THE INFORMAL SECTOR AND ITS IMPACT ON SUSTAINABLE DEVELOPMENT: AN EMPIRICAL STUDY ON URBAN PERSPECTIVE

A Thesis submitted by

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(BSc Honours, MSc, MEc in Economics)

For the award of

Doctor of Philosophy

2023

ABSTRACT

This research aims to critically evaluate the economic, social, and environmental dimensions of the informal sector, which has become a significant aspect of urbanization in developing countries and presents various challenges to development. The particular objective is to evaluate the role of the informal sector in achieving the green, inclusive, and resilient development agenda outlined in the Sustainable Development Goals (SDGs). This is a thesis based on published works and consists of nine empirical studies covering both the macro and micro aspects of the topic. These studies collectively contribute to a well-founded resolution of the issue by answering the research questions. The findings of the initial studies (Study 1 and Study 2) pinpoint urbanization as one of the catalysts for environmental degradation, which underscores the pressing requirement to confront the economic, social, and environmental concerns associated with the process of urbanization. Exploring urbanization in the broader context of environmental degradation through environmental Kuznets' relationships, this research finds evidence of pursuing economic growth with targeted green growth arrangements in Bangladesh, the primary country of study for this research. Since urbanization process leads to the proliferation of the informal sector and its growth appears to be a complex urban issue in developing countries, this research seeks to generate empirical evidence on the informal sector, which is also a participant in SD, by examining its economic, social, and environmental aspects. Constructing and using a symptomatic composite index of sustainability, this research examines the impact of this sector on the overall sustainability of development in developing countries and ends up with a derogatory outcome (Study 3). This research also generates time-series data on the economic contribution of the informal sector in Bangladesh and examines its symmetric and asymmetric impacts on the GDP growth of the country. Findings suggest that downsizing informal sector activity would be in the best interest of achieving higher economic growth, thereby paving the way towards SD (Study 4). However, this research reveals the positive contribution of informal employment to the economic growth of developing countries in the context of SD (Study 5). Therefore, this research focuses on the socio-economic context of informal workers and uncovers their food insecurity, which impacts negatively on their health outcomes (Study 6). For digging into environmental consequences, the research constructs pollution load indices (PLIs) for two environmental compartments from surrounding areas of urban informal (manufacturing) enterprises. The study assesses their economic efficiency level and, using PLI, uncovers associations with pollution that subsequently indicate potential routes for promoting green growth (Study 7). This research further unveils the possibility of pollution shifts occurring from formal to informal sector enterprises when stringent institutional mechanisms are employed (Study 8). This leads to the investigation of raising environmental awareness (Study 9), which can serve as a strategy for implementing indirect environmental regulations in informally operated firms. The studies conducted in this research contribute to a deep understanding of the complex interactions between the informal sector and various dimensions of sustainable development, which is significant for achieving green growth in urban areas. Given the enduring presence of the informal sector within urban areas in developing countries, attributed to its survival dynamics, the findings and recommendations proposed by the studies will play a pivotal role in making well-informed choices directed at sustainable development. These resolutions are particularly centered around fostering awareness and limiting informal activity, facilitating integration into the formal economy, embracing eco-friendly technology, and leveraging synergies with the circular economy and social business practices.

CERTIFICATION OF THESIS

I, Nahid Sultana, hereby declare that the thesis entitled *The informal sector and its impact on sustainable development: An empirical study on urban perspective* presented for examination is my original work, except where otherwise acknowledged, with most of the contribution to the papers presented as a thesis by publication. I also declare that the thesis does not exceed 100,000 words in length, including quotes, exclusive tables and figures. I affirm that the thesis doesn't contain any material that has been previously submitted, either in its entirety or in part, for the purpose of obtaining any other academic degree, except where duly acknowledged.

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STATEMENT OF CONTRIBUTION

(List of published, under review and submitted papers included in the thesis)

The following detail outlines the agreed share of contribution for candidate and co-authors in the published and submitted papers presented in this thesis:

Paper 1 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam, K.M. Zahidul Islam (2022). 'The causative factors of environmental degradation in South Asia'. *Journal of Asian Economics*, 70:101452. (Quartile 2 ranked, Impact Factor: 2.681, H-Index: 51, SJR: 0.658, Publisher: Elsevier). https://doi.org/10.1016/j.asieco.2022.101452

Nahid Sultana contributed 70% to the paper. Collectively Dr. Mafiz Rahman, Dr. Rasheda Khanam and Dr. K.M. Zahidul Islam contributed the remainder.

Paper 2 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam (2022). 'Environmental Kuznets curve and causal links between environmental degradation and selected socioeconomic indicators in Bangladesh'. *Environment Development and Sustainability*. (Quartile 1 ranked, Impact Factor: 4.08, H-Index: 62, SJR: 0.68, Publisher: Springer Netherlands) https://doi.org/10.1007/s10668-021-01665-w

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman and Dr. Rasheda Khanam contributed the remainder.

Paper 3 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam (2022). 'The effect of the informal sector on sustainable development: Evidence from developing countries'. *Business Strategy and Development*, 1-15. (Quartile 1 ranked, Impact Factor: 2.878, H-Index: 11, SJR: 0.58, Publisher: John Wiley & Sons Inc.) doi: 10.1002/bsd2.217

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman and Dr. Rasheda Khanam contributed the remainder.

Paper 4 [Addressed Review]

Nahid Sultana, Mohammad Mafizur Rahman, S.M. Woahid Murad. 'Asymmetric role of the informal sector on economic growth: Empirical Investigation on a developing country'. (Under Review:

Structural Change and Economic Dynamics, Quartile 1 ranked, Impact Factor: 5.4, H-Index: 61, Publisher: Elsevier)

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman and Dr. Rasheda Khanam and S.M. Woahid Murad contributed the remainder.

Paper 5 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam (2022). 'Informal Sector Employment and Economic Growth: Evidence from Developing Countries in SDG Perspective'. *Sustainability* 14:11989. (Quartile 1 ranked, Impact Factor: 3.889, H-Index: 109, SJR: 0.66, Publisher: MDPI AG) https://doi.org/10.3390/su141911989.

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman and Dr. Rasheda Khanam contributed the remainder.

Paper 6 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam, Istihak Rayhan, Roni Hossain. 'Food insecurity and health outcome nexus: Empirical evidence from the informal sector enterprises in Bangladesh'. *BMC Public Health*, 23:722. (Quartile 1 ranked Impact Factor: 4.545, H-Index: 159, SJR: 1.2, Publisher: BioMed Central). https://doi.org/10.1186/s12889-023-15655-2

Nahid Sultana contributed 65% to the paper. Collectively Dr. Mafiz Rahman, Dr. Rasheda Khanam, Istihak Rayhan and Roni Hossain contributed the remainder.

Paper 7 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam, K.M. Zahidul Islam, Md Rayhanul Islam Rayhan (2023). 'Investigating the prospect of cleaner production in informal enterprises: A scientific assessment of environmental burdens and economic efficiency'. *Heliyon*, 9(3): e14583. (Quartile 1 ranked, Impact Factor: 3.92, H-Index: 46, SJR: 0.55, Publisher: Elsevier BV.) https://doi.org/10.1016/j.heliyon.2023.e14583

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman, Dr. Rasheda Khanam, Dr. K.M. Zahidul Islam and Md Rayhanul Islam Rayhan contributed the remainder.

Paper 8 [Published]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam, S.M. Zabaidul Kabir (2022). 'Environmental quality and its nexus with informal economy, corruption control, energy use, and

socioeconomic aspects: the perspective of emerging economies'. *Heliyon*, 8: e09569. (Quartile 1 ranked, Impact Factor: 3.92, H-Index: 46, SJR: 0.55, Publisher: Elsevier BV.) https://doi.org/10.1016/j.heliyon.2022.e09569.

Nahid Sultana contributed 65% to the paper. Collectively Dr. Mafiz Rahman, Dr. Rasheda Khanam and Dr. S.M. Zobaidul Kabir contributed the remainder.

Paper 9 [Submitted]

Nahid Sultana, Mohammad Mafizur Rahman, Rasheda Khanam. 'Interconnections between environmental awareness and green technology adoption: An empirical evidence from informal business enterprises' (Submitted to: *Journal of Environmental Economics and Policy*, Publisher: Taylor & Francis Online).

Nahid Sultana contributed 75% to the paper. Collectively Dr. Mafiz Rahman and Dr. Rasheda Khanam contributed the remainder.

ACKNOWLEDGEMENTS

At the beginning, I would like to express my deepest gratitude to the almighty Allah, who is the most generous, gracious, and merciful. Then, I would like to extend my profound respect and gratefulness to my principal supervisor, Associate Professor Mafiz Rahman, for his continuous support, intensive guidance, insightful suggestions, inspiration, and encouragement throughout my candidature. It has been a great opportunity to learn from Dr. Mafiz Rahman, and his dedicated mentoring and invaluable input on my research work helped me stay focused on my goal and encouraged me to improve the quality of my research. I would also like to express my heartfelt thanks and gratitude to my associate supervisor, Professor Rasheda Khanam, for inspiring me to work hard and provided support to frame the research ideas. Her valuable suggestions have helped me improve the quality of my research. Both of my supervisors have encouraged me to face the challenges that came my way during the journey and provided the necessary support to keep my spirits high. I feel privileged to have had the opportunity to undertake studies under such an excellent supervisory team. This research has required significant personal sacrifices, which have been borne by my parents and children in particular. I would like to dedicate this thesis to my father, A.K.M. Nuruzzaman, who encouraged and supported me greatly at the beginning of this course. Unfortunately, I lost him halfway through my Ph.D. journey. However, I believe that his blessings were with me throughout my candidature and guided me towards a positive conclusion. I regret that I couldn't attend in his funeral due to border restrictions during the pandemic period. I would also like to express my regret for my mother, Selima Banu, and loving sons, Isam Ajwad and Iram Ajwad, who I had to stay apart from and couldn't take care of for three and a half years due to the demands of my enrolment and study load. I am greatly indebted to my parents for their unwavering love and support for my studies throughout my entire life. I am also thankful to my only sister and brother-in-law, who played a vital role in caring of my father when he was struggling with cancer. I am grateful to them for taking care of my mother and children in my home country while I remained busy with my Ph.D. studies. I am appreciative to my kids for their understanding and patience during my study period.

I would like to thank the Head of the School of Business and all the staff of the 'Faculty of Business, Education, Law and Arts' for their kind support and cooperation. My special thanks go to Professor Peter C Terry for his sympathetic mind, which was a great pillar of support during my PhD candidature. I appreciate the great cooperation of the Graduate Research School, Division of Research & Innovation, Human Resource Ethics Office of the University of Southern Queensland (UniSQ). Without their active and on-time support, it would be difficult for me to address the administrative issues that were involved in this program. I am grateful to the funding body of the University of Southern Queensland, Australia, for the financial support through the Research Training Program (RTP) [International Stipend and International Tuition Fees Scholarship]. Without the financial support from UniSQ, this research would not be possible. I would like to acknowledge the contribution of UniSQ for providing me with excellent working facilities, library resources, and IT services. I am beholden to the research support team of BELA, who always working behind the scenes to satisfy my needs throughout the study period. I am also obliged to the Department of

Economics, Jahangirnagar University (JU), Bangladesh; Department of Environmental Science, JU, Bangladesh and Dr. Wazed Mia Science and Technology Institute, Bangladesh for their kind collaboration on the project undertaken by this research.

I would like to extend my appreciation to my co-authors, Prof. K.M. Zahidul Islam, Dr. S.M. Zobaidul Kabir and S.M. Woahid Murad for their contribution to my research by sharing their expert knowledge. My appreciation also go to Roni Hossain, Istihak Rayhan and Mohammad Rayhanul Islam Rayhan, who contributed a lot as team leaders in field survey conducted in Bangladesh. Besides them, there were many important faces behind this research, whom I cannot mention individually, but without them, this PhD would not have been such a memorable experience. They all deserve to receive my wholehearted thanks for their contributions.

Lastly, I would like to thank all the team members and participants of the survey for their time and support. Without their time and generosity in sharing information, this research would be incomplete. I am also thankful to online search engine Google.com, video-sharing website YouTube, KOBO toolbox, and the producers of Stata, Eviews, DEP, and AMOS software command manuals. This PhD thesis would not have been completed without accessing the services of these software. I also acknowledge the contribution of World Bank, ILO Statistics, and other data sources for making their excellent database available for researchers like me. Finally, I thank Almighty Allah once again for providing me with physical and mental health, strong motivation, and patience to complete this research.

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Akaika Information Criteria (AIC)

Augmented Mean Group (AMG)

Augmented Dickey-Fuller (CADF)

Augmented I'm Pesaran-Shin (CIPS)

Autoregressive Distributive Lag (ARDL)

Asia Pacific Economic Cooperation (APEC)

Carbon Dioxide (CO_2)

Cleaner Production (CP)

Corporate Social Responsibility (CSR)

Cross Section Dependence (CD)

Corruption Control (CC)

Currency Demand Approach (CDA)

Data Envelopment Analysis (DEA)

Decision-Making Unit (DMU)

Driving Forces–Pressures–State–Impact–Response (DPSIR)

Dynamic Fixed Effect (DFE)

Dynamic Ordinary Least Squares (DOLS)

Ecological Footprint (EF)

Economic Index of Sustainability (EcoIS)

Environmental Index of Sustainability (EnvIS)

Environmental Awareness Index (EAI)

Economic Freedom Index (EFI)

Environmental Kuznets Curve (EKC)

Environment Protection Agency (EPA)

Error Correction Term (ECT)

European Union (EU)

European Environment Agency (EEA)

Food and Agriculture Organization (FAO)

Food Insecurity (FI)

Food Insecurity Experience Scale (FIES)

Food Insecurity Experience Scale Survey Module (FIES-SM)

Fixed Effect (FE)

Fully-Modified Ordinary Least Squares (FMOLS)

Fully Generalized Ordinary Least Squares (FGOLS)

Global Value Chain (GVC)

Gross Domestic Product (GDP)

Gross National Income (GNI)

Health-Related Quality of Life (HRQoL)

Human Resource Ethics Office (HREC)

Informal Economy (RE)

International Labor Office (ILO)

International Union for the Conservation of Nature (IUCN)

Intergovernmental Panel on Climate Change (IPCC)

Lagrange multiplier (LM)

Mean Group (MG)

Medium and Small Manufacturing Enterprises (MSMEs)

Mental Component Summary (MCS)

Middle East and Africa (MEA)

Middle East and North American (MENA)

Multiple Indicator Multiple Causes (MIMIC)

Nitrous Oxide (NO)

Non-linear Autoregressive Distributive Lag (N-ARDL)

Nongovernmental organizations (NGOs)

Ordinary Least Squares (OLS)

Organization of Economic Co-operation and Development (OECD)

Panel-Autoregressive Distributive Lag (PARDL)

Perceived Ease of Use (PEOU)

Perceived Usefulness (PU)

Physical Component Summary (PCS)

Pollution Load Indices (PLI)

Pooled Mean Group (PMG)

Principal Component Analysis (PCA)

Random Effect (RE)

Research Question (RQ)

Short Form 12v2 (SF12v2)

Micro, Small, or Medium-sized enterprises (MSMEs)

Small and Medium Enterprises (SME)

Social Index of Sustainability (SocI)

South Asian Association for Regional Cooperation (SAARC)

Structural Equation Modeling (SEM)

Sustainable Development (SD)

Technology Acceptance Model (TAM)

Theory of Planned Behavior (TPB)

Variable Returns to Scale (VRS)

Vector Error Correction mechanism (VECM)

United Nations Environment Programme (UNEP)

World development Indicator (WDI)

World Bank (WB)

LIST OF PUBLISHED ARTICLES DURING THE PH.D. PROGRAM (NOT INCLUDED IN THE THESIS)

Mohammad Mafizur Rahman and Nahid Sultana (2022). 'Impact of institutional quality, economic growth, and exports on renewable energy: Emerging countries perspective'. *Renewable Energy*, 189: 938-951. https://doi.org/10.1016/j.renene.2022.03.034.

Mohammad Mafizur Rahman and Nahid Sultana and Eswaran Velayutham (2021). 'Renewable energy, energy intensity and carbon reduction: experience of large emerging economies'. *Renewable Energy*, 184:252-265. https://doi.org/10.1016/j.renene.2021.11.068

Mohammad Mafizur Rahman, Istihak Rayhan and Nahid Sultana (2023). How Does Electricity Affect Economic Growth? Examining the Role of Government Policy to selected Four South Asian Countries. *Energies*, 16(3), 1417, https://doi.org/10.3390/en16031417

Zobaidul Kabir, Nahid Sultana and Imran Khan (2022). 'Environmental, social, and economic impacts of renewable energy sources'. Chapter 3, *Renewable Energy and Sustainability: Prospects in the Developing Economies*. Elsevier Inc. 10.1016/B978-0-323-88668-0.00009-7.

CHAPTER 1: INTRODUCTION

1.1 Background

The informal sector has gained significant importance in the economic and social development policies of many countries and it has been a source of concern for policy makers (Ohnsorge and Yu, 2021; Briassoulis, 1999; Straub, 2005; Godfrey, 2011; Charlot et al., 2015; ILO, 2018; Medina and Schneider, 2019; Afonso et al., 2020; Elbahnasawy, 2021; Estevão et al., 2022). Initially coined by social anthropologist Keith Hart (1971, 1973), the term "informal sector" refers to a segment of the urban labor force employed outside of the formal labor market. The International Labor Office (ILO)'s 1972 report on employment in Kenya is marked the formal inception of research on this sector (Zaki, 2017; Peter Lang Ag, 2010; Grexhani, 2004). Generally, the informal sector is linked to less favorable economic consequences (Ohnsorge & Yu, 2021; Benson et al., 2014). Countries with larger informal sectors are typically exhibited with greater poverty, lower per capita incomes (25% to 30% lower than countries with below-average informality), less financial development, and inferior growth in output, investment, and productivity (Ohnsorge & Yu, 2021; ILO, 2018; Gutierrez et al., 2019). Despite these facts, the informal economy has expanded globally, and contributing significantly to both developing and developed economies (Huang et al., 2020; Gutierrez et al., 2019; Onyenechere, 2011; Zaki, 2017; Meghar, 2013). Especially, in nations with demographic advantages, the informal sector serves as a crucial source of employment for those excluded from the formal sector due to inadequate skills or education (Lamba & Mace, 2011; Gutierrez et al., 2019, Blades, 2011). According to the International Labor Office (ILO), the informal sector is considered to be the sector of survival and provides a source of living for about 62 percent (2 billion) of the

world's working population, the majority of whom live in low-and middle income countries (90 percent) (ILO, 2020). Factors such as low rates of industrialization, surplus labor, low technology levels, high taxes, regulatory complexities, weak legal frameworks, and corruption contribute to the prevalence of informal activities in these countries (Gërxhani, 2004).

The informal sector encompasses all economic activities related to the production of legal goods and services that remain hidden from authorities due to financial, regulatory, and institutional reasons (Ohnsorge & Yu, 2021; Schneider & Buehn, 2017; Medina & Schneider, 2019). There is no single common understanding of the informal sector, as there are multiplicity of definitions, (Gërxhani 2004; Chen, 2012; Andrews et al. 2011). Three ideas, taken collectively, can describe economic informality: the informal sector, informal employment and the informal economy. The informal sector involves employment and production in unincorporated, unregistered small businesses; informal employment refers to jobs outside labor protection laws in formal or informal enterprises, or own account workers; and the informal economy includes all firms, employees, and activities operating outside legal and regulatory structure along with their products (Meagher, 2013; Lewis et al., 2019). The informal sector focuses on enterprises, while informal employment pertains to jobs (ILO, 2013; Benson et al., 2014).

The informal sector has been studied by institutions and researchers under various definitions and contexts of urban areas (see Obadan et al., 1996; Sethuraman, 1981; Lubell, 1991; Lewis et al., 2019; Qayyum et al., 2021). The growth of the informal sector is closely linked to the growth of urban area, particularly in countries where urbanization is accelerating at a rapid pace due to rural-urban migration (Lv & Xu, 2021; Qayyum et al., 2021; BBS, 2018;. Huang et al., 2020; Hossain, 2011).

Urbanization in these countries is often attributed to the structural transformation from agrarian to industrial economies, coupled with inadequate infrastructure amenities and informal settlements where the growth of the informal sector is the general response to the incapacity of the urban area to provide formal job opportunities (Qayyum et al., 2021; Damayanti, 2000; Hart, 1973; BBS, 2018). The informal sector serves there as a safety net for rural migrants and urban unemployed on their way to formal jobs (Harris & Todaro, 1970; Ghose, 2017; ILO, 2018; Gutierrez et al., 2019; WB, 2021, p.3). It is often treated as a static and less productive sector associated with broader development challenges. Therefore, the informal sector can be a suitable agenda in a study on urban sustainability, particularly in developing and emerging countries, as its growth holds significant implications for urban sustainability (Onyenechere, 2011).

Understanding the complexities and interrelationships between urbanization and informal sector activities is crucial for policymakers and researchers. Urbanization is treated as a pursuing agents of green or sustainable development (Lyons & Snoxell, 2005; BBS, 2018, Totatforti, 2020), whereas informal economy plays a complex and contradictory role in sustainable development (UNEP, 2011; Huang et al., 2020; Estevão et al., 2022). On the one hand informality is considered a key determinant of inclusive growth (Amponsah et al., 2021. Ruzek, 2015) which align with sustainable development (SD) ideals, like the green economy formulated by the United Nations Environmental Program, (UNEP, 2011), on the other hand it contributes to resource misallocation, technological backwardness, productive inefficiency, fiscal weakness, environmental pollution, indecent work conditions, health hazards, and poverty. This dual characteristics makes informal sector activities, its growth, and regulation critical concerns for both national governments and global organizations (Huang et al., 2020; Zaki, 2017).

