributes to the theoretical knowledge of the optimal role of public debt for the energy transition.

1.4.2 Practical Contribution

From a practical perspective, the findings provide empirical evidence to support a more prudent public debt management in association with the renewable energy development. Recognizing of nonlinear effects and spatial spillovers highlights the need to determine the optimal debt level and strengthen cross-country policy coordination. This research paper will provide a useful reference in evaluating the renewable energy financing policies as well as sustainable financing instruments for an effective and inclusive energy transition.