The activities in the informal sector contribute to a range of environmental, social, and economic issues (Smit & Musango, 2015). However, due to their small, numerous, and geographically dispersed nature, and their supportive role to the most vulnerable populations, conventional regulation seems challenging, often leaving them unregulated or overlooked (Blackman, 2000). Consequently, the informal sector's compatibility with socially cost-minimizing green or sustainable development, which put forwards the concept of inclusive growth, along with coordinated economic, social, and environmental development, remains debatable (Arvin-Rad & Willumsen, 2010; Shi et al., 2019). Therefore, to accomplish sustainable development, it is important to evaluate critically the varying roles of the informal sector, particularly in the context developing countries.

The literature on sustainable development has not thoroughly explored the informal sector's contribution to a country's socioeconomic and environmental sustainability. This study aims to address this by assessing the role of the informal sector as a participant in the sustainable development process through analyzing its performance within various dimensions of the sustainable development framework. This is particularly significant given the need for unconventional and innovative solutions for the informal sector (see, Blackman & Bannister, 1998). The COVID-19 pandemic has underscored the importance of this research, as the informal sector is seen as a means of economic recovery (ILO, 2020). This research focuses on Bangladesh, particularly its capital city Dhaka, along with other developing and emerging countries, as it is experiencing rapid urbanization and a proliferation of the informal sector (Roy, 2021). In Bangladesh, the informal sector accounts for 86.2% of employment according to the Labor Force Survey2015–16 (CPD, 2018; BBS, 2018). With 36% of national GDP, most employment in Dhaka

is in the informal sector. The dominance of the informal sector, which is reflective of the growth of low productive sectors, poses a significant challenge to the economic growth of Bangladesh (Roy, 2021).

1.2 Statement of problem

The rapid expansion of cities and urban areas in terms of population growth and increased use of natural resources, coupled with the resulting growth of the informal sector, poses significant challenges to sustainable development (Cohen, 2006). This has created enormous pressure on the immediate and surrounding environment, making it difficult to envision how urban consumption and output levels can remain stable without conforming to sustainable norms. As a result, sustainability has emerged as a philosophical and empirical issue in cities (see Totaforti, 2020; Cohen, 2006). Moreover, its social dimension, which captures inclusion, accessibility, and quality of urban life, has been largely overlooked and under-represented (Totaforti, 2020).

The urbanization process in developing countries leads to the proliferation of the informal sector, which remains controversial in its performance towards sustainability (Godfrey, 2011; La Porta & Shleifer, 2014). While some studies regard informality as an untapped reservoir of entrepreneurial energy (Ruzek, 2015), others adopt a more critical stance, viewing informal enterprises as parasites that enjoy advantages from evading taxes and regulations, and engage in unfair competition with their formal counterparts (ILO, 2018; Blackman & Bannister, 1998). This conflicting perception often misguides decision-makers in its integration into strategic economic plans aimed at fostering development and managing economic fluctuations. Moreover, the magnitude of the informal

economy is considered a key factor in determining fiscal and regulatory policies (ILO, 2018; Medina & Schneider, 2019). However, the undocumented nature of the informal activities and the deliberate obscurity maintained by those involved in it renders the task of acquiring accurate statistics about the informal economy a formidable challenge (Charmes, 2012; Medina & Schneider, 2019; Chen, 2012; Smith & Musango, 2015). This has enhanced the intricacy of employing empirical investigative methodologies to quantify the extent and propose strategies for the rapidly expanding informal economy (Medina & Schneider, 2019; Schneider & Buehn, 2017; ILO, 2018).

The informal sector in developing countries often exhibits weaker compliance with official environmental standards compared to the formal sector. This discrepancy arises due to less stringent enforcement methods for social and environmental issues in these countries (Ditlev-Simonsen, 2022; Baksi & Bose, 2016). In recent years, developing nations have come under increased pressure to upgrade their production processes, working conditions, and environmental quality. Governments of these counties typically respond to these issues by imposing strict limits on producers (Baksi & Bose, 2016). However, these efforts are hindered by weak and incomplete enforcement mechanisms, as well as the presence of a large informal sector that prevents the complete and effective enforcement of regulations dealing with pollution, occupational health, and safety, resulting in harm and welfare loss (Baksi & Bose, 2016; Blackman, 2000). This situation provides an opportunity for the formal sector as well to evade costly regulations by outsourcing part of its production to the informal sector, which can result in increased pollution (Baksi & Bose, 2016; Qayyum et al., 2021).

Economic activities in informal firms pose a threat to environmental security as they can avoid taxes and regulations, unlike the formal sector (Dincbas et al., 2021; Gupta & Barman, 2015). The use of

toxic chemicals and carcinogens in informal manufacturing, and improper disposal of toxic by-products strain ecosystems and cause long-term environmental pollution (Qayyum et al., 2021). The accumulation of scrap by the informal enterprises also causes environmental contamination in surrounding areas (Tong et al., 2021). Enforcement of command and control regulations that depend on peer monitoring doesn't work on informal sector enterprises (Blackman, 2000; Biswas et al., 2012).Therefore, environmental management becomes a challenging task in these enterprises (Blackman, 2000; Blackman et al., 2006; Elgin & Oztunali, 2014; Yang et al., 2021; Abid, 2015; Blackman & Bannister, 1997).

Besides, the informal sector exposes workers to low wages and job insecurity, often leading to poverty and destitution (Gangopadhyay et al., 2014). Data shows that poverty increases annually by 100 million people due to underpayment, high exposure to occupational health and safety risks, a lack of protection, and the likelihood of suffering from illness or accidental death, which are prevalent in informal sector employment (ILO, 2018; ILO, 2020). The outbreak of COVID-19 has further exacerbated these risks (ILO, 2020). Upgrading the informal sector can offer a viable solution to uplift the income of impoverished individuals (Tong et al., 2021). However, policy interventions can be challenging due to the heterogeneity and diverse characteristics of the informal sector (Brown & McGranahan, 2016). Therefore, understanding the intricate dynamics and features of the informal sector in various aspects and unveiling their resulting implications through empirical research stands as a critical imperative. Failing to do so would render the formulation of policies and strategies leading to sustainable development (SD) an intricate challenge, fraught with the potential for significant shortcomings.

1.3 Theoretical underpinning

The current economic system, known as neoliberal, has intensified environmental disruption and social inequalities between countries and has been identified as the root cause of the unsustainable path (Özgür et al.,2021). Neoliberalism separates individuals from the social whole in which they exist and restrict economic options to individual choices, leading to an unclear concept of growth (Alenda-Demoutiez, 2022). The informalization of the labor market has increased in this era of neoliberalism (Benería et al., 2016, p. 151) and has worsened the economic and social challenges leading to an unsustainable path (see Rada & Von Arnim, 2014). Informality traps labor in low productivity, low wage sectors and hampers income growth needed for sustainable development (Ozgur et al., 2021). To better grasp economic development in an eco-social context, an evolutionary economic approach that views the economy as a set of self-organizing systems is recommended. This approach acknowledges the integration of the economic, social, and environmental dimensions for sustainable development (Ozgur et al, 2021; Griethuysen, 2002).

Shifting back to neo-classical economic theories of development that viewed labor, capital, and technology as key factors of growth, overlooked the negative consequences of resource utilization. These standard theories of economic growth ignored waste products or by-products of resource use that may harm the human quality of life and future development potential (Smith, 1776; Ricardo, 1817; Acemoglu, 2008; Cumming & Von Cramon-Taubadel, 2018). Therefore, the studies presented in this thesis utilize deductive reasoning and focus on data-driven analytical investigations rather than pure theory. Still, there are foundational theoretical elements underpinning the research questions, which are mentioned below.

1.3.1 Theoretical background of the informal sector

In early studies of the informal sector (1960–1970), colonial economist Boeke introduced the concepts of a dual economy and social marginality. However, these concepts were criticized for being more descriptive than explanatory in nature. Subsequently, the dominant theory viewed informality as a reality with its own rules, circumstances, and distinct ways of representation (Harding & Jenkins, 1989). Putting differently from a set of survival activities performed in a marginal society, this theory was characterized by the recognition of the dependency of the informal sector on the formal sector, which could be either complementary (e.g., via sub-contracting activities) or competitive (e.g., unregistered business activities where labor is cheaper and prices are lower) (Gerxhani, 2004). The growth of the informal sector is also linked to the theory of tax evasion, which aligns with the social welfare theory and the public choice theory. Additionally, the theory of democratic economic policy introduced by Frey (1989, p. 118) suggests that both formal and informal sector activities are driven by self-interested decision-makers pursuing their own utility (Gerxhani, 2004).

Given the intricate and multifaceted nature of the informal sector, it is widely acknowledged that a single theory cannot comprehensively explain its dynamics. Instead, multiple theories contribute to conceptualizing the nature of informal economies, each with its own strengths and limitations (Gërxhani, 2004, Chen, 2012; Andrews et al., 2011; Benson et al., 2014). These include modernization (dualism), neo-Marxism (or structuralism), and neoliberalism (Huang et al., 2020) aligned with three schools of thought: dualists, structuralists, and legalists, respectively (Zaki 2017). The explanatory power of these theoretical perspectives elaborated under these different schools varies for the informal economies in countries due to the unique interplay of economic, social and institutional factors in specific geographical context. Therefore, these theories are employed to grasp

the general dynamics of informal economies and serve as the theoretical foundation for analyzing the informal sector in this research. The subsequent sections delve deeper into these prominent theories, which provide the basis for the research questions.

Modernization perception (Dualists School)

The modernization perspective, often termed dualism, is rooted in the works of Lewis (1954) and Harris and Todaro (1970). This school of thought viewed the informal economy as a collection of subsistence activities pursued by individuals who lack access to formal employment opportunities and defined it as a residual category, a symbol of backwardness and pre-modernity (Huang et al., 2020; Heintz & Pollin, 2005). The modernization perspective claims that the formal economy's inability to provide adequate jobs for urban labor forces, the economic crisis in formal sectors, rural-to-urban migration, and the rise in the number of unemployed people are all factors behind the expansion of the informal economy. Some scholars of early neo-classical and Marxist backgrounds have labelled these views as marginalist (Debrah, 2007) and anticipated their contraction as countries progress economically (Huang et al., 2020).

After extensive theoretical debates, the dualistic view of informality projects that firms will persist in remaining informal, hiring informal workers, buying inputs, and selling products for cash, despite their unproductive nature. These firms are unlikely to benefit significantly from formalizing their operations, and under specific circumstances, a considerable portion of the population will continue to work in hazardous informal jobs. This phenomenon will result in protracted duality due to insufficient economic growth and an inadequate number of formal job opportunities. As a result, a significant part of the population remains trapped in informal employment, unable to accumulate the necessary capital or human capital to transition into formal activities (Gutierrez-Romero, 2020; Chen et al., 2002). Indicating the economic dynamics inherent in the informal sector, particularly during

conditions like recession, Meagher (1995) has mentioned that the growth of the informal sector serves as a direct challenge to the marginalists' assumptions.

Neo-Marxist perspective (Structuralists school)

The early Marxian analysis viewed the informal sector as a collection of activities preceding capitalism that provided cheap wage goods and served as a labor reserve for capitalists without social protection (Heintz & Pollin, 2005; Zaki, 2017). The neo-Marxist or structuralist approach perceives the informal sector as a byproduct of current capitalism's restructuring, where the informal economy is functionally linked to the formal economy and capitalist companies deliberately exploit informality to cut costs, boost competitiveness, and weaken the influence of unions (Castell, 1989; Sassen,1997). Globalization is considered a key driver of the growth of the informal economy as it facilitates the expansion of subcontracting and outsourcing activities, linking the formal and informal sectors while aiding industrialization and modernization (Huang et al., 2020).

Neoliberal perspective (Legalists school)

Neoliberals consider informal work arrangements a rational response for entrepreneurs facing excessive bureaucratic burdens, regulations, and high costs of formality (Huang et al., 2020, Zaki, 2017; Chen et al., 2002). As they believe in free-market capitalism and minimal government intervention, privatization, and reductions in public spending and trade restrictions, informality is conceptualized as a symbol of free market forces responding to the failure of state intervention (Heintz & Polin, 2005; Huang et al., 2020). This interpretation of the informal economy has influenced the development policies recommended by the World Bank, as it advocates deregulation. However, such deregulation often worsens job quality and promotes indecent work, as observed by the neo-Marxist perspective. Neoliberals propose a way out of the informal economy by creating institutions, incentives, and removing barriers to promote formality (Godfrey, 2011). Additionally, the convergence view of the informal sector suggests state intervention to transform the informal

sector from marginal and survival activities to an engine of growth, providing full-time employment and meaningful self-employment (Debrah, 2007).

1.3.2 Theoretical and historical background of sustainable development

The concept of sustainable development originated from an economic perspective in the early 1800s, when the English political economist Thomas Malthus raised concerns about the earth's limited natural resources and their ability to provide continuous support to a growing human population. Historically, theories explaining long-term growth and technical progress were left unresolved by economists (Freeman, 1973) until attention turned to addressing Malthusian concerns, which warned about exponential population growth and resource use compared to linear growth in technology and subsistence, leading to a social and environmental crisis. A significant milestone in this area was the influential work "The Limits to Growth," which raised global apprehension about a potential crisis at the intersection of environment and development (Basiago, 1999). The 1972 United Nations (UN) Conference on the Human Environment in Stockholm marked a pivotal moment by prompting a call for strengthened environmental policies alongside economic development efforts (Basiago, 1999; Shi et al., 2019).

The United Nations Environment Programme (UNEP) and the International Union for the Conservation of Nature (IUCN) coined the term "sustainable development" in the World Conservation Strategy drafted in 1980 (Basiago, 1999). The theory of sustainable development (SD) has evolved through three stages: the embryonic stage (before 1972), the molding stage (1972–1987), and the developing stage (1987–present), with a focus on the coordinated development of the

economy, society, and environment, and gains prominence in high-level political agenda (Shi et al., 2019). In 1987, the UN's World Commission on Environment and Development, chaired by Gro Harlem Brundtland of Norway, reaffirmed the need for "sustainable development" to address poverty, environmental protection, and global food security. The Brundtland Commission Report, Our Common Future (WCED, 1987), defined sustainable development as meeting present needs without compromising future generations' ability to meet their own, which was widely circulated and accepted as authoritative. The "Earth Summit," in 1992 marked sustainable development's ascendancy as a primary global objective of the twenty-first century, reconciling economic growth with environmental protection and introducing social dimensions. According to this theoretical advance, the three pillars of SD are the economy, society, and environment, and these three theoretical foundations are supported by Agenda 21, which also works as a roadmap for its execution (Basiago, 1999). The UN Summit "Rio+20"in 2012 expanded sustainable development by including governance as the fourth pillar (Shi et al., 2019), and the UN General Assembly in 2015 approved a set of sustainable development goals (SDGs) for the year 2020 (Ozgur et al, 2021).

1.4 Knowledge Gap

The existing literature can't resolve the complexity of informal economies in their structural association with modern economies. The debate on the contribution of the informal sector to development still centres around two opposing viewpoints (pessimistic and optimistic), with early literature and policy climate in the 1980s portraying the informal sector pessimistically and subsequent research in the 1990s highlighting its potential for accumulation and development (see Gerxhani, 2004). Under this backdrop, the debate concerning the contributions of the informal sector

to long-term development, which necessitates a comprehensive and evidence-based analysis for its resolution, remains unattended to. However, given the significant and multidimensional impact of the informal sector on developing countries (See, Gerxhani, 1999; Charmes, 1990), the informal sector activity needs to be investigated for the sustainable development of human society, which encompasses various dimensions, including economic, environmental, ecological, material, social, legal, cultural, political, and psychological aspects (see Bossel 1999). Unfortunately, the informal sector has never been investigated under most of these dimensions of sustainable development, resulting in a significant knowledge gap in theoretical or empirical research. It is important to resolving this knowledge gap not only to achieve the UN 2030 agenda for sustainable development, which includes the informal sector as a thematic area, but also to address concerns about the overall development of these countries. The present research aims to fill the gap and expects to provide a reasonable solution to the urgent concern.

1.5 The aims and objectives of the study and the research questions

This research aims to investigate the multifaceted nature of the informal sector, and its role in advancing sustainable development (SD), while also exploring potential strategies aligned with the United Nations' sustainable development goals (SDGs). The specific objective is to evaluate both challenges and opportunities the informal sector faces in progressing across the three dimensions of sustainable development: economic, environmental, and human well-being. This research seeks to formulate practical policies to realize these objectives.

By viewing the informal sector as a combination of three interlinked dimensions: informal activities, informal employment, and informal units—an approach recognized by the International Labor

Organization in its 2002 International Labor Conference (see Zhu at al., 2020) —this research encompasses both macro and micro perspectives to identify pathways toward socio- environmentally conscious growth in urban settings. The ultimate aim of this research is to offer guidance to policymakers in shaping strategies that foster the achievement of SDG 8, which also holds interconnectedness with SDGs 1, 5, and 10.

To address the aforementioned objectives, which have also been identified as research gaps in the existing body of literature—carefully outlined in the literature review section of each study—the present research has formulated a set of research questions (RQs). These questions are tailored to address the voids identified across various facets of the informal sector. Each research question is systematically investigated through separate empirical study. The studies conducted within this research not only substantiate its purpose but also furnish valuable insights that can inform policy interventions. The research questions (RQs) are mentioned below:

RQ1. How does urbanization, as a spatial dimension of the informal sector, intersect with the discourse surrounding sustainability?

RQ 2. What are the impacts of the informal sector on the sustainability of development?

RQ3. In the context of sustainable development, what role does the informal sector play in terms of contributing to economic growth through output and employment?

RQ 4. What is the socioeconomic status of individuals involved in the informal sector?

RQ 5. What are the impacts of informal sector activities on the environment? Can informal sector enterprises offer potential avenues for promoting sustainable development?

RQ 6. Are there viable solutions that informal sector enterprises can adopt to aid the transition towards sustainable development?

1.6 Significance or scope of the study

Urban areas are considered a priority for sustainable development, while the urbanization process leads to the proliferation of the informal sector (Azurne et al., 2021). Cities are becoming increasingly informal due to the global economic transition (Yang et al., 2015). The growing size of the informal sector, which is heterogeneous by nature appears to be a significant economic feature not only in developing countries but also in developed ones (Huang et al., 2020; Azurne et al., 2021; ADB 2012; Peter Lang AG, 2010; Briassoulis, 1999). However, the role of the informal sector in shaping economies is not well understood yet, and it has become a concern and challenge for policymakers in developing countries (Aryeetey, 2015). Despite the deficiency of its perceived contributions to dynamic economic efficiency, informality has emerged as a coping strategy for many urban residents in the Global South (Azurne et al., 2021). Therefore, analyzing the informal sector is crucial in discourse of urban dynamics. Understanding the informal sector will provide insights to policymakers and urban planners about labor market issues like underemployment, wage disparities, and the quality of jobs available in urban areas. This knowledge is essential for designing policies that promote decent work and fair labor practices, which was proposed by the United Nations in 2005 as the ultimate solution to sustainable development.

Moreover, research into the role of the informal sector in urban green growth has the potential to focus on the symbiotic relationship between the urban informal sector and the circular economy since specific interconnections between the circular and green economy are anticipated (see Stankevičienė et al., 2020; Daniek, 2020). With proper understanding and integration of informal activities in urban systems, cities can promote waste reduction, resource efficiency, and improved livelihoods for urban residents. The studies conducted in this research with field-level data and

analysis help to realize the potential synergy between the urban informal sector and the circular flow of resources in cities. The outcomes help to reduce environmental pressures associated with resource extraction and disposal in urban areas. The policy suggestions of the research will also guide to transform urban areas into thriving hubs of sustainable economic activity and environmental stewardship, encouraging the concept of the circular economy, which has emerged as a powerful model for sustainable development.

This research is also significant as it is designed with studies across all three dimensions of SD, helpful for crafting strategies regarding the informal sector and its adoption on the SD roadmap. Identifying strategies for the gradual formalization of informal businesses, establishing social support programs, promoting pollution-minimizing manufacturing, and implementing indirect regulations that demand immediate attention have all remained unattended to due to a lack of substantial evidence within the domain of informality studies. By drawing attention to these crucial aspects of the informal sector, this research has justified the importance of effective governance as a policy tool, which has recently been considered the fourth pillar of sustainable development (see Shi et al., 2019). Thus, this research contributes to the validation of this paradigm by emphasizing the intrinsic importance of strategic policy implementation in the context of the informal sector's multifaceted challenges and contributions.

Evidence-based policymaking stands as a pivotal requisite for attaining the benchmarks associated with the informal sector and employment precariousness, identified as thematic areas of SDGs 8.3 and 10.2 (ILO, 2018a, 2015b, 2015a). This research presents an immense opportunity to contribute to all three aspects of the SD outlined by the UN (economy, environment and equity). It can serve

as a valuable guide for navigating the realm of implementing indirect policies, formalizing informal enterprises, and realizing the principles of green growth through integration with contemporary thrusts like corporate social responsibility, eco-friendly technology, and most importantly, the circular economy, which require the harmonious interplay of economic, environmental, and social dimensions, encapsulating the very essence of sustainable development. The insights and recommendations furnished by this research hold the potential to ameliorate urban socio-economic life and facilitate reaching UN 2030 targets on the SDGs. Notably, the dearth of funding has emerged as a principal impediment to achieving these goals, as indicated in the Sustainable Development Goals Report of 2018. In this context, advocating for building environmental awareness and behavioral change in production can emerge as a prudent and cost-effective strategies that align with long-term sustainability objectives.

1.7 The main Conceptual Framework

The concept of environmentalism, which emerged in the 1970s, focuses on the pressing environmental challenges and the underlying social, political, and economic problems caused by humans interacts with the environment. In this context, human-related activities, such as resource exploitation, environmental risks, habitat management, and habitat restoration, have been used to examine the link between humans and nature (Seymour, 2016). It states that the human-nature relationship is not a one-way track. Human activities are influenced by changing conditions that affect the environment, and the environment responds to human manipulation, resulting in a state of dynamic equilibrium with constant adjustment and readjustment in space and time (Onyenechere, 2011). The principle of sustainable development harmoniously encompasses the environment, the economy, and the societal aspects in a framework that may be presented as three balanced rings.

There is a risk of raising issues in sustainable development if these three rings are separated (Kikuchi, 2011; Bassiago, 1999). The intricate interactions between these three interconnected and overlapping fundamental systems give rise to the urban system as a unique entity, which poses challenges in identifying the causes of urban socio-environmental problems and developing policies to address them (Alberti, 1999). In the urban sphere, the usefulness of informality continues to be debated (Azurne et al., 2021). In this connection, research into the informal sector from a sustainable development perspective provides an understanding of challenges and opportunities for change (Chazireni & Chigonda, 2018). The inclusion of sustainability principles and measurement of the proportionate equilibrium between economic, social, and environmental issues is required for the sustainable operation of a firm (Machado et al., 2012). A framework for sustainability assessment was developed by Labuschagne et al. (2005), entailing all three objectives of sustainable development into the operational practice of the firm and based on this idea, the challenges and opportunities of firms operating in the informal sector have been explored.

Being concerned about the above mentioned issues, the main conceptual framework of this study has been developed based on a cause-and-effect relationship between the environment and socio-economic systems, which may be considered a tool for policymakers in structuring information and indicating causal links between environmental indicators (Tscherning et al., 2012; Kjellstrom et al., 2007). The Driving Forces–Pressures–State–Impact–Response (DPSIR) framework has been used for parallel assessments addressing environmental and socioeconomic perspectives and implications. The increase in research on sustainable development has broadened the use of DPSIR because it permits integrative, multidimensional assessments. DPSIR is designated as a dependable scientific tool for dealing with environmental issues. The DPSIR framework was developed in 1990

and proposed by the Organization of Economic Co-operation and Development (OECD, 2003) as a means of structuring and organizing indicators in a way that is meaningful to decision-makers. It was adopted by the European Environment Agency (EEA) in 1995 (Tscherning et al., 2012). Guided by the initial work of the World Health Organization, which expressed the impact of social determinants on health through a pathway of environmental exposures in urban areas (Kjellstrom et al., 2007), a more detailed conceptual framework, DPSIR, was suggested by Maxim et al. (2009). It captured the consequences of environmental problems and their relationship with the socioeconomic domain through a casual framework between various components, which was useful for suggesting policy in a meaningful way (Pinto et al., 2013; Jiboye et al., 2018; Maxim et al., 2009; Kristensen, 2004). The present research has follows this conceptual idea and is presented in the diagram below.

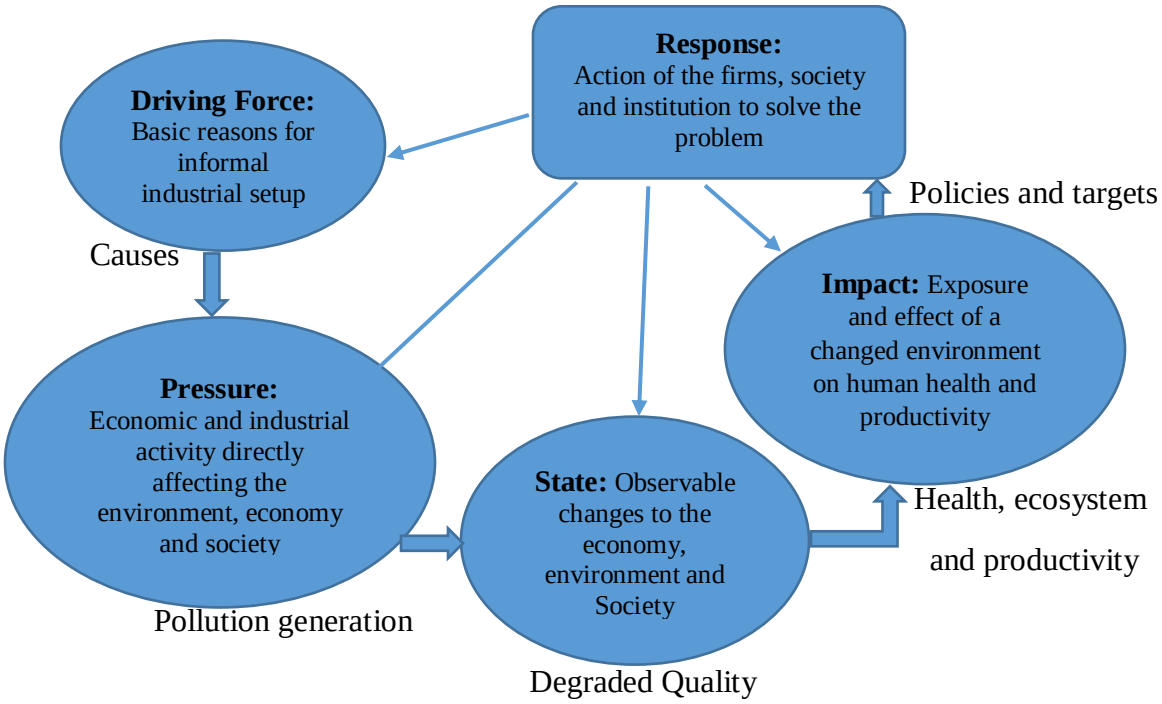

Fig 1: The DPSIR assessment framework. Source: Kristensen (2004)

Population growth, economic growth, poverty, need for mobility, food and water are considered as **driving forces** that give rise to urban informal sector and exert **pressure** on the environment, economy, and human life. Urbanization, industrialization, and economic and extractive activities are considered as pressure (Tscherning et al., 2012; Svarstad et al., 2008; Kristensen, 2004), which impose costs on the environment, economy, and human life. This imposed costs of sustaining the human-engineered components of social–ecological systems indirectly affect economic growth and associated pathways connecting to health and environment (Seymour, 2016). Thus, affected **states** arise that have an **impact** on the economy, environment, health, and welfare of the surrounding population. The **response** of stakeholders, policymakers, or society is due to the state and the impact, and can influence any segment of the chain starting from the driving force and moving to the impact. An adoption of technology, a change in mode of production or raising awareness can be an example of this (Jiboye et al., 2019; Kristensen, 2004). Firms' awareness, motivation and choice of action either as resilience or innovation in cost minimization on environment, economy, and society are portrayed as response strategies in the framework (Tscherning et al. 2012).

1.8 Data, Study design and perspective

This study has conducted a detailed analysis of the topic by combining both macro and microeconomic aspects. Time series and panel analysis techniques have been applied to cover macro aspects using secondary data collected from established national and international data sources. In addition, primary data collected from field-level surveys have been used for micro-level (enterprise) studies, applying cross-sectional analysis techniques. The survey areas were selected from Dhaka, the capital city of Bangladesh. In order to adhere to international standards for data collection involving human participation, this research project proposal was submitted as a Human Ethics

application to the Human Resource Ethics (HREC) office of the University of Southern Queensland (UniSQ) (H21REA014) for approval. The HREC office granted approval in July 2021 after determining that the project met the requirements of the National Statements on Ethical Conduct in Human Resource (2007) (Approval date: 05/07/2021, Expiry date: 05/07/2024). Following all procedures approved by HREC, UniSQ, the field survey began in August, 2021 and successfully ended in March 2022, overcoming all the constraints imposed by COVID-19 pandemic and the consequential lockdown in the survey area. Fortunately, the field survey was able to collect a high-quality data set from the respondents that has been utilized to address the research questions (RQ.4 – RQ.6).

To accomplish the objective of the study, skilled personnel collected samples from two environmental components (water and soil) in the survey areas. Scientific analysis of the collected samples was required, and the tests were carried out according to the plans outlined in the data collection procedure of the human ethics application. All the analyses were conducted under the supervision of an authorized person from the assigned organization who had been contacted beforehand and agreed to provide support. The official laboratory report of the tests was received from the designated organization in a timely manner. The scientific analysis of the environmental components (soil and water) identified the concentration level of harmful metals in the collected samples. The pollution load of selected metals in the surrounding areas of three categories of manufacturing industries namely, leather and leather products, plastic and small machinery, and dyeing, fabrics, and clothing, was determined by constructing Pollution Load Indices (PLI) for three selected areas (Hemayetpur, Lalabagh, and Keraniganj) in the capital city of Bangladesh.

At the commencement of the research, it has examined the long-run influence of spatial, economic and socio-economic factors on environmental degradation at both regional (South Asia) and country (Bangladesh) levels in **Study 1** and **Study 2** respectively and attempted to answer **RQ.1**. The Panel-Autoregressive Distributive Lag Model (PARDL) and Autoregressive Distributive Lag (ARDL) model with structural break are applied in the studies in a respective manner, along with causal analysis. The results have indicated that the spatial factor (urbanization) and economic factor (economic growth) are significant determinant of carbon emissions in South Asian region. These two factors are also found to contribute negatively and significantly to overall environmental quality in Bangladesh, although the Environmental Kuznets' hypothesis is evident in this country. Two research papers (**Paper 1** and **Paper 2**) have been published on this topic in two prestigious international journals (Q2 and Q1, respectively) with high impact values. The findings of these two studies justify the selection of a spatial or urban perspective for this research, where the growth of the informal sector is highlighted as a key feature for unplanned urban growth, as they reinforce each other.

In the next step, this research has addressed RQ.2 by constructing a symptomatic index of sustainable development and investigating the impacts of the informal sector on the sustainability of development in developing countries (including Bangladesh) in **Study 3**. A global panel dataset has been employed for this, and Principal Component Analysis (PCA) has been applied to construct a symptomatic composite index of sustainability using economic, social, and environmental impact indexes. Panel analysis techniques (Fixed Effect, Random Effect, Fully-Modified OLS, Dynamic OLS) are then applied to investigate the effect of the informal sector (for which working poor is used

as proxy) and other macroeconomic and institutional factors on the composite index of sustainability. The resulting research paper (**Paper 3**) has been published in a Q1 journal.

Next, the research has progressed to a component-specific analysis of sustainable development employing the informal sector. Firstly, the research has focused the impact of the informal sector on long-run economic growth in terms of its contribution to the economy and employment. However, due to the lack of sufficient data for a panel analysis of an unobserved sector, the research has conducted a country-specific analysis at this stage. A time series of data on the informal sector as a percentage of Gross Domestic Product (GDP) has been generated for Bangladesh, the primary country of interest in this research. The Structural Equation Modeling (SEM) techniques, specifically The Multiple Indicator Multiple Causes (MIMIC) model, which is well-suited for estimating an unobserved sector like the informal sector, has been utilized, and then benchmarking and calibration techniques are applied to project the estimation as a percentage of GDP in Bangladesh. To ensure the robustness of the result, the research has also applied the Monetary Approach, specifically the Currency Demand Approach (CDA) to construct the time series dataset of the informal sector's contribution to GDP in Bangladesh. Details of this estimation technique are presented in Appendix A of this thesis. In both analyses, an increasing trend in the informal sector's contribution to GDP has been discovered for Bangladesh, which validates the selection of Bangladesh for this research. The time-series data constructed from MIMIC estimation and calibration is used to answer RQ 3, for which both the symmetric and asymmetric effects of the informal sector on the economic growth of Bangladesh are studied. By employing long-term analysis techniques such as linear (ARDL) and non-linear ARDL (N-ARDL), **Study 4** provides insights into the economic prospects of the informal

sector in Bangladesh towards sustainable economic growth and recommends relevant policies. This research papers (**Paper 4**) is currently under review in a reputed (Q1) journal.

Furthermore, **Study 5** investigates the impact of informal employment, a crucial component of the informal sector and an important agenda in Sustainable Development Goals (SDG), on the economic growth of developing countries (including Bangladesh), within the context of SDG. This study also addresses RQ.3 by employing a long-run panel analysis techniques (Fully-Modified OLS, Dynamic OLS and Dynamic Fixed Effect models) on a secondary data set of developing countries. The findings of this study underscores the significance of safeguarding the decent work agenda and other macroeconomic growth indicators to achieve the targets mentioned in SDG 8. The research paper on this topic (**Paper 5**) has been published in a Q1 journal.

To address RQ.4 regarding the socio-economic conditions of informal sector workers, this research focuses on their basic survival needs, specifically the food security status of the workers, and investigates its impact of on their health outcomes in **Study 6**, utilizing survey data from the study area. The Food Insecurity Experience Scale (FIES), consisting of eight items, is used to screen for food insecurity, while the Short Form 12v2 (SF12v2) scale, comprising 12 questions validated for use with Bengali respondents, is used to measure the health status of informal workers. The empirical analyses of this study are cross-sectional and include descriptive statistics, mean score comparisons, and multivariate regression analysis to establish the relationship between food insecurity and health outcomes. The findings of this study suggest policies to address the socio-economic problems faced by informal sector workers, which significantly impact their productivity. The research paper on this study (**Paper 6**) is published in a Q1 journal.

This research has utilized the survey data and scientific analysis of environmental samples to address RQ.5 that focuses on environmental aspects of SD. The Pollution Load Indexes (PLIs) have been constructed based on the results of scientific analysis, which are used in **Study 7**. The study has employed Data Envelopment Analysis (DEA)-TOBIT regression analysis to assess the economic efficiency level, its correlation to pollution and to identify the future prospects of informal sector enterprises towards cleaner production, which can facilitate the achievement of SDG goals, particularly in the context of decent work and pollution reduction. The empirical findings suggest the need for institutional support to endorse the positive participation of informal sector manufacturing enterprises in sustainable development. This scientific research paper (**Paper 7**) has published in a Q1 journal. **Study 8** investigates the informal sector and environmental degradation nexus, to addresses RQ.5 adequately. This study has employed three environmental degradation indicators: carbon dioxide emissions, ecological footprints, and nitrous oxide emissions and takes into account the informal and formal sectors and institutional variable in the model. Panel analysis techniques (Pooled Mean Group-ARDL, FMOLS and DOLS) are applied to a secondary data set of emerging countries and the findings demonstrate the necessity of finding indirect institutional measures to prevent pollution caused by informally operated enterprises. A research paper on this study (**Paper 8)** has been published in a Q1 journal.

Getting motivated by the findings of earlier study, this research attempts to answer RQ.6 by focusing on raising awareness among stakeholders of informal enterprises in **Study 9**. A firm-level Environmental Awareness Index (EAI) is constructed based on survey data, under the presumption that enhanced awareness of the environment can drive actions that optimally harness the sustainability attributes of informality, while minimizing its negative consequences. Applying

discrete choice Probit and Logit regression models, this study examines the effect of EAI on the firm-level decisions regarding the adoption of clean technology. The findings of this study are expected to inform policy measures to build awareness among informal enterprise owners, leading them towards the path of clean technology adoption, which will facilitate the achievement of SDG targets such as a green growth. A research paper on this topic (**Paper 9**) is currently submitted to a reputed (Q1) journal. The combined results of all these studies (from **Study 1** to **Study 9**) are expected to provide an evidence-based understanding of the informal sector as a whole and suggest its path towards sustainable development.

1.9 Thesis organization

The present research evolves into the conceptual framework and contributes to ongoing debates on informal sector activities to achieve its objectives. All studies that are included in this thesis, have been conducted to address the objectives by employing quantitative methods and using established econometric as well as advanced statistical techniques. This is a thesis **by publication,** and consists of nine empirical studies to address the research questions, each employing different but established analytical designs and approaches within the context of a particular country or a set of countries. The introduction chapter is followed by the analytical chapters of this thesis. The research framework is presented below.

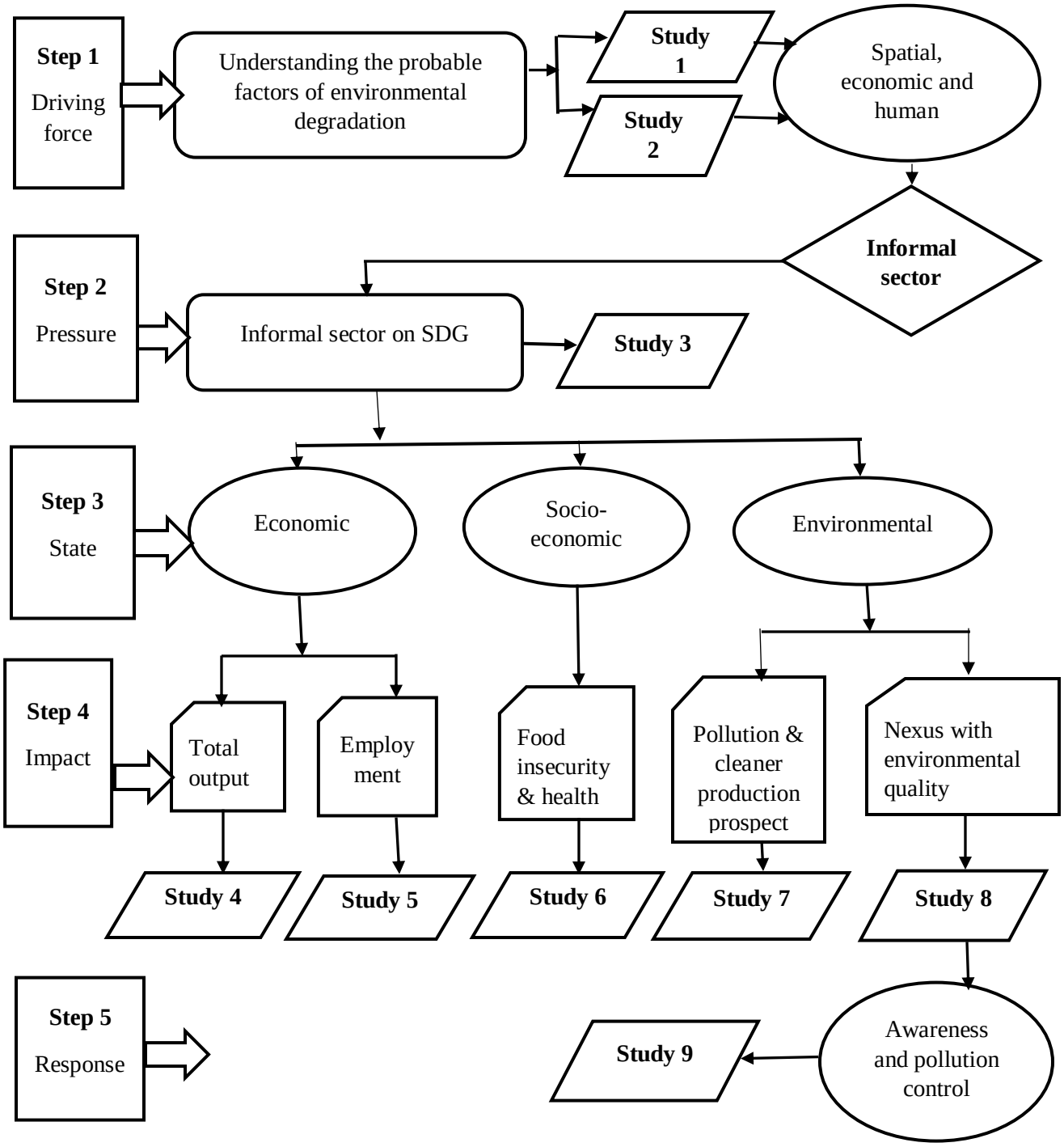

Fig 2: Research framework

CHAPTER 2: URBANIZATION, ECONOMIC GROWTH AND ENVIRONMENTAL DEGRADATION

2.1 Introduction

The informal sector is an officially unrecognized and unobserved segment of the economy, but it originated in an urban context (see Lv & Xu, 2021, Quyyum et al., 2021). Economic growth in developing countries tends to be concentrated in primate cities due to social structure and the centralization of power, which make them the only suitable location for economic and social opportunities (Baye et al., 2020; Hall, 1975). Urban areas serve as the center of production, innovation, employment, and socio-economic development, and as a result, they experience remarkable increases in population growth and faster urbanize. However, this rapid, unregulated, and unplanned growth of urban areas creates different types of urban problems due to its close link with economic, social, and environmental issues. Urban problems are not only caused by growth, but also by misguided policies and unguided expansion of cities. The expansion of informal economic activities is one such challenge (see Baye et al., 2020), which worsens environmental quality and hampers sustainable economic growth in a region (Abbasi et al., 2020). Sustainability is an essential dimension of urban development (Zhang et al., 2022; Montoya et al., 2020). Therefore, this research primarily targets urbanization, which is parallel to the growth of the informal sector in developing countries. The study presented in Section 2.2 examines the impact of economic growth, industrialization, and spatial dimensions of economic growth, i.e., urbanization, on environmental degradation in the South Asian region. The outcome of this study identified urbanization as one of the causative factors for environmental degradation in this region. Hence, urbanization and its

development need to be integrated into long-term economic planning, with a particular focus on the informal economy due to its strong linkage with the urban development of South Asian countries (see Quyyum et al., 2021).

As the qualitative nature of urbanization varies across countries and the environmental degradation of varying types and degrees is generally unevenly distributed in most countries (Jiboye et al., 2019), this research finds it necessary to assess this urbanization-environmental quality nexus at the country level. Bangladesh has been selected for this purpose since it is a rapidly urbanizing country. The Environmental Kuznets' hypothesis has been examined for Bangladesh to provide an indication of a long-run growth-environment nexus in which the role of the spatial dimension of economic growth and the environment, e.g., urbanization, has been reassessed. The details of this study are presented in section 2.3 of this chapter.

2.4 Links and Implications

The studies presented in this chapter demonstrate that urbanization is a significant cause of environmental degradation. Since urbanization is often accompanied by the growth of the informal sector in the region, the findings of these two studies, which project the impact of urbanization as a challenge to environmental quality, justify the need to focus on the informal sector to proceed towards urban sustainability. However, a long-standing debate exists between two main schools of thought, where one believes that informality hinders the economic, environment, and social sustainability and constrains the ability of future generations to satisfy their needs, and the other maintains that informality propels sustainability. Therefore, informality requires the attention of academics, urban planning practitioners, and city authorities concerning policies for sustainability (see Azurne et al., 2021). This research attempts to contribute to achieving urban sustainability by focusing on the multidimensional and multifaceted aspects of informality aligned with the sustainability perspective. The following chapter empirically examines the impact of the informal sector on the sustainability of development in the context of a global panel of developing countries to provide assistance in policy measures.

CHAPTER 3: THE INFORMAL SECTOR AND SUSTAINABILITY OF DEVELOPEMNT

3.1 Introduction

Sustainability is a dynamic concept that evolves over time (Bossel, 1999). It creates conflicts of interest among the economy, society, and environment, which are becoming increasingly apparent. The foundation of the non-sustainable society we live today was created by the migration of people from rural to urban areas to work in factories, and the expansion of production and international trade. These were the consequences of the accelerated industrialization process during the Industrial Revolution in the eighteenth century, when humans were exploiting nature's wealth and releasing large volumes of waste and pollutants into the environment. At that time, the rapid and ongoing human-caused environmental changes posed a serious threat to human survival (Deitlev and Simonsen, 2022; Shi et al., 2019). Simultaneously, humanity was facing increasing problems, including food shortages, energy crises, environmental pollution, slowing economic growth, and rising local social unrest. These challenges forced humanity to search for a new path for long-term survival and development (Shi et al., 2019). Under these circumstances, the concept of SD evolved and was adopted as a basic strategy to guide global socioeconomic transformation (Shi et al., 2019), with the potential to resolve conflicts among economic, social, and environmental issues. Sustainable development is only feasible if the component systems, as well as the total system, are viable (Bossel, 1999).

The informal sector, which is an unobserved, contentious, but significant component in a socioeconomic context (Gibson, 2013), can be a good candidate for structural transformation of a

society and economy towards sustainability because it projects a contextual similarities with pre-sustainability economic mechanisms and behaviors. Studies in the earlier chapter also hinted that the urbanization process, which is integrated with informal sector growth (see Quyyum et al., 2021) as well as economic growth, is a significant contributor to environmental degradation. Therefore, the activities of the informal sector need to be evaluated in terms of their contribution to the components of sustainability to provide feedback to the global challenge and a constant concern to policymakers (Stankevičienė et al., 2020). The impacts need to be analyzed in an ideal paradigm of development, i.e. sustainability, which is a quest for the simultaneous satisfaction of three objectives: economic efficiency, social equity and environmental protection (Briassoulis, 1999). This is important because sustainability is the capacity of a system to last over time (Montoya et al., 2020). It bears significance particularly in the developing world, as the size of the informal economy has remained high or even increased despite their robust economic growth (Pham, 2017).

3.2 Study3

Received: 5 February 2022 | Revised: 9 May 2022 | Accepted: 9 May 2022
DOI: 10.1002/bsd2.217

RESEARCH ARTICLE

Business Strategy and Development WILEY

The effect of the informal sector on sustainable development: Evidence from developing countries

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Abstract

This study aims to explore the impact of the informal sector on the sustainability of development. A large panel data set of 50 developing countries that spans over 2010–2019 has been utilized to this end while the informal sector is evaluated in terms of working poverty. Selecting indicators from three dimensions of sustainability, that is, economy, society, and environment, this study has constructed three indices and combines those to construct a symptomatic composite index of sustainability. Both the short run and long run panel data models have been applied to empirically investigate the impact of informal economic activities on the sustainability of development. Economic growth, national expenditure, and economic freedom of countries are used as control variables in the models and the estimated outcomes are found to be robust in empirical investigations. The outcomes of the study imply that the informal sector plays a detrimental role in the sustainable development of developing countries while economic growth and economic freedom contribute positively. Therefore, the prescribed strategy is to reduce informality from business and other economic activities that limit the scope of the economies and to understand the domain through which interventions can be made to move to a more formal economy. Integration of informal business and SMEs into the formal sector and firm-level awareness building in Corporate Social Responsibility can also be suggested to find a path towards sustainable development in addition to increased economic growth and enhanced economic opportunities of the developing countries.

KEYWORDS
developing country, economic freedom and opportunity, economic growth, informal sector, sustainable development

JEL CLASSIFICATION
O11, Q01, O43, E26, F63

1 | INTRODUCTION

The informal sector has wide-ranging impacts on the economic and social development of developing and less developed countries and it has become a central issue in development discourses (Arvin-Rad et al., 2010; Elbahnasawy et al., 2016; La Porta & Shleifer, 2014). The informal economy that comprises small and medium enterprises and relates to economic activities outside of government regulation or

taxation is largely visible in these countries (Adeola et al., 2019; Elbahnasawy et al., 2016). It is highlighted for entrepreneurship, business, income, and employment since public authorities often face inadequacy of resources to support and regulate business activities in developing countries (Maloney, 2004; Martinez et al., 2015). Informal economic activities have been projected as the thematic area in United Nation's Sustainable Development Goals (SDGs), SDG 8.3 and SDG 10.2 (ILO, 2015b, 2015a) and are considered one of the most significant challenges to sustainable development in the 21st century (Huang et al., 2020). Poverty, population, pollution, participation, policy and market failures (including good governance), and prevention and management of disasters are the strategic factors to govern sustainable development and are regarded as the major pillars on which sustainable development rests. To achieve sustainable development two vicious cycles that feed on each other must be addressed: poverty and development, leading to resource depletion, and environmental degradation (Roger et al., 2008). The informal sector links to both of these cycles in developing countries due to its association with low income, low productivity, labor rights abuses, unfair competition, and environmental degradation. Therefore, sustainable development is considered to be rooted in a sound understanding of the informal sector (Adeola et al., 2019). It needs to be addressed in the development planning of these countries, especially when actions taken in the direction of the SDGs are to be inclusive and favorable to the poor.

Sustainable development is viewed as the ideal paradigm of development and a quest for satisfying three aims: environmental protection, economic efficiency, and social equity (Briassoulis, 1999; Ruzek, 2015). In the Global Sustainable Development Report (2019), the informal sector is highlighted as a potential contributor to more than four entry points of an urgent transformation in socio-economic and environmental system that may separate over nations but can add up global outcomes to ensure human well-being, social health and minimal environmental impact as a priority. However, the role of the informal sector in sustainable development has been debated in many studies due to its pervasive characteristics of non-regulation by formal institutions. From the viewpoint of sustainability, the main issue regarding the informal sector lies in the fact that production and business activities in this sector do not ensure long-term economic efficiency and welfare although it bears the potential of more effective satisfaction to social needs. The informal sector creates a decentralized model of economic organization that makes formal coordination and planning a cumbersome task by distorting the factor, resource, and product market in many ways (Briassoulis, 1999). It is negatively linked to formal investment and impedes growth by hindering the government from raising revenue. Thus, it limits public sector resources from playing a complementary role to private investment through infrastructure development and improvement in the business environment (Misati, 2010). Economies with high informality face difficulties accessing credit, providing poor protection of investors and running with ineffective tax and licensing systems, which increases the risk of collapse of the formal sector (Estevao et al., 2022). Moreover, precarious work conditions are visible in informal enterprises where workers are deprived of their rights along with increased risk of abuse and job uncertainty (Estevao et al., 2022; Dell'Anno, 2018). Contrary to these views, the informal sector is viewed as the lifeline for the poor and acts as a reasonable response to the over-burdened regulations that ultimately provide the economy with a dynamic and entrepreneurial spirit with competition, innovation, efficiency, and investment (Schneider, 2005; Misati, 2010). In the context of environment, informal economic activities are often linked to land, water, air and sound pollution-in one hand and on the other hand are applaud as a cleanser of environment due to their capability to re-use waste materials erupted from formal sector (see, Chirisa & Bobo, 2018; Elgin & Oztunali, 2014; Huynh, 2020; Köksal et al., 2020). Under such a backdrop, this study has initiated a comprehensive and holistic investigation to explore the effects of informal sector activities on different dimensions of sustainability.

The informal sector activities are operated outside the world of the formal economy, where small-scale production and business activities are carried out by subsistence entrepreneurs and workers without contractual agreement and division between labor and capital. These unincorporated private enterprises are poorly managed, undercapitalized, less-productive, and transient that get no coverage or insufficient coverage by formal agreements (Azunre et al., 2021; Eijdenberg et al., 2019; ILO, 2013). They produce goods and services at a lower level of organization and technology with a preliminary objective to generate employment and incomes. These activities are largely unrecorded, unrecognized, and are often considered as a cause of improper functioning of the formal sector that is capable of affecting sustainability (Briassoulis, 1999; Ruzek, 2015). Since the workers become business owners with little preparation to manage the business, their profit gets meager and usually gets constrained to informal getting failed to comply with government regulations, taxes, and property rights (Barron, 2020; De Soto, 1989). These constraints give rise to a contrasting view of the informal sector activities and publicize its hidden danger due to unfair competition with formal firms. Activities in the informal sector are often considered to be the byproduct of poverty and deliberated to be the last resort for poor, unskilled, low-paid workers (Basu & Chau, 2015; De Soto, 1989; Ghose, 2017; La Porta & Shleifer, 2014). Maintaining informal employment is argued to play a role in poverty reduction and socio-economic stability (Huang et al., 2020), while some others argue in favor of reducing the size of the informal sector for pursuing poverty reduction (Chen, 2006; Larsson & Sevensson, 2018). Since eradication of poverty is one of the relevant areas of sustainable development, this study has analyzed informal sector activities in terms of poverty beneath employment following Loayza and Rigolini (2011) and Chen (2012) to assess its impacts on the facets of sustainable development.

The informal sector has appeared as a means of survival to a vast section of people in developing and less developed countries. Fifty percent to 90% of the non-agricultural workforce in the developing world are employed in informal activities (Gutiérrez-Romero, 2021). It provides earning opportunities for 62% (2 billion) of the entire working population of the world, of which 90% are in low-income countries, 67% in middle-income countries, and 18% in high-income

countries (ILO, 2020). Considering the significant presence of informality and its dominating role in employment generation, issues linked to the informal sector should gain attention in policy-making, particularly in developing countries. The present study will contribute to this end in several ways. First contribution is to focus on the impact of the informal sector on the sustainability of development of developing countries where the informal sector is evaluated by poverty in employment. The second contribution is to explore freshly the long tradition of developing and using indicators for improved decision-making in policy issues related to economic development, social progress, environment and natural resource, community health, and sustainability (see Miller et al., 2013; Hezri & Dovers, 2006). This study has constructed indices on the above-mentioned aspects of sustainability outcome and has combined those in a symptomatic composite index of sustainability utilizing a panel data set of 50 developing countries.[1] The third contribution lies in the empirical investigation that employ both short-run and long-run econometric techniques. These techniques rigorously address the problems related to endogeneity, bias and measurement errors and confirm the results in the long-run adjustment mechanism. This comprehensive and robust empirical evidence will guide the impact of informal activities on the prospect of sustainability.

The structure of the paper is as follows: Section 2 contains literature review, Section 3 describes the data and explains the methodology, Section 4 presents and discuss the result. Section 5 concludes the study by summarizing it and suggesting some policy measures.

2 | LITERATURE REVIEW

The topic of assessing sustainability in informal economic activities of developing countries has not been explored enough. This section will discuss the existing evidence on how the main features of informal sector activities affect the three facets of sustainability: economy, environment, and social equity under three sub-sections.

2.1 | Informal sector and the economy

Amidst the persistent view of the existence of large informal sector as a hindrance to investment, growth, and development, it has appeared in an expansionary manner in developing countries due to the rapid growth of already widespread unemployment in these countries (Misati, 2010; La Porta & Shleifer, 2014). In Pakistan, half of the total GDP is sourced from the informal economy which is revealed by the study of Khuong et al. (2021). The significant positive impact of the informal economy on the growth of nominal GDP was also revealed in Nigeria by Yelwa and Adam (2017). The informal sector was found to be dependent on economic growth, working-age population, government policies, and trade-related globalization in developing countries by Pham (2017). A well-functioning and regulated informal economy was mentioned as a critical prerequisite for achieving sustainable economic growth by Yelwa et al. (2015). However, since the linkage between informality, growth and inclusiveness was not fully understood, extensive informality was recognized as an obstruction towards long-run economic development and poverty alleviation by their study. Elgin and Birinci (2016) projected an inverted U relationship between the informal economy and economic growth in the long run where countries of low income were found to have a negative correlation between the two while the opposite was revealed for high-income countries. A one-way causal relationship of informality with GDP was established by Duarte's (2017) study on Spain though an alternative model failed to find a long-run equilibrium and causal relationship between these two. Institutional quality was identified as an important interacting factor in economic growth and the shadow economy relationship by Baklouti and Boujelbene (2020). In their study, higher GDP per capita was associated with a smaller shadow economy in countries with high institutional quality, while increased GDP per capita has no influence on the size of the shadow economy in countries with low institutional quality. Relative volatility of consumption to output positively influenced the size of the informal economy. Horvath (2018) revealed this by constructing a two-sector real business cycle model of a small open economy with a poorly measured informal sector where an increase in country interest rate generated a contraction in output, investment, consumption, and an expansion of the informal sector.

Recent studies focus more on formalization of business. Barron (2020) has found increased evidence of formalization of small-scale enterprises after examining the effects of two large business training programs on formalization of microenterprises in Peru. The opportunity to reconsider the business plan, the declaration of the tax procedures, and access to basic capital have worked behind the improvement by this study. Estevao et al. (2022) have demonstrated several possible alternatives for reducing informality in the African context that are linked to market efficiency, improved access to credit, tax system, and investor protection. Taking into note the transient nature of business in the informal sector Akintimehin et al. (2019) showed that social capital had a significant effect on business performance. This study recommended that informal entrepreneurs take advantage of internal social capital resources and build external social capital since both were found valid for business success.

2.2 | Informal sector and environment

The size of the informal sector is important for the efficacy assessment of environmental policy (Bali Swain et al., 2020). The informal sector was proved to be the long-term driver of ecological footprint levels when it was linked to formal economies by Köksal et al. (2020). In general, a larger informal sector contributes significantly to environmental damage since firms operating in the sector can escape regulatory policies on the environment (Biswas et al., 2012). Projecting an inverted U relationship, Elgin and Oztunali (2014)showed that a lower level of pollution was associated with small and large size informal economies, and a higher level of pollution was linked to medium size informal economies. In case of air pollution (both local and global) the

marginal impact of the shadow or informal economy was found to be positive by Biswas et al. (2012). This study revealed that the damaging impact of the shadow economy on pollution could be reduced by preventing the corruption level, which reinforced the growth of the shadow economy in developing countries. A lower corruption level is also suggested by Bali Swain et al. (2020) for improving the marginal impact of the informal economy on environmental pollution. The positive influence of the informal sector on emissions of local pollutants has been established by this study, although no significant impact has been established on global pollutants, that is, CO_2. The study has pointed out that since the informal sector in developing countries mostly relies on labor-intensive production techniques and utilizes less energy, it leads to lower levels of emissions. While investigating the causal relationship between economic growth and CO_2 emissions in Tunisia, informal sector activities were found to promote environmental degradation, and hence a reduction in the size of the informal sector was suggested by Abid (2015).

Tax enforcement supposed to intensify the problem of environmental pollution according to Huynh (2020). The degree of tax enforcement variable on an informal sector projected an inverse U relationship through the scale effect and deregulation effect in a study by Chaudhuri (2005) where a polluting informal manufacturing sector firm subcontracted for the formal sector. The result confirmed tax enforcement as the key policy tool to reduce pollution but with an increased possibility of growing intensity of informality. Indirect taxes on the formal sector might improve emission scenarios with a welfare tradeoff. Therefore appropriate fiscal policy was recommended in these studies to move to cleaner economies. Introducing a model for an optimal tax that captured substitution between formal and informal parts of the economy, Bento et al. (2018) showed that certain narrower taxes placed on environmental externalities could become more efficient in the presence of the informal sector. Their study suggested that developing countries were better venues for introducing energy taxes because energy tax would correct environmental externalities and collected taxes more efficiently. The indirect method of pollution control was also suggested by Chaudhuri and Mukhopadhay (2006). According to this study the formal sector firms that used output from the informal sector as an intermediate input should burdened with more tax since informal sector units could not afford to pay pollution taxes or installed pollution abating equipment or targeted for their polluting activities.

2.3 | Informal sector and social issues

Although the informal sector accounts for almost one-half of economic activities, and contributes to employment in developing countries (Chen, 2012; Basu & Chau, 2015; La Porta & Shleifer, 2014), there is little consensus on the utility of such employment on poverty eradication (Gulyani & Talukdar, 2010) which is the area relevant to sustainable development. Informal sector workers are forced to accept low-paid jobs with inadequate job security in the cities since they are not in a socio-economic position to wait indefinitely for a high-paid job in the formal sector. Workers are often exposed to difficult and hazardous working conditions in informal firms with no social security or health benefit schemes (Kar & Marjit, 2009; Macgregor et al., 2012). A predominance of monopsonistic exploitation and working poverty conditions in the urban informal sector of South Asia were studied and explained by Gangopadhyay and Shankar (2016). An index of destitution for the working poor in the informal sector of developing countries was constructed by Gangopadhyay et al. (2014) that explained various economic and social variables responsible for worsening destitution among the working poor in the informal sector. This destitution and poverty are neglected in profit considerations. In Bangladesh, the profit scenario of brick kiln industries operating under the informal sector was found to turn negative when associated health impact and other social costs of pollution were accounted by Croitoru and Sarraf (2012). Past levels of inequality have been identified as an important factor in explaining the size of the informal sector in the long run by Gutiérrez-Romero (2021). It was established by Dell'Anno (2018) that countries with a low-level of inequality faced a negative correlation with informality while high inequality increased informality.

Yelwa et al. (2015) found that the socioeconomic factors of the informal sector had a positive influence on the economy. The possibility of performing social responsibility by informal enterprises was investigated by Villanueve et al. (2020) in Mexico city through a face-to-face interview with entrepreneurs. The outcome of this study found the evidence that the informal enterprises could perform the social responsibility in an implicit form despite their adverse and vulnerable conditions. Uzo and Shittu (2019) was able to establish a linkage between informal social responsibility and sustainable development after investigating the mechanism of practicing social responsibility in informal economy of Nigeria.

The informal sector can provide the balance between "Three Es": economy, environment and equity and provide an intra and inter-generational future. Ruzek (2015) opined this and considered the informal sector a change maker that would shift focus from a globalized capital society to eco-localism where local economy and small scale flexible markets with the ability of rapid adjustment to changes in demand would be encouraged and the true cost of goods would be reflected. However, examining the association between the size of the informal sector and the various indicators of sustainable development, Özgür et al. (2021) have found a negative association of the informal sector with most of the indicators of sustainability under their consideration. All these contrasting outcomes indicate a research gap in understanding the nexus between informal business and production performance and the tripartite dimensions of sustainability. Eventually, the impact of informal sector activities on a combined effect of these three dimensions of sustainability remains critical. To fill this gap, the present study aims to assess the impact of the informal sector activities on the overall sustainability of development by constructing and utilizing a composite index of sustainability which will be the first attempt so far on this topic.

3 | DATA AND METHOD

3.1 | Data

This study has employed an extensive panel data set spanning 2010–2019, strongly balanced and consisting of 50 developing countries. The countries are selected from the World Bank classification of countries (WDI, 2019). The availability of data guides the selection of the countries and study period. However, due to the unavailability of recent data set on the size of informal sector of countries (which is the main independent variable), this study has considered a proxy of the informal sector, taking insights from earlier literature. The selected proxy is working poor (WP) recommended by International Labour Organization (2011), which is also an SDG indicator 1.1.1. WP includes all workers who live under the nationally defined poverty line of the countries (US$1.90 PPP per day) and pursue the evidence that informally employed workers receive a lower wage than their formally employed counterparts (Bonnet et al., 2019; Chen, 2006; Nordling, 2017). The data are collected from https://ilostat.ilo.org/data/#. The details of the variables and the source of data for the construction of the sustainability indices (that are the dependent variables in this study) are presented in Table 1 below. Only a small number of missing data are linearly interpolated through E-views software.

3.1.1 | Sustainability indices

This study attempts to construct a symptomatic composite index by capturing three dimensions of sustainability: economy, society and environment to explore its link to informal sector. A critical step in constructing a sustainability index is identifying the sustainability indicators that measure performances under the three broad categories mentioned above. The secondary information sources, for example, relevant literature (see Özgür et al., 2021; UN, 2021), have been used to derive indicators under each index to reflect the concerns about sustainability while availability of data is considered a priority (Miller et al., 2013). Applying the principal component analysis (PCA), the indicators are summarized in a simple way to find a new set of meaningful measures for further analysis (Abeyasekera, 2006). PCA is a multivariate statistical technique that combines and modifies the data from interdependent categories in a way that a new set of mutually independent categories arises which is free from multicollinearity lied in the dataset. It facilitates reducing the number of variables in a data set into a smaller number of 'dimensions' without losing much information. The steps that are followed for computing individual Index using PCA are: a collection of data on selected variables, normalization of variables (since different explanatory variables are measured in different units), and running PCA in the software STATA (version 15) using the normalized values of different variables that produce principal components, that is, variables have significant variations, eigenvalues, and factor loading values (Mahida & Sendhil, 2017; Roger et al., 2008). PCA is suitable for converting the highly correlated data into uncorrelated indices (Roger et al., 2008). The three indices: economic index (EcoI), social index (SocI), and environmental index (EnvI) are constructed in this way and are used for the construction of a composite index of sustainability (CIS). The indicators considered under each index are presented in Table 1.

This study has followed the multivariate method to construct the composite index of sustainability. Equal weights have been assigned for each of the indices since it is critical to give equal attention to each of the three dimensions to achieve sustainability where weights should be $0 \le w_j \le 1$ and $\sum_{j=1}^{3} w_j = 1$ (Roger et al., 2008). Combining with the indices this allows the construction of scale free composite indicator for sustainability as follows:

$$CSI_{i,t} = \frac{1}{3}\left(\sum EcoI_{i,t} + \sum SocI_{i,t} + \sum EnvI_{i,t}\right). \quad (1)$$

3.1.2 | The control variables

Some relevant variables identified from the literature have been incorporated into the model. The GDP growth rate per capita, National expenditure to GDP and Economic freedom index of countries are used as the control variables in this study. Economic growth is represented by GDP growth per capita, national expenditure is represented by gross national expenditure as a percentage of GDP and both are extracted from WDI (2020). The Index of Economic Freedom (2021), which captures economic freedom, prosperity and opportunity by summing up 12 economic freedom indices, for example, property rights, government integrity, judicial effect, tax burden, financial health, business freedom, monetary freedom, trade freedom, government spending, labor freedom, financial freedom and investment freedom, is collected from https://www.heritage.org/index/explore?view=by-region-country-year&u=637509928185688064#top. It is expected that GDP growth rate per capita, National expenditure to GDP ratio and Economic freedom index of countries will demonstrate positive relation with the sustainability of development.

3.2 | Methodology

3.2.1 | Pre-estimation testing

The study follows some pre-estimation test procedures before applying the main estimation method. It tests for the time series and cross-sectional properties of the panel data set in first hand. Since the countries are from the same economic category they may have inter linkage in political, economic, social and technological issues that need to be detected a priori to select the econometric techniques. If cross-country dependence exists among the panel data set, the estimated parameters may provide inconsistent and inefficient results due to the misspecification of the model. Therefore, four different types of cross-sectional dependency tests have been applied: Breusch and Pagan (1980) BP Lagrange multiplier (LM) test, Pesaran (2004) scaled

TABLE 1 Description of dependent variables (dimensions of sustainable development) and details of the abridged variables used for their construction

Sustainable development dimensions	Definitions	Abridged variables	Introduction to variables	Source
Economic index of sustainability (EcoIS)	Economic sustainability index refers to the ability of the economy to sustain economic growth in the long run (Azunre et al., 2019)	GDP per capita	GDP per capita, PPP (constant 2017 international $)	WDI, 2020
		Trade to GDP ratio	Trade (% of GDP)	WDI, 2020
		Access to Electricity	Percentage to total population under accessibility to electricity	WDI, 2020
		Employment poverty	Employed by sex, age and economic class (less than USD 3.20ppp) per day (in thousands)	ILOSTAT, 2021
Social index of sustainability (SocIS)	Social sustainability index includes the factors that provide preventive capability of the social structure to create and sustain a healthy and socially sound community (Azunre et al., 2019)	Life-Expectancy at Birth	Life-Expectancy at Birth in total years	WDI, 2020
		Maternal Mortality rate	Maternal mortality ratio per 100,000 live births	WHO, 2020 https://www.who.int/data/gho/data/indicators/indicator-details/GHO/maternal-mortality-ratio-(per-100-000-live-births)
		Under 5 Mortality Rate	Mortality rate, under-5 per 1000 live births.	WDI, 2020
		Immunization DPT	Percentage of children immunized for DPT ages 12–23 months	WDI, 2020
		Immunization Measles	Percentage of children immunized for Measles ages 12–23 months	WDI, 2020
Environmental index of sustainability (EnvIS)	Environmental sustainability index includes the factors that need to be considered for the protection of environmental resources to guarantee long term gain (Azunre et al., 2019)	Carbon Dioxide emissions per capita	Average per capita CO_2 emissions, measured in tones per year	Our World in Data. GCDL University of Oxford. https://github.com/owid/co2-data
		Death due to Air Pollution	Share of deaths attributing to total air pollution both outdoor and indoor	Our World in Data. https://ourworldindata.org/air-pollution
		Nitrous Oxide Emissions per capita	Per capita methane emissions in tons of CO_2 equivalent	Our World in Data. GCDL University of Oxford. https://github.com/owid/co2-data
		Population weighted PM2.5 emissions	Ambient particulate matter pollution by average annual population weighted PM2.5 ($\mu g/m^3$)	State of Global Air 2020. https://www.stateofglobalair.org/data/#/air/plot
		Methane per capita	Per capita methane emissions in tons of CO_2 equivalent	Our World in Data. GCDL University of Oxford. https://github.com/owid/co2-data

LM test, Pesaran (2004) CD test, and Baltagi et al. (2012) biased-corrected scaled LM test to check the existence of cross-sectional dependence. Based on the results, the second generation unit-root tests: cross-sectionally augmented Dickey-Fuller (CADF) and cross-sectionally augmented I'm Pesaran-Shin (CIPS) panel unit root tests proposed by Pesaran (2007) have been applied. These tests address cross-sectional dependence in panel data set while verifying the stationary of the variables. Then the study uses the residual-based panel cointegration test suggested by Kao (1999) and Pesaran (1999) and the second-generation panel cointegration test suggested by Westerlund (2005) that takes care of cross-sectional dependence in the data series.

3.2.2 | Estimation method

Fixed effect (FE) and random effect (RE), the two classes of panel estimation approaches, are applied in this study for modeling the panel data. A choice between the two models depends on the investigation of whether the regressors are correlated with individual effects. The optimal model between the two is determined by the Hausman test (1979). This is a Chi-square-based estimate, and if the Chi-square statistic is significant, the FE model should be utilized, acknowledging its relevance over the RE model. The FE model can control all time-invariant differences between individuals and eliminates the bias sourced from the omitted variables that do not change over time. FE model also allows for possible endogeneity (Anton & Nucu, 2020; Aşici & Acar, 2015; Baltagi, 2005). Taking insight from the study by Elbahnasawy et al. (2016) and Anton and Nucu (2020) this study has designed the models as follows:

$$\mathrm{CIS}_{i,t} = \alpha + \delta \mathrm{Informal}_{i,t} + \gamma \mathrm{Economic\ growth}_{i,t} + \rho \mathrm{National\ expenditure}_{i,t} + \varphi \mathrm{Economic\ freedom}_{i,t} + \mu_{i,t} + \varepsilon_{i,t}, \quad (2)$$

$$\mathrm{EcoIS}_{i,t} = \alpha_1 + \delta_1 \mathrm{Informal}_{i,t} + \gamma_1 \mathrm{Economic\ growth}_{i,t} + \rho_1 \mathrm{National\ expenditure}_{i,t} + \varphi_1 \mathrm{Economic\ freedom}_{i,t} + \mu_{i,t} + \epsilon_{i,t}, \quad (3)$$

$$\mathrm{SocIS}_{i,t} = \alpha_2 + \delta_2 \mathrm{Informal}_{i,t} + \gamma_2 \mathrm{Economic\ growth}_{i,t} + \rho_2 \mathrm{National\ expenditure}_{i,t} + \varphi_2 \mathrm{Economic\ freedom}_{i,t} + \mu_{i,t} + \pi_{i,t}, \quad (4)$$

$$\mathrm{EnvIS}_{i,t} = \alpha_3 + \delta_3 \mathrm{Informal}_{i,t} + \gamma_3 \mathrm{Economic\ growth}_{i,t} + \rho_3 \mathrm{National\ expenditure}_{i,t} + \varphi_3 \mathrm{Economic\ freedom}_{i,t} + \mu_{i,t} + \tau_{i,t}, \quad (5)$$

where $\mathrm{CIS}_{i,t}$ indicates the composite index of sustainability for the countries, which is the weighted average of three indices, economic index ($\mathrm{EcoIS}_{i,t}$), Social index ($\mathrm{SocIS}_{i,t}$), and environmental index ($\mathrm{EnvIS}_{i,t}$). Each of these three indices has been calculated by applying the principal component analysis (PCA), and the variables selected as indicators are presented in Table 1. $\mathrm{Informal}_{i,t}$ denotes the informal sector and is represented by the proxy, working poor. $\mathrm{Economic\ growth}_{i,t}$, $\mathrm{National\ expenditure}_{i,t}$ and $\mathrm{Economic\ freedom}_{i,t}$ are the three controlled variables used in the model where $\mathrm{Economic\ growth}_{i,t}$ refers to GDP growth rate per capita, $\mathrm{National\ expenditure}_{i,t}$ refers to Net national expenditure and $\mathrm{Economic\ freedom}_{i,t}$ refers to the indices of economic freedom of the countries. $\mu_{i,t}$ is the unobservable time invariant country specific effect, $\varepsilon_{i,t}$ denotes the disturbances that vary with country i and time t for model-2 where as $\epsilon_{i,t}$, $\pi_{i,t}$ and $\tau_{i,t}$ denote the disturbances for rest of the models 3, 4, and 5, respectively. μs are assumed to be random and distributed independently of the errors. Equations (2)–(5) will be estimated via the fixed effect (FE) and random effect (RE) model and the optimum model selected by the Hausman test will be noted.

To find out the long-run cointegrating vector, this study has applied the fully modified ordinary least squares (FMOLS) and panel dynamic ordinary least square (DOLS) principles, following Rahman and Velayutham (2020), Rahman (2020), and Rahman et al. (2021), that are able to accommodate substantial heterogeneity across individual panel members. This cointegrated panel approach allows pooling the long run information confined in the panel by permitting short-run dynamics and fixed effects as being heterogeneous among different members of the panel (Pedroni, 2001). This method also adjusts least squares to account for the serial correlation effect and endogeneity in the regressors that result from the presence of the co-integrating relationship (Phillips, 1993). FMOLS model corrects for serial correlation and simultaneous bias while DOLS augments the panel cointegration equation with cross-section specific lags and leads to eliminate endogeneity and serial correlation among the variables. Lastly, the long-run adjustment of this model is checked with short-run variables in this study. The error correction model has been estimated by following the Engle-Granger two step procedure.

4 | RESULT AND DISCUSSIONS

Before presenting the main results of this study the summary of the complete data set that are used for index construction and regression is presented in Table 2.

This study has calculated the variance inflation factor (VIF) and tolerance for each variable to check the multicollinearity among the independent variables. Table 3 reports the results of test for multicollinearity which project that there are no multicollinearity issues among independent variables as the tolerance values are not less than 0.20 and the VIF values are not greater than 5 (Gujarati, 2009). This implies that all independent variables selected for the model are independent of each other.

The results for the cross-sectional dependence test are presented in Table 4. The results for all four tests provide evidence of the presence of cross-sectional dependence in the data series.

Based on the results of Table 4, this study has found it relevant to apply the second generation unit root tests. Hence it applies the

TABLE 2 Summary statistics of data set

Variables	Mean	Std. dev	Min	Max	Observation
Working poor	18.094	20.823	0.050	77.230	500
GDP growth rate per capita	2.359	3.525	6.556	18.066	500
GDP per capita	7077.334	5953.539	751.66	25.165	500
National expenditure	109.176	13.063	77.368	187.079	500
Trade to GDP ratio	65.363	31.292	0.200	210.400	500
Economic Freedom Index	56.271	7.843	21.400	70.00	500
Access to electricity	66.608	30.591	4.100	100.000	500
Employment poverty	6292.235	22727.461	1.381	174542.6	500
Life-expectancy at birth	67.359	7.620	47.312	80.279	500
Maternal mortality rate	295.649	412.624	12.000	7444.000	500
Under 5 mortality rate	49.397	33.296	7.000	207.000	500
Immunization DPT	84.894	12.899	23.000	99.000	500
Immunization measles	84.928	12.518	25.000	99.000	500
Carbon dioxide emissions per capita	1.472	1.834	0.034	9.117	500
Death due to air pollution	7.312	1.978	0.290	13.950	500
Nitrous oxide emissions per capita	0.649	1.074	0.060	7.760	500
Population weighted PM2.5 emissions	35.462	17.623	9.300	95.200	500
Composite index of sustainability	0.002	0.599	−2.206	1.842	500
Economic index of sustainability	0.006	0.949	−2.425	2.784	500
Social index of sustainability	0.005	0.973	−2.429	2.353	500
Environmental index of sustainability	−0.007	0.978	−3.843	2.736	500

TABLE 3 The results of the test for multicollinearity

Variable	Tolerance	VIF
Informal (working poor)	0.784	1.27
Economic growth	0.984	1.02
National expenditure	0.837	1.19
Economic freedom	0.907	1.10

CADF and CIPS unit root tests to check for the stationarity of the data. The results of the tests are projected in Table 5 and the findings reveal that all the variables are stationary either at their level or at their first differences or at both.

The results of the unit root tests lead to the check for cointegration among the variables in the models. This study has applied the Westerlund (2005) cointegration test and checked the null hypothesis of no cointegration against the alternative hypothesis of the existence of cointegrating relations among the variables considered in the model. The cointegration test result has rejected the null hypothesis. The Kao (1999) test and Pedroni (1999) test also provide support for the cointegration relationship among the variables in this model (Table 6).

Equations (2)–(5) are estimated via the FE and RE panel data models using the following dependent variables: Composite index of sustainability, economic index, social index and environmental index of sustainability respectively. All the results are presents in Table 7 along with the result of Hausman tests.

The Hausman test results select FE as the optimal model and acknowledge the relevance of FE over RE model for this study. Hence, the estimation results of the FE model are explained in details below.

The panel fixed effect regression results of Equation (2) indicate a significant negative impact of the informal sector on the overall sustainability of development. This indicates that a growth in the informal sector will delay achieving sustainable development in a significant manner. However, economic growth and improvement in economic freedom and opportunities of countries contribute to achieving sustainable development. The results of the panel fixed effect model for each individual indices (economic, social and environmental) provide the similar indication regarding the informal sector towards sustainability. The informal sector performs negatively to sustainability achievement in all three dimensions (mentioned in Equations (3)–(5)), which is significant for the economic and environmental sustainability indices. Economic growth and economic freedom are found to be positive and statistically significant for achieving social sustainability, while economic growth, national expenditure, and economic freedom all are found to be positive and statistically significant for achieving environmental sustainability.

To pool the long-run information contained in the panel by permitting the short-run dynamics, this study has also applied FMOLS and DOLS estimation on Equation (2). The results of the estimation of cointegrating vectors are presented in Table 8 that reveal the

TABLE 4 The results of cross-sectional dependence test

Variables	Breusch-pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Working poor	6001.391***	96.496***	93.718***	44.884***
GDP growth rate per capita	2153.299***	18.754***	15.976***	9.123***
GDP per capita	7840.886***	133.661***	130.883***	54.142***
National expenditure	3043.306***	36.735***	33.957***	3.741***
Economic Freedom Index	3071.389***	37.302***	34.524***	3.142***
Trade to GDP ratio	3883.836***	53.716***	50.938***	13.569***
Access to ELECTRICITY	7754.549***	131.916***	129.139***	84.353***
Employment poverty	6965.770***	115.981***	113.203***	−0.981
Life-expectancy at birth	12104.330***	219.795***	217.018***	110.015***
Under 5 mortality rate	11524.141***	208.072***	205.294***	99.361***
Maternal mortality rate	7812.748***	133.093***	130.315***	77.453***
Death due to air pollution	0.00	−2.493***	−1.671	−2.558***
Carbon dioxide emissions per capita	4711.944***	70.447***	67.669***	31.523***
Population weighted PM2.5 emissions	2829.554***	32.417***	29.639***	15.620***
Methane emissions per capita	3384.200***	43.622***	40.845***	7.352***
Nitrous oxide emissions per capita	2809.104***	32.004***	29.226***	9.932***

***Significance level: ≤.01.

TABLE 5 The results of unit root tests

	Pesaran/CADF—constant and trend		CIPS—constant and trend	
Variables	I (0)	I (1)	I (0)	I (1)
Working poor	−1.578	−2.361***	−1.673	−2.474***
GDP growth rate per capita	−2.175***	−2.283***	−2.541*	−2.874***
GDP per capita	−1.139	−2.447***	−1.211	−2.631***
National expenditure	−1.554	−3.093***	−2.113***	−3.454***
Economic Freedom Index	−1.430	−1.982**	−1.729	−2.560***
Trade to GDP ratio	−1.472	−2.792***	−1.454	−3.069***
Access to electricity	−2.333*	−2.462***	−2.957*	−3.900***
Employment poverty	−1.619	−2.799***	−1.897	−2.786***
Life-expectancy at birth	−0.983	−2.454***	−2.676***	−3.059***
Immunization DPT	−1.076	−1.865	−1.423	−2.22**
Immunization Measles	−1.605	−2.468***	−1.533	−2.469***
Under 5 mortality rate	−1.282	−1.999**	−1.483	−2.201**
Maternal mortality rate	2.757	−1.604**	—	—
Death due to air pollution	−1.381	−2.493***	−1.671	−2.558***
Carbon dioxide emissions per capita	−2.209*	−2.519***	−1.834	−2.134*
Population weighted PM2.5 emissions	−1.484	−2.892***	−1.538	−4.092***
Methane emissions per capita	−2.229***	−1.611	−2.666***	−3.102***
Nitrous oxide emissions per capita	−2.175***	−2.056**	−3.090***	−3.414***
EcoIS	−1.501	−2.223***	−1.538	−3.203
SocIS	−2.388***	−1.545	−3.720***	−1.187
EnvIS	−1.484	−1.829	−1.759	−2.954***
CIS	−1.935*	−2.172***	−2.344***	−2.818***

***Significance level: ≤.01;
**Significance level: ≤.05;
*Significance level: ≤.10.

common long-run relationship. These results are consistent with the outcomes of the Fixed-Effect (FE) model and project a significant negative relation between the informal sector and overall sustainability of development. The results of the control variables also project similar findings of the FE model. The findings are in line with the findings of Özgür et al. (2021) where several indicators of sustainable development projected negative associations with economic informality. The correlogram residual plots for both the models indicate that there is no pattern and therefore they have stationarity in nature.

The results of these empirical analyses provide insights into the fact that informal sector activities have to be scaled down to gain sustainable development in developing countries. Economic growth and improvement in economic freedom, prosperity, and opportunity of the countries can facilitate in the achievement of sustainable development in these countries. Finally, the Error Correction Model results presented in Table 9 confirm the earlier results. The negative and significant value of the error correction term (ECT) implies that the model has the potential to approach long-run stability.

TABLE 6 The results of the tests for co-integration

Co-integration test		
Westerlund		
Statistic	***t*-statistic**	***p*-value**
Variance ratio	2.849***	.002
Kao		
Statistic	***t*-statistic**	***p*-value**
Modified Dickey Fuller *t*	2.013**	.022
Pedroni		
Statistic	***t*-statistics**	***p*-value**
Modified Phillips-Perron *t*	8.943***	.000
Phillips-Perron *t*	−11.608***	.000
Augmented Dickey-Fuller *t*	−9.782	.000

***Significance level: ≤.01;
**Significance level: ≤.05.

5 | CONCLUSION AND POLICY SUGGESTIONS

Sustainable development has been put forward as a universal remedy to the three challenges of development applicable mostly for developing countries. The informal sector is relevant to sustainability issues since one of the SDGs promotes work and sustainable economic growth by supporting the policies of small businesses and labor-intensive sectors and by encouraging people to involve in sustainable production and consumption activities (UN, 2015). Getting motivated by this, the present study explored the impact of the informal activity on three dimensions of sustainable development: economy, environment, and social equity. Utilizing a global panel data set of

TABLE 7 The results of panel fixed effect and random effect regressions (Equations (2)–(5))

	(2) Composite index		(3) Economic index		(4) Social index		(5) Environmental index	
Variables/Models	**FE**	**RE**	**FE**	**RE**	**FE**	**RE**	**FE**	**RE**
Informal	−0.057*** (5.752)	−0.001 (0.001)	−0.118*** (0.016)	−0.002 (0.002)	−0.022 (0.016)	0.001 (0.002)	−0.032* (1.880)	−0.001 (0.002)
Economic growth	0.029*** (3.101)	0.016** (0.008)	−0.011 (0.015)	−0.007 (0.012)	0.054*** (0.016)	0.029** (0.012)	0.046*** (2.880)	0.028** (0.012)
National expenditure	0.003 (0.562)	0.002 (0.002)	−0.010 (0.008)	0.001 (0.003)	0.001 (0.008)	0.001 (0.004)	0.018** (2.080)	0.004 (0.003)
Economic freedom	0.031*** (3.532)	0.003 (0.004)	0.007 (0.134)	−0.0004 (0.006)	0.055*** (0.015)	0.008 (0.006)	0.029** (2.010)	0.003 (0.005)
Constant	−1.089 (0.807)	−0.448 (0.324)	2.879** (1.275)	0.044 (0.523)	−2.945** (1.356)	−0.661 (0.533)	−3.202** (1.369)	−0.724 90.536)
Hausman test	48.47 (0.00)	—	34.14 (0.00)	—	17.69 (0.00)	—	14.23 (0.01)	—
No of groups	500	—	500	—	500	—	500	—
Observations	50	—	50	—	50	—	50	—
Heteroscedasticity (Breusch-Pagan)	0.50 (0.48)	—	0.22 (1.00)	—	8.35 (1.00)	—	18.27 (1.00)	—
F-statistic	1.05 (0.39)	—	1.102 (0.29)	—	0.44 (0.99)	—	0.36 (0.99)	—

Note: Std. errors of the variables are in parenthesis. For test results probability values are presented in parenthesis.
***≤.01;
**≤.05;
*≤.10.

TABLE 8 The results of FMOLS and DOLS

	FMOLS		DOLS	
Variables	**Coefficient**	***t*-statistic**	**Coefficient**	***t*-statistic**
Informal	−0.057***	−3.759	−0057***	4.183
Economic growth	0.056***	4.374	0.029***	2.256
National expenditure	0.005	0.700	0.003	0.409
Economic freedom	0.041***	3.460	0.030***	2.565
R-squared	0.089		0.111	
Wald χ^2	40.426***		20.208***	

***Significance level: ≤.01.

TABLE 9 The result of error correction model

Variables	**Coefficient**	***t*-statistic**
ΔInformal	−0.028**	1.923
ΔEconomic growth	0.009*	1.886
ΔNational expenditure	−0.002	0.648
ΔEconomic freedom	0.008***	1.081
ECT_{t-1}	−0.131***	2.597
R-Squared	0.043	
S.E. of regression	0.369	
F-statistic	3.506***	
Durbin-Watson stat	1.669	

*≤.01;
**≤.05;
***≤.10.

50 developing countries that confront severe structural impediments to achieve sustainable development (UN, 2021), the study has constructed a synoptic composite index of sustainability (CIS), acknowledging that sustainability is a vast concept and is hard to capture in a single research. Applying the analysis of principal component (PCA) of the indicators considered under each aspect of sustainable development: economic, social, and environmental, the study constructs three individual indices, economic index of sustainability, social index of sustainability, and environmental index of sustainability. Then, a multivariate method of constructing the composite index has been followed to construct a composite index of sustainability where equal weights are assigned to each of the indices. This composite index is used to investigate the nexus of the informal sector to the sustainability of development of the selected developing countries. The nexus between the informal sector and each individual index has also been investigated in this study. The empirical results imply that informal economic activities impede achieving sustainable development. The results hold when the study controls for economic growth, national expenditure and economic freedom of countries.

Several empirical techniques have been employed to obtain the outcome of the informal sector- sustainable development nexus. Observing the presence of cross-sectional dependence, this study has employed second-generation unit root tests to check for data stationarity and then apply the Westerlund (2005) and the residual-based cointegration tests. The panel fixed effect (FE) model and random effect (RE) model are employed and the results of the estimated FE model are accepted due to its relevance over RE in this study as per the result of the Hausman test. The results of FE model project the empirical evidence of significant negative impact of the informal economic activities on the sustainability of development for the selected countries. Based on the cointegration test result, the long run information of the model has been extracted by applying FMOLS and DOLS. The results of the estimated cointegrated regression model validate the results of the FE model and finds those reliable for the long run in developing countries. Lastly, the ECM analysis results confirm the earlier outcomes and approve the gradual approach of these models towards the long-run equilibrium by projecting the negative sign and statistical significances of error correction term (ECT). The negative role of the informal sector on sustainability is a reminder of the need to address poverty, pollution, and economic deregulation issues indulged in the informal sector activities in developing countries. Therefore, the prescribed strategy is to reduce informality from business and other economic activities that limit the scope of the economies and to understand the domain through which interventions can be made to move towards a more formal economy.

The countries considered in this study are highly vulnerable to economic and environmental shocks and have low levels of human assets (UN, 2021). These are the basic reasons for subsistence employment and the spread of economic and business activities in informal arrangements in these countries. Other contributing factors are lack of efficiency and education of entrepreneurs, difficulties accessing credit, ineffective tax system, complex registration system. The spread of informality penalizes competition, promotes corruption and creates socio-economic and environmental issues. However, stringent measures to reduce the size of informal sector may lead to greater socio-economic fragility and can reverse by adverse economic shock since a large section of families and a significant portion of the economy depend on informal economic activities. Moreover, due to the linkage of the informal sector to the formal sector through subcontracting in the labor-intensive stages of production of the formal sector, the formal-informal relationship can be considered as complementary at a given level of government regulation, and attempts to expand or contract in one can influence the other in the same way (Arvin-Rad et al., 2010; La Porta & Shleifer, 2014). Therefore, strengthening the integration of informal economic activities into the

formal sector can be a good strategy to regulate the informal ones. Strategies for this can be widening the tax net, having respect to certain labor rules, cultural preparedness to produce for demanding markets where entrepreneurs will seek the benefit of pooling productive resources and associate with other producers for gaining access to the marketplace, practicing professionalism in production by maintaining timelines and quality. To facilitate the integration process enterprises in the informal sector should bring a cultural change by getting acquainted with ways and means of collective representation, such as joining to business and trade unions. The supply of educated entrepreneurs through proper training and expertise can also be a useful strategy to improve the scenario since educated entrepreneurs and managers can run the business proficiently.

An increase in economic growth of these countries can be an effective way to reduce informality and achieve sustainability. Due to economic growth and enhanced opportunity, demand will increase that inspires business and workers to move towards formal market-based operations. Fiscal and structural policies should be designed accordingly. A large-sized government that is consistent with enforcement effect and simplification of registration, and taxation policies can be encouraged as these can work negatively towards the growth of the informal sector. Ease of market entry cost, flexibility in entry requirements, and competitiveness in market mechanism can also be considered initial measures to attract firms towards formality. Countries should seek political solutions to the socio-economic and environmental adversities related to informality considering its dual nature. In all respects, economic policies should focus on strengthening the institutional quality of the countries to uphold overall economic freedom that will expedite a well-functioning economic system. Implementing corporate social responsibility (CSR) can be a good strategy to deduce into informal small business firms. The social dimension of sustainable development is represented by CSR and it can be viewed as an organization's contribution to sustainable development (Adeola et al., 2019; Bhagwat, 2011). Since CSR involves with diverse voluntary initiative apart from legal and contractual requirements that are absent in informal arrangements, its effective utilization can benefit workers and the local communities. Implementation of CSR will impose an obligation on informal businesses to pursue desirable policies that will add value to the society and will address adequately the changing relationship between business and society where informal activities are significantly visible. Availability of comprehensive information about CSR, orientation to CSR practices related to small and medium enterprises (SMEs), provision of training programs to educate on CSR themes (i.e., business ethics) can be helpful to promote CSR among informal firms and businesses.

Business in the informal sector has appeared to be a part of the economic development process in developing countries since the formal sector's crowding out of the informal sector is not unlikely. The informal sector bears a potential by opening economic opportunities through employment, social capital, a boost of local economies, supply of low-cost products. However, its negative contribution to technology and productivity, decent work condition and rights, employment protection, maintaining environmental quality, gaining fiscal revenue cannot be ignored. Sustainability policies are also often neglected by the business and firms operating under this sector. The findings of this study will put forward the demand for further investigation and assessment of informal sector business and economic activities to reassess the strategies of enterprises under this sector if sustainability of development is targeted to be achieved by the year 2030.

ACKNOWLEDGMENT

Open access publishing facilitated by University of Southern Queensland, as part of the Wiley - University of Southern Queensland agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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ENDNOTE

[1] Algeria, Argentina, Bangladesh, Benin, Bolivia, Brazil, Burundi, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chile, Colombia, Comoros, Congo, Costa Rica, Dominican Republic, Ecuador, El Salvador, Ethiopia, Gambia, Ghana, Guatemala, Guinea-Bissau, Haiti, Honduras, India, Indonesia, Kenya, Liberia, Mauritania, Morocco, Mozambique, Myanmar, Nigeria, Pakistan, Paraguay, Philippines, Rwanda, Senegal, Sri Lanka, South Africa, Thailand, Tunisia, Togo, Uganda, Uruguay, Vietnam, Zimbabwe, Zambia.

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How to cite this article: Sultana, N., Rahman, M. M., & Khanam, R. (2022). The effect of the informal sector on sustainable development: Evidence from developing countries. *Business Strategy & Development*, 1–15. https://doi.org/10.1002/bsd2.217

3.3 Links and Implications

In this chapter, the informal sector has been explored in its capacity to contribute to the sustainability of developing countries, employing a composite index, which is one of the most commonly used methods for evaluating sustainable development (see Zhang et al., 2022). As the informal sector is unobserved in nature, it is captured by using a proxy, namely working poverty, in the presented study and the study validates the informal sector as a concern for the developing countries in the long run. To avoid any debate about using proxy measures of the informal sector, this research finds it necessary to proceed with a detailed analysis of this topic under different components of sustainability. Given that the path to sustainable development is shaped by an unpredictable result of an evolutionary process (see Bossel, 1999), this research aims to investigate the underlying economic, institutional, socio-economic, environmental, and innovative factors that may contribute to the challenges and opportunities of the combined effect of the informal sector and urbanization on attaining sustainability. Subsequent chapters will focus on the evolution and contribution of the informal sector to various aspects of sustainability, starting with an evaluation of its impact on the economy.

CHAPTER 4: ECONOMY AND THE INFORMAL SECTOR

4.1 Introduction

The economic aspect of sustainable or green development aims to promote economic growth and development (Ali et al., 2021). However, economic growth in inappropriate production and business areas may lead to mass production of less efficient and polluting products, which goes against the principle of sustainable development (SD) (Ditlev-Simonsen, 2022, p. 75). Therefore, to achieve SD, it is crucial to focus on economic growth in appropriate sector. The percentile share of the informal sector in total output and total employment is commonly considered an indicator of development (Sinha & Kanbur, 2012). Therefore, this research has focused on these two essential economic aspects of the informal sector: the size of the informal sector (percentile share of GDP) and informal employment.

Understanding the differences among countries and their development policies assists individual countries in achieving sustainable growth and greater living standards, and remains a fundamental driving force behind the study of economic growth (Cumming & Von Cramon-Taubadel, 2018). Similarly, the nature of the informal sector also varies significantly among countries with different structures and levels of development (Gerxhani, 1999; OECD/ILO, 2019, p.46). Sometimes, greater informality is found to be associated with lower growth (Loayza, 1997), while recent analyses of panel data reveal a more complex and dynamic inverted-U relationship between the size of the informal sector and the growth of GDP per capita (Elgin & Birinci, 2016). Therefore, this research has been motivated to extend this analysis by investigating and comparing the increasing and

decreasing effects of informal sector contributions on economic growth at the country level. **Study 4**, presented in Section 4.2 of this chapter, focuses on this analysis in the context of Bangladesh. This study needs to estimate the relative share of output or income sourced from the informal economic activities to total output as this is not recorded or reported in national statistics. The indirect methods are more popular for this estimation in the studies and they use macroeconomic and policy indicators that are related to the development of the informal economy. This research has applied both monetary and model-based approaches, which are widely used in assessing the extent of activities of the informal sector (See Schneider & Enste, 2000; Duarte, 2017). Although the monetary approach has been previously applied in Bangladesh, the model-based approach is rarely applied in the available literature on this particular topic in Bangladesh. Therefore, this method has been applied in **Study 4** to measure the relative size or contribution of the informal sector to total GDP in Bangladesh. The Currency Demand Approach, which is a monetary approach for calculating the relative share of the informal sector, is also applied and presented in the **Appendix A**. Both approaches reveal the internal dynamics of the economy and project the direction of the informal sector over the years, which is found to be parallel to the real GDP growth trend of the country.

The role of informal employment in boosting the economy in general and offering opportunities to reduce poverty and inequality in most developing regions (Chen, 2016) has also been explored in this connection. This is relevant because informal employment is often undervalued or ignored due to the challenges it poses to mainstream assumptions about traditional work (Tucker & Anantharaman, 2020). Therefore, its impact on economic growth of developing countries (including Bangladesh) has been investigated from the perspective of sustainable development, which is presented in **Study 5** under Section 4.3.

4.2 Study4

Asymmetric role of the informal sector on economic growth: Empirical investigation on a developing country.

Abstract: The role of the informal sector in economic growth still remains an issue of debate. This study contributes to resolving this by taking into account the asymmetric effect of the informal sector on economic growth. The study applies the Non-linear Autoregressive Distributed Lag (N-ARDL) model to capture the asymmetric relationship between the informal sector activity and economic growth for the period 1982-2018 in Bangladesh. The estimation of the N-ARDL model reveals that the informal sector asymmetrically affects the domestic output and economic growth in Bangladesh for both the short-run and the long run. The study has observed an asymmetrically larger effect on output and economic growth from the falling contribution of the informal sector. Urbanization and capital growth also contribute to an increase in economic growth. Therefore, proper incentives and careful policy measures are suggested to reduce the size of informality by allowing its transition to a more formalized structure.

Key words: Informal sector, Economic growth, Structural Equation Model, Non-linear Autoregressive Distributed Lag, Bangladesh

JEL Classifications: O11, O47, E02, E26, P25, C22

1. Introduction

The informal economy is a pervasive phenomenon and has become a decisive issue in the economic and social development policies of countries (Elbahnasawy, 2021, Estevao et al., 2022; Briassoulis, 1999; Afonso et al., 2020; Benkraim et al., 2019; ILO, 2018; Medina and Schneider, 2018; Charlot et al., 2015; Godfrey, 2011; Straub, 2005). In low-income and developing countries, the informal sector has been recognized as a source of employment and survival (Chen, 2016; IMF, 2020; Amponsah et al., 2021). This unofficial sector accounts for almost one-third of Gross Domestic Product (GDP) in developing and emerging economies (Elgin et al., 2021). However, its contribution to the national accounting of countries is poorly measured or remains unaccounted (Benkraim et al.,

2019, Hassan and Schneider, 2016; Ghose, 2017; Restrepo-Echavarria, 2014). Moreover, a number of economic, social, and environmental challenges are upraised by the expansion of this sector that also remain unevaluated (Smit, and Musango, 2015, La Porta and Shleifer, 2014). Therefore, the overall contribution of the informal sector to the economy of developing countries remains an issue of debate (Loayaza and Rigolini, 2014; Yelwa et al., 2015) that necessitates a critical investigation on this topic.

The informal economy includes all the economic activities that remain hidden from the monitoring authority for financial, regulatory, and institutional reasons. Financial reasons comprise avoidance of tax payments and social security contributions, regulatory reasons comprise avoidance of regulatory burden due to governmental bureaucracy, and institutional reasons embrace corruption, weak political institutions, and weakness in the rule of law (Medina and Schneider, 2019, Hassan and Schneider, 2016). The informal sector is viewed as a static and less productive sector that serves as a refuge for rural migrants and urban unemployed on their way to formal jobs (Harris and Todaro, 1970, Ghose, 2017, Gutierrez et al. 2019). It pays less wage to the workers and put in question the rule of law and integrity of public institutions throughout their existence (Charlot et al., 2015; Ghose, 2017). The dominance of the informal sector hits the foundation of public policy, distorts investment, promotes inefficient use of resources, encourage small scale production and adoption of low-return technology (Maiti and Bhattacharyya, 2020, Elbahnasawy et al., 2016). However, policies for reducing the scope of informality may have some undesirable effects on poverty and income distribution since there is a trade-off between informality and unemployment (Charlot et al., 2015; Amponsah et al., 2021). Studies on the informal sector mostly focus on public finance (i.e., tax burden) and/or public administration aspects (i.e. intensity of regulations and bureaucratic

procedure) that drives agents' decision in favor of informal (Elbahnasawy et al., 2016). A few empirical literatures comprehend the informal sector as a proficient, dynamic, significant contributor to national output and capable of absorbing and supporting labor in its own rights (Huang et al., 2020, Bhattacharya, 2011; Chen, 2016). Under such a backdrop, it is logical to take into account all the aspects of the informal sector (both the positive and negative) in an evaluation of its impact on the economy while developing policy measures.

The connection between the informal economy and economic growth is complex. The mechanism through which the two variables interact seems to differ from country to country with dimensions of the informal economy (Afonso et al., 2020). Workers and economic units in the informal economy present a broad diversity of characteristics and needs. It varies widely in terms of income and employment status, type and size of the enterprise, level of productivity, location of the workplace, degree of coverage of social, health and work protection, degree of compliance with laws and regulations (ILO, 2018). The diversity and unaccounted nature of the informal sector affect the behavior of the business cycle in a country (Restrepo-Echavarria, 2014). The existence of a large informal sector also creates volatility in consumption which is found to be greater than output and the relative volatility in consumption to output changes when the magnitude of the informal economy increases. The informal sector is also responsible for creating precarious work condition which is incompatible with decent work and right (Estevão et al., 2022). Because of these, the informal sector is considered to be an important challenge to sustainable development in the 21st century (Huang et al., 2020; Estevão et al., 2022) although informality is a key determinant of inclusive growth which is an agenda of SDG (Amponesh et al. 2021). The present study attempts to play a role in addressing these challenges and satisfying the SDG agenda (SDG 8, target 8.3) by examining the increasing

and decreasing effect of the informal sector on the economy. Bangladesh has been considered for this investigation since informal activities are largely visible in this country which is economically categorized as a newly emerging country.

In Bangladesh, the demographic and geographic context, economic policies, and their consequences allowed economic growth, but it was unaccompanied by formal employment growth (See ILO, 2013). Experts have considered this 'jobless growth' as a reason to divert the economy to the low-productive service sector. The informal sector growth in Bangladesh can be defined by the supply side, demand side, and institutional factors. Massive population with high growth rate and migration of labor from rural agriculture to urban business, manufacturing and service sector contribute to supply side, increased labor demand in urban industrial economy for expansion of private sector business, subcontracting and urban basic services for households contribute to demand side, and absence of appropriate public policy with inadequate regulatory framework acts as institutional factors behind the growth of the informal sector in Bangladesh (ILO report, 2013). At present, 35 to 88 percent of the total labor force is employed in the informal sector and around 49 to 64 percent of total GDP comes from informal sector activities in Bangladesh (Yeasin, 2021). Two-thirds of the total informal contribution to GDP comes from the informal manufacturing sector in Bangladesh (Sarker et al., 2016).

However, the growth of the informal sector in Bangladesh and other developing countries has made policymakers concerned for several reasons. First, this puts restrictions on the government's ability to provide support for public goods and infrastructure due to its tax-avoiding nature. Second, this enforces inefficient allocation of resources by promoting different marginal costs between informal

and formal firms competing in the same industry. Third, informal firms extract a cost advantage over law-abiding formal firms. Fourth, they cannot obtain legal credit from formal financial sources. All these factors put a hindrance to the growth of formal-sector firms and limit the potential for economic growth (Rothenberg et al., 2016). In an opposed idea, the presence of the informal sector has been identified as a cause of improved competitiveness and effectiveness in the formal sector which is contributory to a faster pace of economic development (Nguyen and Luong, 2020) and therefore, the functioning of the informal sector is suggested through institutions, policies, and government expenditure in a way to facilitate inclusiveness, poverty reduction, and economic growth (Nguyen and Luong, 2020; Amponsah et al., 2021). The present study expects to contribute to resolving this debate and aims to find the path of the informal sector towards economic growth in Bangladesh.

The present study will contribute to the literature in the following ways: First, due to the unavailability of data on the informal sector which is an unobserved sector of the economy, this study has constructed a time series on the informal sectors contribution to GDP by applying the Multiple Indicator and Multiple Causes (MIMIC) Model and data calibration technique. Second, this is the first in-depth empirical analysis of the effect of the informal sector on economic growth employing a model that comprises the dominating players of growth, namely, capital and labor;

Third, it proposes an econometric model that allows for the contemplation of both symmetry and asymmetry in the cointegrating relationship between the informal sector and economic growth and explores the impact (both symmetric and asymmetric) of the informal sector on the economic prospects; Fourth, the study focus on urbanization in terms of population in this relation since informal sector activities are most visible in urban areas and the growth of the informal sector is

linked to the growth of the urban labor market (Lyons and Snoxell, 2005; Bhattacharya, 2011; BBS, 2018). Moreover, urbanization facilitates economic activity that leads to economies of scale in the production of goods and services (Shahbaz, et al., 2016; Zhang, 2019) contributing to growth prospects.

The remaining of the paper is organized as follows. Section 2 provides insights on theoretical aspects of the informal sector and its integration to the economy with some empirical evidence in a brief literature review, section 3 describes data, theory and methodological aspects of this study. Empirical outcomes will be presented and discussed in section 4 and section 5 considers the policy implications with concludes remarks.

2. Literature Review

2.1 Theoretical Background of informal sector: debates and integration

The potential of the informal sector as a contributor to economic growth and independent employment is emphasized by neo-liberal theories of informality that find it a result of excessive state regulations (Neves and Du Toit, 2012; Huang, 2020). However, the basic assumptions of marginalists have underpinned neo-liberal theories by characterizing it as a feature of peripheral economies and a transitory phase of economic development that will disappear with development and modernization. It has also been stated by this view that the informal sector deals with a subsistence level of activities and income and lacks the potential for independent growth (Meaghar, 1995; Debrah, 2007). Putting it differently, advocates of structuralist perception consider the informal sector as a pool of local entrepreneurial energy with the potential to generate employment and growth. They argue that the economic dynamism of the informal sector becomes profusely clear during periods of recession or extreme regulation and structural adjustment. In such contexts, the

entrepreneurial capability of the informal sector acts as a valuable economic endeavor – a vibrant source of employment and income and a power wheel of economic growth rather than a marginal activity (ILO, 2002; Rakowski, 1994; WB, 1989; Debrah,2007). However, the critics of the structuralist view find a lack of entrepreneurial enthusiasm in the informal sector. Critics also argue that workers in this sector are unprotected, involved in survival activities and are often exploited by the formal sector due to the complicity of the state (Birbeck, 1979; Lomnitz, 1982). In such a context, the formal sector business benefits from the informal sector and prevents informal firms from being registered and growing large to avoid competition in fear of a reduction in their profit and share (Djankov et al., 2002). These arguments can be linked to the exclusion model of informality that provides reasons for operating firms in the informal sector (De Soto, 1989; 2000). Along with the exclusion model, another classical theoretical approach, the rational exit model also explains why firms remain informal. It theorizes that firms exit the formal sector when they find it profitable to stay in informality by enjoying cheaper labor wages, tax benefits, and other cost-related advantages from non-compliance with regulations (Rothenberg *et al.*, 2016).

The third possibility is explained by the dual economy model where formal and informal sectors are considered separate. The existence of the informal sector is explained in this model as the result of an oversupply of labor due to the inability of the state to provide adequate employment opportunities in the formal sector, low demand for semi-skilled or unskilled workers, and poverty. Proponents of this model consider informal firms as typically unproductive that are initiated by inefficient and poorly educated entrepreneurs. They produce products with different inputs and technology and serve different customers who usually operate in the low-wage informal sector. They presume economic growth, increased income, and poverty reduction will boost demand for formal sector

products and diminish informal firms without any need for policies that explicitly tax or punish informal firms (Rothenberg, 2016). Consequently, endorsing macroeconomic policies targeting to expand employment and incomes in the modern sector can increase real economic growth and significantly reduce dependence on the informal sector (Rakowski, 1994; Debrah, 2007). Neo-liberals and Legalists, who view the existence and persistence of informal economy as a rational response to excessive regulation by government bureaucracies, have suggested institutions and incentives and removing relevant barriers towards formality as a way out of the informal economy (Godfrey, 2011)

2.2. Review of empirical literature on informal sector and economic growth

The contribution of the informal sector to economic growth is investigated in a number of empirical works. Using a novel data set of 161 countries, Elgin and Birinci (2016) revealed that small and large informal economies were associated with little growth while the medium-size level of informal economies was associated with high growth levels. Highlighting the role of institutions Elgin and Oztunali (2014) showed that in the presence of a lower level of institutions a higher level of GDP per capita is associated with a larger informal sector, while the opposite is true in countries with good institutions. In Sub-Saharan African countries, Amponsah et al. (2021) investigated the measures of inclusive growth and revealed the role of government in promoting inclusive growth based on gender and rural-urban division by implementing an effective regulatory framework and removing bureaucratic procedures within the informal sector. This study suggests ensuring the proper utilization of government expenditure for encouraging inclusiveness and reducing poverty, which helps improve the functioning of the informal sector. Economic policies and corruption control are also highlighted by Nguyen and Loung (2020) for Asian emerging, and developing

countries while they find a positive effect of a reduction in the size of the informal economy on economic growth. Developing a theoretical framework, Maiti and Bhattachrya (2020) revealed a positive association between taxation and enforcement. They found the role of a relatively lower level of enforcement to allow the informal sector to survive and to ease the distortionary effect of formal sector production from high taxes that ultimately contributed to growth. If the enforcement level was raised, the state would raise taxes and subsidies for the informal sector to ensure redistribution that limited growth. However, at an extremely low level of enforcement, the formal sector would also be affected that lowered economic growth.

Causal association was not found between the informal sector and GDP by Duarte (2017), and hence the informal sector appeared as an independent arena for economic exchange in Spain. Contrasting the result, Khuong et al. (2021) have revealed a bidirectional relationship between the informal sector and economic growth, while the informal sector is found to contribute to more than half of GDP in Pakistan. In Nigeria, the study of Yelwa and Adam (2017) resulted in a significant positive impact of the informal economy on nominal GDP growth. In another study by Yelwa et al. (2015), the informal economy was identified as a critical prerequisite for achieving sustainable economic growth if it was regulated and functioned properly. However, since there existed a lack of understanding of the link between informality, growth and inclusiveness, extensive informality was accepted as an obstruction to long-run economic development and poverty alleviation. Bhattacharya (2011) empirically showed that the expansion of the informal sector and migration of manual labor to the informal sector played an important role in inequality reduction. Policies designed to strengthen the subcontracting relationship between the formal and informal sectors were suggested as policies effective in this context. This study also praised the informal sector for producing

efficiently many goods and services, opportunity to enjoy a symbiotic relationship with the formal sector and contributing significantly to the national economy.

From the above review of literature, it is viewed that still there prevails a theoretical and empirical debate on the role of the informal sector. Among varying theoretical standpoints on the informal sector empirical works also project a combination of results in the informal sector-economic growth nexus. However, the asymmetric impact of the informal sector on economic growth, considering its uncertain nature, is not yet investigated in any empirical study. This study attempts to fill this gap by initiating a nonlinear analysis of the informal sector in Bangladesh.

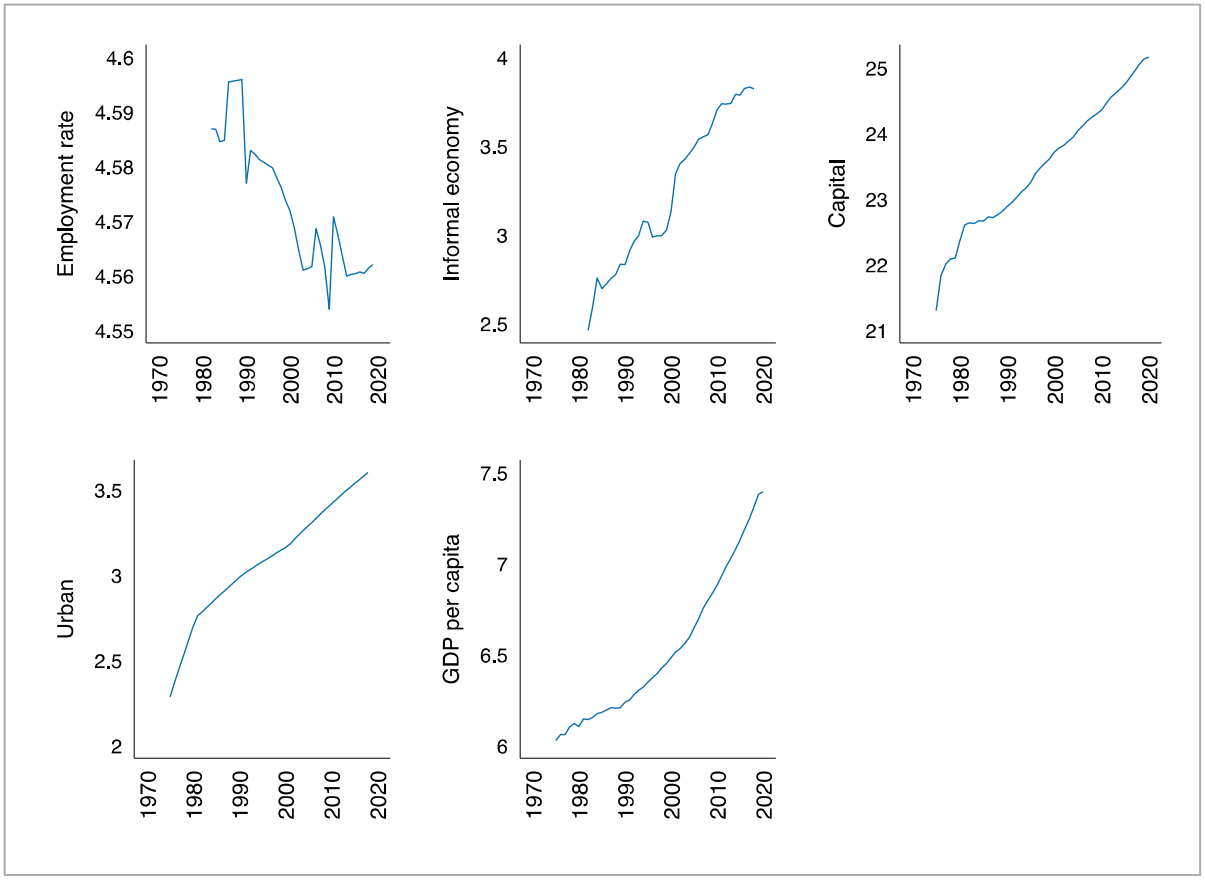

Figure 1: The graphical presentation of the variables considered in the model.

3. Theoretical framework, Data and Methodology

3.1 Theoretical framework

In this section, the study provides an intuitive econometric framework that channelizes the effect of structural changes in the economy. Utilizing the neo-classical framework that postulates macroeconomic growth as an attributor to external and internal factors and is influenced by government policies, it basically records two factors-capital and labor as the main inputs in production function and the long-run economic growth. Taking insights from Mamun et al. (2020), Yelwa and Adam (2017), the model can be specified as follows:

$$Y_t = f(K_t, L_t, A_t) = K_t^{\alpha_1} L_t^{\alpha_2} A_t^{\alpha_3}, \quad \alpha_1, \alpha_2 > 0, \alpha_3 \gtreqless 0 \ldots\ldots(1)$$

Where, Y_t is per-capita output, A_t is the proportion of changes of output explained by factors other than capital and labor. K_t is the capital measured as gross capital formation in percentage of GDP and L_t is labor represented as a percentage of the total employed population. In considering the assumptions broadly, the informal sector and urbanization are included in the model as contributing factors to growth that are likely to bring a structural change in the economy by influencing productivity and economic output. The study assumes the effect as multiplicative and can be written in a logarithmic form as follows:

$$lnY_t = \alpha_0 + \alpha_1 lnK_t + \alpha_2 lnL_t + \alpha_3 lnIS_t + \alpha_4 lnU_t + \vartheta_t \ldots\ldots(2)$$

Where, $\alpha_0 = \ln(A_0)$, IS implies informal economy as a percentage of total GDP and U implies urbanization represented as a percentage of the population living in urban areas. Since the informal sector is unobserved or unrecorded, secondary data is not available. Following Wang et al. (2019), Restrepo-Echavarria (2014), Kpognon (2021) this study has constructed a time series of informal sector contribution as a percentage of GDP applying the Dynamic Multiple Indicator Multiple Causes (MIMIC) model where the informal sector is considered as a latent or unobserved variable. After calibration, the data is used for empirical investigation. A number of empirical studies has

intensively used MIMIC model to predict the size of the shadow economy (Wang et al., 2019; Schneider et al., 2010; Dell'Anno and Schneider, 2006 to name a few). In a meta-analysis of the literature estimating the impact of the informal economy on economic growth, the effect of the MIMIC model developed by Joreskog and Goldberger (1975) is found to be more prominent than the other methods (Afonso et al., 2020). The details of the data generation process are presented in the following sub-sections.

3.2 Data

This study uses annual data for the period 1982-2018 for Bangladesh since data on a few selected variables before and after this period is unavailable. The data for GDP per capita, gross capital formation, urbanization are collected from World Development Indicators (WDI, 2020). Unemployment data used for calculating the employment data are collected from yearly publications of Bangladesh Economic Review (1982-2019). Since informal sector contribution is not recorded officially, the time-series data for the informal sector is generated by applying the MIMIC model. For estimating the MIMIC model, data are collected from various sources. Data for real GDP growth rate and nominal GDP are collected from yearly publications of Bangladesh Economic Review (1982-2019) and WDI (2020). Money supply and tax collection data are collected from the publications of Bangladesh Economic Survey and Bangladesh Economic Review, data for real interest rate and inflation rate from the WDI (2020) and the data of electricity consumption per capita is collected from WDI (2020) and International Energy Agency (IEA, 2019).

3.3 Methodology

The MIMIC model

The multiple indicators and multiple causes (MIMIC) model is a special kind of Structural Equation Modelling (SEM). It is used to measure the latent or unobserved variable, which is the size of the informal sector in this study. It combines two observable parts 'causes' and 'indicators'. The causal relationships with the unobserved variable are identified by structural equations and association between the unobserved variables and observed indicators is expressed by measurement equation. The data on causes and indicator variables are used to find the index values.

The error correction-based Autoregressive Distribution Lag Model (ARDL) has been applied as an additional measure to check the long-term cointegrating relationship between causes and indicators of the informal sector. Having confirmed the long-run association between causes and indicators, the SEM technique has been applied and the unknown coefficients are estimated that are used to find an index of the unobserved or latent variable (Breusch, 2005; Schneider and Enste, 2000). The latent variables are interpreted as 'index' due to the presence of a degree of indeterminacy in scale (Bruesch, 2005; Schneider and Enste, 2000).

The MIMIC model considers five causes as responsible for the growth of informal sector. Those are: currency in circulation as a proportion of broad money (Curr_M_2), tax/GDP ratio (Tax_GDP), financial development measured as M_2/GDP ratio (M_2_GDP), real interest rate (IntR) and inflation rate (InfR). This model also considers two indicator variables: real GDP growth rate (RGDPgr) and per capita electricity consumption (Elec). The details of the model are presented in Figure 2. Following (Arby et al., 2010), the structural equations of the model can be written as follows;

$$\eta = \acute{\phi} X + \varepsilon \quad \text{(3)}$$

Here, η denotes the latent variable, $\acute{\phi}$denotes the matrix of cause variables, X is a vector of parameters and ε is the error term with zero mean and unit variance. The measurement equation can be written as follows:

$Y = \lambda\eta + \vartheta$…….. ……(4)

Where, Y is the vector of indicators, λ is the vector for scalars and ϑ is the vector of stochastic error terms that corresponds to the equations for each indicator. Now solving the two models the reduced form of MIMIC model is obtained as follows

$Y = \lambda[\acute{\phi}X + \varepsilon] + \vartheta$…….(5)

Estimation of the model requires normalization of any of the two indicators to quantify the effect of other variables. Here, the coefficient of the real GDP growth rate is normalized to 1. The MIMIC model projects the relative estimates of the size of the informal economy. The structural equation modeling software AMOS 23 is used to find the parameters. The variables are used in their standardized deviations from their mean following Schneider et al. (2010). The obtained ordinal estimates of the latent variable, the index needs to be calibrated with exogenous estimates. For this, the required benchmarking or calibration technique follows Schneider et al.'s (2010) procedure. Year 2010 is selected as the base value and extracted from the database reported in Medina and Schneider (2019). The size of the informal economy $\widehat{n_t}$ is then calculated following the technique below:

$$\widehat{n_t} = \frac{\widetilde{n_t}}{\widetilde{n_{2010}}}\dot{\eta}_{2010}$$

Where, $\widetilde{n_t}$ denoted the value of MIMIC index at t, $\widetilde{n_{2010}}$ denotes the value of the index at base year and $\dot{\eta}_{2010}$ indicates the exogenous estimates (base value) of the informal economy in the year 2010.

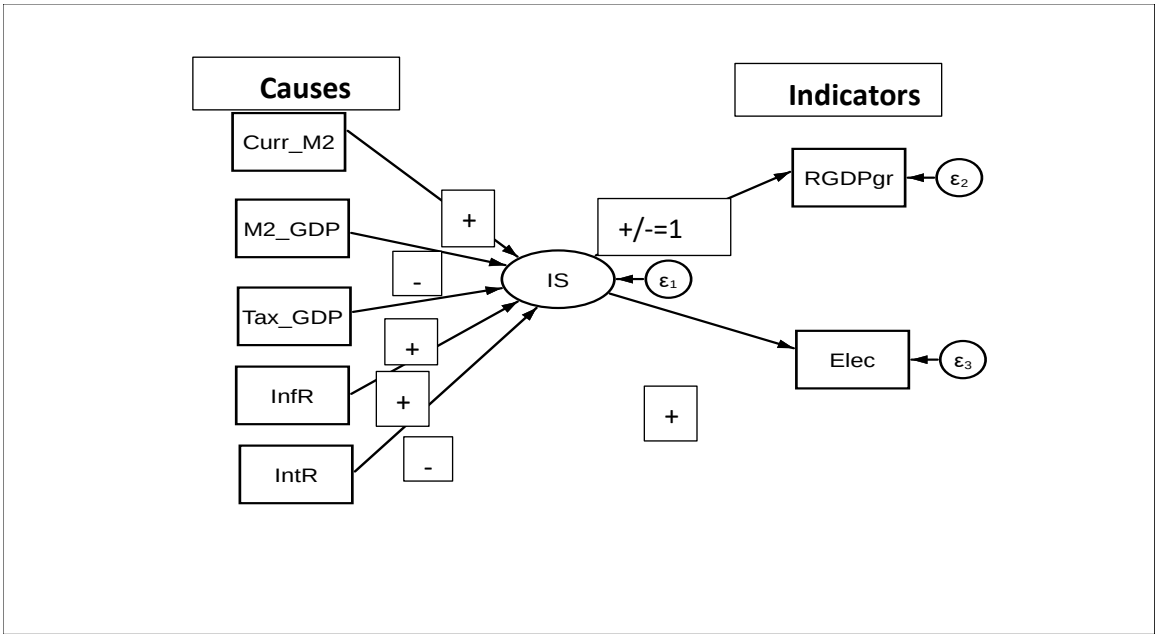

Fig-2: The estimated MIMIC model

Pre-estimation econometric analysis

The study has started the analysis with some pre-tests. First, it applies the unit root tests to determine the order of integration of the variables used for MIMIC model estimation. Detection of the order of integration of variables is important to check the applicability of the autoregressive distributive lag (ARDL) model. The ARDL bounds testing approach explores the short-run dynamics and the long-run relationship among the variables. The main advantage of Pesaran 2001 ARDL model is that this time series cointegration test can be estimated even at a small sample size (Shin et al., 2014, p.290). If the dependent variable is $I(1)$ and the independent variables are either $I(0)$ or $I(1)$, the ARDL model can be estimated (Pesaran, 2001). The details of the unit root test of the variables used in MIMIC model are presented in the Appendix 1.

In the next stage, this study has employed both linear and nonlinear unit root tests, namely, Phillips Perron (1988) unit root test and Kapetanios, Shin & Snell (2003) ESTAR nonlinear unit root test[1] for the variables used in linear and non-linear ARDL models. Once the order of integration of the variables is confirmed, the study has proceeded to estimate the long-run relation among the variables. By the ARDL and N-ARDL estimation method, the long run can be estimated only in the presence of cointegration that can be checked by the F distribution in bounds test. This study has also checked for long-run and short-run asymmetric effects using the standard Wald test where the null hypothesis $H_0: \delta_4^+ = \delta_5^-$ is tested against the alternative $H_1: \delta_4^+ \neq \delta_5^-$. The short-run additive summary is also tested with the null hypothesis $H_0: \sum_{i=0}^{q} \rho_{4i}^+ = \sum_{i=0}^{l} \rho_{5i}^-$ against the alternative $H_1: \sum_{i=0}^{q} \rho_{4i}^+ \neq \sum_{i=0}^{l} \rho_{5i}^-$.

The baseline model of investigation: bounds testing approach

This study is interested to investigate the short run and long run impact of informal sector on economic growth. The conventional way of doing this is to re-written equation (2) as an error correction model (ECM) and apply the ARDL model of Pesaran et al. (2001) that can estimate both

[1] [1] The study proposed a GLS based nonlinear unit root test proposed by Kapetanios and Shin (2008). In this tests the presence of nonstationarity is checked against the alternative hypothesis of a globally stationary exponential smooth transition autoregressive (henceforth, ESTAR) process was, which referred to $\sim \omega$ j and were obtained by the Wald tests for $\phi 1 = \phi 2 = 0$ using the following regression:

$$\Delta\tilde{y}_t^j = \varphi_1 \tilde{y}_{t-1}^j 1_{\{\tilde{y}_{t-1}^j \leq r_1\}} + \varphi_2 \tilde{y}_{t-1}^j 1_{\{\tilde{y}_{t-1}^j > r_1\}} + \sum_{i=1}^{k} \partial_1 \Delta\tilde{y}_{t-1}^j + \emptyset_t$$

where, j = μ for demeaned series and, j = τ for detrended series. r_1 and r_2 are the threshold parameters. Like ERS, the lags of $\Delta\tilde{y}_t^j$ are measured to deal with serially correlated residuals.

the short run and long run effect. Following Pesaran et al. (2001) eq. (2) can be expressed as an ECM as follows:

$$\Delta lnY_t = \alpha_0 + \alpha_1 lnY_{t-1} + \alpha_2 lnK_{t-1} + \alpha_3 lnL_{t-1} + \alpha_4 lnIS_{t-1} + \alpha_5 lnU_{t-1} + \sum_{i=1}^{p} \beta_{1i} \Delta lnY_{t-i} +$$

$$\sum_{i=1}^{n} \beta_{2i} \Delta lnK_{t-i} + \sum_{i=1}^{s} \beta_{3i} \Delta lnL_{t-i} + \sum_{i=1}^{q} \beta_{4i} \Delta lnIS_{t-i} + + \sum_{i=1}^{m} \beta_{5i} \Delta lnU_{t-i} + \vartheta_t \ldots \ldots \ldots (6)$$

The short run impacts are specified by the estimates of the coefficients $\beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i}, \beta_{5i}$ and the long run effects are specified by the estimates of the coefficients $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$. In order to investigate cointegration, the null hypothesis ($H_0: \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$) is tested using F-statistic of Pesaran et al. (2001). This bound testing approach accounts for the integration of the order of the variables, irrespective of whether they are I(0) or I(1) or both. The null hypothesis of no-cointegration is rejected for the higher values of the calculated F-statistic than the upper critical value.

The N-ARDL bound testing approach of cointegration

According to the linear ARDL model, output responds symmetrically due to a change in independent variables. However, given the earlier discussion about uncertainty and asymmetries in the main independent variable (i.e., the informal activities), this study utilizes the multivariate Nonlinear ARDL (N-ARDL) bound testing approach of Shin et al. (2014) to capture both the nonlinear and asymmetric cointegration between the variables. Observing the Wald test result, the study finds that asymmetries matter and hence, has proceeded to develop the asymmetric model that possesses the strength of linear ARDL with its ability to incorporate both the short-run and long-run estimates simultaneously. It captures the series of mixed order of integration, corrects for possible endogeneity and provides the long run equilibrating estimate (error correction term) representing the rate at which

variables approach together in the long run after being disrupted by shocks in the short run. These merits are added to N-ARDL by decomposing the main independent variable into positive and negative changes under the consideration of the fact that economic agents may respond differently to those changes. Accounting for asymmetries in the relationship between the informal sector and economic growth, model (2) can be re-specified as follows:

$lnY_t = \delta_0 + \delta_1 lnK_t + \delta_2 lnL_t + \delta_3 lnIS^{+}{}_t + \delta_4 lnIS^{-}{}_t + \delta_5 lnU_t + \vartheta_t$……………………….(7)

Here, δ_i are the vector of coefficients. Including the positive changes $lnIS^{+}{}_t$ and negative changes $lnIS^{-}{}_t$, the asymmetric impact of informal sector are accounted for, where $lnIS^{+}{}_t$ and $lnIS^{-}{}_t$ are the partial sums of the positive and negative changes respectively.

$$lnIS_t^{+} = \sum_{i=1}^{t} \Delta lnIS_i^{+} = \sum_{i=1}^{t} \max(lnIS_i, 0)$$

$$lnIS_t^{-} = \sum_{i=1}^{t} \Delta lnIS_i^{-} = \sum_{i=1}^{t} \min(lnIS_i, 0)$$

Eq. (7) can be written in an unrestricted error correction form which is proposed by Shin et al. (2014) as follows:

$\Delta lnY_t = \delta_0 + \delta_1 lnY_{t-1} + \delta_2 lnK_{t-1} + \delta_3 lnL_{t-1} + \delta_{4i}^{+} lnIS^{+}{}_{t-1} + \delta_{5i}^{-} lnIS^{-}{}_{t-1} + \delta_6 lnU_{t-1} +$
$\sum_{i=1}^{p} \rho_{1i}\, \Delta lnY_{t-i} + \sum_{i=1}^{n} \rho_{2i}\, \Delta lnK_{t-i} + \sum_{i=1}^{s} \rho_{3i}\, \Delta lnL_{t-i} + \sum_{i=1}^{q} \rho_{4i}^{+}\, \Delta lnIS_{t-i}^{+} + \sum_{i=1}^{l} \rho_{5i}^{-}\, \Delta lnIS_{t-i}^{-} +$
$\sum_{i=1}^{m} \rho_{6i}\, \Delta lnU_{t-i} + \vartheta_t$……...(8)

For confirmation of long-run relation the null hypothesis of no cointegration is stated as $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ and is checked using F-statistic of Pesaran et al. (2001). The long run impacts of positive and negative changes in informal sector size on economic growth are equivalent to $\theta_1 = \frac{\delta_4}{\delta_1}$ and $\theta_2 = \frac{\delta_5}{\delta_1}$. The short-run impact of an increase in informal sector size on economic growth is represented by $\sum_{i=1}^{q} \rho_{4i}$ while the short run impact of a decrease in informal sector size on economic growth is represented by $\sum_{i=1}^{l} \rho_{5i}$.

4. Result and Discussions

4.1 The results of MIMIC model

Investigating the long run association between causes and indicator variables of the MIMIC model the study has found that the indicator variables are co integrated with cause variables. The result of the unit root tests for cause and indicator variables, and cointegration analysis between the indicators and causes are presented in Appendix-1 and Appendix-2 respectively. Applying the SEM technique, the results obtained from estimating the MIMIC model is presented in Table-1. Tax burden, currency in circulation, and the state of financial sector development are identified as significant causes of the informal economy. The indicator variable has projected expected signs with strong statistical significance for electricity consumption per capita. Acceptance of the MIMIC model estimation result depends on many Goodness-of-fit statistics. Table 1 shows that all the indicators in the diagnostic check are maintained within the range of fitness.

Table-1: The results of MIMIC model

Cause Variables	Estimated Coefficients	S.E	*P*-Value
Curr_M_2	0.16**	0.06	0.02
Tax_GDP	0.63***	0.13	0.00
M_2/GDP	0.49***	0.13	0.00
InfR	0.02	0.04	0.71
IntR	-0.04	0.04	0.38
Indicator Variables	Estimated Coefficients	S.E	*P*-Value
RGDPgr	1.00	-	-
Elec	1.21	0.15	0.00
Diagnostic Tests			
Fit Indices	Scores	Recommended value	
Chi-Square/Degree of freedom	0.709	≤3.00	
Root mean square error of approximation (RAMSE)	0.00	≤0.05	
Adjusted goodness-of-fit index (AGFI)	0.87	≥0.90	
Goodness-of-fit index(GFI)	0.97	≥0.90	

Note: *** and ** indicate significance at 1% and 5% levels respectively.

Since the model is well-identified and possesses a strong explanatory power, the significant coefficients are used to find the ordinal estimate of the informal economy. Applying the calibration procedure a series for the contribution of informal sector has been developed as a percentage of total GDP. The result shows that the size of informal economy is gradually increasing over the periods which is presented in the figure 1.

4.2 Descriptive statistics and unit root tests

Table 1 presents the result of descriptive statistics. The table projects that the maximum contribution of the informal sector is almost half, and minimum is almost one-fourth of the total GDP in Bangladesh. Figure 1 graphically presents the data that will provide some insight into the logic for asymmetric analysis of the informal sector on growth in this study. The employment rate is also high, of which a substantial portion comes from the informal sector as per the projection of ILO (2013).

Table 2: Descriptive statistics (before log transformation)

	Y	K	L	IS	U
Mean	760.506	22.567	96.896	27.817	3.103
Median	653.808	23.808	96.730	22.850	3.270
Maximum	1498.388	31.234	99.080	46.153	5.000
Minimum	465.250	15.473	95.000	11.724	0.920
Std. Dev.	294.761	5.069	1.177	11.312	1.177
Skewness	0.996	-0.018	0.377	0.308	-0.377
Kurtosis	2.865	1.578	2.013	1.600	2.013
Jarque-Bera	6.151	3.117	2.376	3.607	2.376
Probability	0.046	0.210	0.304	0.164	0.304
Sum	28138.74	835.0046	3585.154	1029.247	114.846

The next step is to test the stationary property of the variables for N-ARDL to ensure none of them are I(2). The results are reported in Table 3.

Table 3: The Phillips-Perron (1988) and the Kapetanios, Shin & Snell (2003) Unit Root Tests Result

	Phillips-Perron (1988) linear unit root test				**Kapetanios, Shin & Snell (2003) ESTAR nonlinear unit root test**			
	Without Trend		**With Trend**		**Without Trend**		**With Trend**	
Series	Level	1st Difference	Level	1st Difference	Level	1st Difference	Level	1st Difference
$gdppc$	6.803***	-3.757***	0.674	-7.157***	-1.453 (3)	-2.825* (3)	-2.220 (2)	-3.189* (2)
$capital$	-2.101	-9.257***	-6.002***	-8.874***	-0.829 (1)	-3.074** (0)	-2.722 (1)	-4.712*** (1)
$labor$	-1.199	-7.731***	-3.120	-7.609***	-2.550 (0)	-5.943*** (0)	-4.446*** (0)	-5.983*** (0)
$informal$	-1.390	-4.650***	-2.636	-4.601***	-0.737 (1)	-3.729** (0)	-1.766 (1)	-3.738** (0)
$urban$	-3.774***	-2.866**	-6.848***	-2.149	0.430 (3)	-3.199** (1)	-2.675 (3)	-4.367*** (1)

Notes: (a) The Newey-West optimum lag for Phillips-Perron (1988) unit root test is 3. The optimum lag length for Kapetanios, Shin & Snell (2003) unit root test has been selected by Akaike's information criterion. The parenthesis values show the optimum lag. (b) ***, **, and * denote the statistical significance level of the estimated coefficients at 1%, 5%, and 10% significance levels, respectively.

The result of linear unit root test of Phillips-Perron (1988) and the nonlinear unit root test of Kapetanios, Shin & Snell (2003) confirm that the dependent variable GDP per capita is integrated of order one with and without trends, while the explanatory variables are either integrated of order zero or one. Consequently, these unit root tests' results satisfy the prerequisite for the ARDL and N-ARDL models.

Table 4. Results of linear and nonlinear ARDL models

Section (a): Short-run Coefficient Estimates				
	Linear ARDL		**Nonlinear ARDL**	
Lag order	0	1	0	1
Variables				
$\Delta capital$	.161**	.101*	.18***	.115**
	(.058)	(.058)	(.044)	(.044)
$\Delta labor$	-.47	.734**	-.071	1.072***
	(.276)	(.331)	(.232)	(.221)
Δinformal	.019			
	(.028)			
Δinformal^{+}			-.099***	
			(.027)	
Δinformal^{-}			.239***	

									(.069)		
$\Delta urban$			-1.21		1.93*				2.187***		
			(1.283)		(1.024)				(.56)		
Section (b): Long-run Coefficient Estimates											
	$Constant$		$capital$		$employme$	$informal$		$informal^+$	$informal^-$		$urban$
Linear ARDL	3.585		-0.069		17.985	0.154		-	-		1.092
	(2.93)		(0.684)		(11.125)	(0.742)					(2.471)
Nonlinear ARDL	2.544		0.697***		-6.993	-		-0.98***	2.479***		1.507***
	(1.976)		(0.133)		(4.397)			(0.259)	(0.51)		(0.527)
Section (c): Diagnostic Tests											
	F	ECT_{t-1}	W_{LR}	W_{SR}	$\bar{R}^2$	$ARCH$	χ^2_{SC}	χ^2_H	χ^2_{SK}	χ^2_{KT}	χ^2_{FF}
Linear ARDL	15.03***	0.046	-	-	0.87	2.12	0.36	33.0	20.08	0.37	0.80
Nonlinear ARDL	25.92***	-0.14**	26.53***	16.57***	0.93	1.16	4.65	33.0	21.20	0.58	2.06

Notes: (a) The AIC has selected the optimum lag length. (b) ***, ** and * denote the statistical significance level of the estimated coefficients at 1%, 5%, and 10% significance level, respectively. (c) The values of standard errors are in the parentheses. (d) The F tests are compared with the upper bound critical values obtained from Pesaran et al. (2001) and Kripfganz and Schneider (2020). (e) ECT_{t-1} presents the speed-of-adjustment coefficient. (f) χ^2_{SC}, χ^2_H, χ^2_{SK}, χ^2_{KT}, χ^2_{FF} denote Durbin's alternative test for serial correlation, White's test of homoscedasticity, skewness, and kurtosis, Ramsey RESET test for omitted variables, respectively. (g) W_{LR} and W_{SR} present the values of the Wald statistic of long-run symmetry and summative short-run symmetry, respectively. (h) $\bar{R}^2$ reports adjusted R^2.

Table 4, section (a) reports the results of short-run estimates from Pesaran et al. (2001) linear and Shin et al. (2014) nonlinear ARDL bounds test approach. The symmetric outcome of informal sector based on linear ARDL is found to be insignificant both in short run and long run. This result supports the meta analysis result of symmetric effect of informal sector on economic growth presented by Afonso et al. (2020). However, the asymmetric outcome of the informal sector based on the result of N-ARDL reveals that both positive and negative changes of the informal sector are highly significant for economic growth. In nonlinear model, a percentage point increase in informal activity lowers economic growth by 0.099 percent, while its percentage point decrease increase growth by 0.239 percent in the short run. For the short run, Capital and urbanization contribute significantly and positively to economic growth in both linear and nonlinear models.

Section (b) in Table 4 reports the long-run results for linear and nonlinear models. Both positive and negative changes of informal sector size are significant in long run for nonlinear model. A percentage point increase in informal sector activity reduces economic growth by 0.98 percent, while a percentage decrease in informal sector activity increases growth by 2.479 percent in the long-run. Since the reducing impact of informal sector activity on economic growth is positive and more prominent for both short-run and long- run, reduction in the size of the informal sector should be the policy suggestion. This result is in line with the results of Nguyan and Houng (2020) for Asian emerging and developing countries in Asia where an increase in the size of shadow economy projected a negative impact on economic growth. This result also supports the findings of Elgin and Birinchi (2016), Schneider and Hametner (2014) but oppose that of Yelwa and Admans (2017) for Nigeria. Similar to short-run results, the elasticity of both capital and urbanization are significant and contribute positively to economic growth in the long run.

Section (c) in Table 4 reports the results of the diagnostic tests along with bounds test results and adjustment parameters. In addition, the long-run and short-run results of asymmetric adjustment are also presented by the Wald statistics in the same part of Table 4. The F-statistic value rejects both the upper and lower asymptotic critical bounds at 1% significance level and consequently supports the cointegrating relationship among the variables considered in the models. The error-correction term (ECT_{t-1}) that measures how quickly the economy adjusts to a deviation from the long-run equilibrium level in each period is found significant for nonlinear model with an expected negative sign. The linear model fails to establish cointegrating relationship but has passed in ARDL bounds tests. This ambiguity in outcome for the linear model may arise due to the nature of irregularity in informal activities. The significant estimates of W_{SR} and W_{LR} also provide support for additive asymmetric effect of the informal sector for the short run and long run. The outcomes of the

remaining diagnostic tests also provide support for non-linear model including the Cumulative Recursive Sum of Squares (CUSUM) and squared recursive residuals (CUSUM Squared) that the study has employed to validate the stability of the model. These tests are based on the cumulative sum of recursive residuals for the first set on n observations. If the plots of both the statistics stay at a 5% significant level the estimates can be established as stable (Brown et al.,1975). The stability of non-linear model for both CUSUM and CUSUM Squared is confirmed by the graphs presented in fig 2. The value of $\bar{R}^2$ is also high in non-linear model.

4.3 Sensitivity Analysis

In this section the study has checked the sensitivity of the results reported in Table 4 by re-estimating the linear and nonlinear models using actual measure of GDP growth rate as the dependent variable instead of per capita domestic output. The results of the informal sector and capital are very similar to the results reported in Table 4. The result regarding labor and urbanization is somewhat sensitive to dependent variable. Labor is found to be significant and positively related to economic growth in the short run model of ARDL and NARDL but for the long run only in NARDL model. Urbanization is found to be significant in the short run models while insignificant in long run models. The diagnostic tests results presented in section (c) of the model also provide sufficient evidences in favor of cointegrating relation and stability of the models.

Table 5. Results of linear and nonlinear ARDL models (Sensitivity check)

Part (a): Short-run Coefficient Estimates				
	Linear ARDL		**Nonlinear ARDL**	
Lag order	0	1	0	1
Variables				
$\Delta gdpgr$	-	.304** (.138)		
$\Delta capital$	.715 (.547)		3.917*** (1.104)	3.25** (1.184)
$\Delta labor$	-6.817 (5.484)	13.805* (6.768)	-11.465** (4.574)	21.739*** (5.057)

Δinformal		.271 (.617)									
Δinformal^{+}						-1.422*** (.481)					
Δinformal^{-}						3.828*** (1.05)					
$\Delta urban$		-62.518** (25.178)			47.209** (21.529)	18.98* (10.1)					
Part (b): Long-run Coefficient Estimates											
	$Constant$	$capital$	$labor$	$informal$	$informal^{+}$	$informal^{-}$	$urban$				
Linear ARDL	36.358 (51.807)	.552 (.428)	-7.662 (7.66)	.209 (.478)	-	-	-1.538 (1.68)				
Nonlinear ARDL	137.01*** (37.083)	.6* (.328)	-29.144*** (7.113)	-	-1.255*** (.431)	3.38*** (.903)	.165 (1.138)				
Part (c): Diagnostic Tests											
	F	ECT_{t-1}	W_{LR}	W_{SR}	$\bar{R}^2$	$ARCH$	χ^2_{SC}	χ^2_H	χ^2_{SK}	χ^2_{KT}	χ^2_{FF}
Linear ARDL	8.59***	-1.29***	-	-	0.75	0.78	4.09	33.0	17.85	1.38	3.93*
Nonlinear ARDL	11.98***	-1.13***	21.56***	20.77***	0.83	0.24	2.85	33.0	21.36	1.52	8.94***

Notes: (a) The AIC has selected the optimum lag length. (b) ***, **, and * denote the statistical significance level of the estimated coefficients at 1%, 5%, and 10% significance level, respectively. (c) The values of standard errors are in the parentheses. (d) The F tests are compared with the upper bound critical values obtained from Pesaran et al. (2001) and Kripfganz and Schneider (2020). (e) ECT_{t-1} presents the speed-of-adjustment coefficient. (f) χ^2_{SC}, χ^2_H, χ^2_{SK}, χ^2_{KT}, χ^2_{FF} denote Durbin's alternative test for serial correlation, White's test of homoscedasticity, skewness, and kurtosis, Ramsey RESET test for omitted variables, respectively. (g) W_{LR} and W_{SR} present the values of the Wald statistic of long-run symmetry and summative short-run symmetry, respectively. (h) $\bar{R}^2$ reports adjusted R^2.

The study also check the sensitivity of the long-run results using a single equation estimator technique which is a nonparametric approach, namely, Fully Modified Ordinary Least Squares (FMOLS) proposed by Hansen and Phillips (1990). This test is asymptotically unbiased and provide efficient estimators that are free from endogeneity and serial correlation. The FMOLS results are consistent with the long-run results of nonlinear ARDL, having the same sign and significance.

Table 6: The result of FMOLS estimates

Variables	Coefficient	Std Error	t-statistic	Probability
$capital$	0.595***	0.071	8.363	0.000
$labor$	3.997***	1.061	3.768	0.001
$informal^{+}$	-0.257***	0.075	-3.453	0.002
$informal^{-}$	1.688***	0.191	8.830	0.000
$urban$	0.567**	0.238	2.379	0.024
$Constant$	-27.211***	5.271	-5.162	0.000
R-Squared	0.992			
Adjusted R-Squared	0.991			

Note: *** and **, denote the statistical significance level of the estimated coefficients at 1% and 5% significance level, respectively.

All the findings show that asymmetries are important in shaping the relation between informal sector and economic growth in Bangladesh.

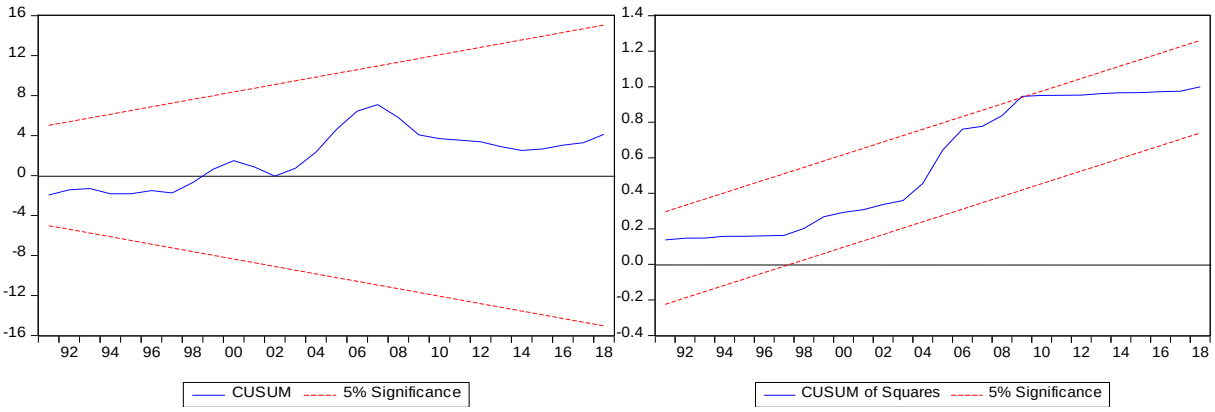

Figure 3: CUSUM and CUSUMSQ for non-linear ARDL model.

5. Conclusion and Policy suggestions

This study has explored empirically the symmetric and asymmetric effect of the informal sector on the economic growth and/or domestic output of a country. Data on Bangladesh have been employed for the period 1982-2018. This study has applied the latent variable method (i.e., the MIMIC model) and calibration technique to measure the informal sector (as % of GDP) in Bangladesh and utilizes this to estimate the effect of the informal sector on economic growth. Due to the complex nature of

the relationship between the informal economy and economic growth (see Afonso et al., 2020) this study has failed to find symmetric support in favor of the informal sector contribution to growth. However, applying the asymmetric cointegration approach (nonlinear cointegration approach i.e. N-ARDL), the study finds that the informal sector has significant short-run and long-run asymmetric effects on economic growth in Bangladesh. The findings reveal an asymmetrically larger positive effect of reducing the size of the informal sector on growth while its increasing effect lowers growth. Applying sensitivity analysis where both the linear and nonlinear models are re-estimated using the percentile growth rate of GDP, the study finds a consistent outcome with the earlier result. The robustness of the long-run nonlinear results is also checked by utilizing a non-parametric long-run cointegrating model (FMOLS) and reports consistent results with earlier estimation. Therefore, based on the empirical outcome, this study suggests that Bangladesh should reduce the size of the informal economy along with planned urbanization and financial sector development for ensuring its higher growth prospects.

Based on the empirical findings of this study it can be suggested that informality issues should be discouraged and handled with care in policy measures since informality is a development issue and limits the ability of the countries to achieve economic development (see Estevao et al., 2022). Otherwise, the dominance of the informal sector will pose a major challenge to economic and social policies in developing countries since capitalist entrepreneurs and the state operate only in the formal sector. Therefore, countries should understand the domain through which they can intervene to establish more formalized economies. Since the features and causes of informality differ considerably across countries, policymakers should identify economy-specific reform priorities. In Bangladesh informality is associated with poor institutional performance, unemployment and

underemployment. Hence, coherent policy measures should be suggested rather than a single policy measure to avoid its limited implication and address the complexity of the informal sector which may also apply to countries with similar contexts.

Improved efficiency in the state functioning can contribute to reducing the size of informality by allowing its gradual transition to a more formalized structure. For example, the prevention of corruption, which has an influence on physical capital accumulation and coexists with informal or shadow economy (see Nguyen and Luong, 2020), may tame the growth of informal activities. Good institutional services such as ease in bureaucratic procedures and licensing requirement, reduction in the tax rate, and simplifying the tax paying system can be effective steps to this end for any developing country. Besides these governments in these countries should focus more on enhancing the attractiveness of formal institutions by providing easy access to financial and banking services, access to cheaper credit from formal financial institutions, diversification in financial products, reduction in payment risk and transaction costs. All these services will facilitate the development of entrepreneurship in the formal sector among the participants in the informal sector through their inclusiveness to financial services. Measures to improve education and training program will also eventually contribute to getting out of informality since educated and skilled entrepreneurs are more prone to work in a formal setup. Policy measures to narrow the wage gap and productivity gap between formal and informal sector workers can also be helpful to reduce the informal sector. This will also help to reallocate wealth and labor from the informal to the formal sector for improved efficiency in production process. Technology-based reforms that will reduce incentives for and increase the cost of operating informally can also be the strategy to increase productivity and propel firms towards formality. Motivational and information campaign that advertises the benefits of

formalizing can also be initiated along with various support programs from the government for Small and Medium Enterprises (SMEs) under the condition of formalization. Well-planned urbanization will also be a measure to reduce the expansion of informal sector activities that will pave to way to economic growth in developing countries like Bangladesh.

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Appendix 1

Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1979) and Phillips Perron (PP) (Phillips & Perron, 1988) unit root tests were applied to check the time series properties of the data used for MIMIC model estimation. All the variables were found to be stationary at their first difference in both intercept and trend model. The results for the unit root test is presented in Table 1.

Table-7: The results of unit-root test

Variables	Models	ADF		PP	
		Level	1st Difference	Level	1st Difference
Cause Variables					
Curr_M_2	Intercept	-3.48***	-5.00***	-3.47***	-4.97***
	Trend and Intercept	-3.14	-5.27***	-3.17	-5.28***
Tax_GDP	Intercept	0.83	-8.58***	0.32	-8.70***
	Trend and Intercept	2.78	-5.85***	-2.78	-8.90***
M_2_GDP)	Intercept	-0.27	-4.29***	-0.29	-4.26***
	Trend and Intercept	2.28	-4.23***	-1.55	-4.16***
IntR	Intercept	-3.87***	-8.71***	-3.84***	-12.63***
	Trend and Intercept	-3.63**	-8.65***	-3.71**	-17.71***
InfR	Intercept	-2.08	-8.17***	-3.66***	-15.95***
	Trend and Intercept	-1.96	-8.11***	-3.72**	-17.06***
Indicator Variables					
RGDPgr	Intercept	-2.69*	-3.87***	-2.59	-13.75***
	Trend and Intercept	-5.82***	-3.88**	-5.82***	-14.32***
Elec	Intercept	-2.01	-6.61***	7.14	-4.87***
	Trend and Intercept	-3.54	-6.78***	1.60	-6.28***

Note: *** indicates significance at 1% level.

Appendix 2: The results of cointegration analysis based on ARDL.

Table-8: The results of cointegration analysis between indicators and causes.

Dependent variable (indicators)	Independent variables (Causes_	Coint.eq	Results	F-statistics	Jarque-bera peobability
$RGDPgr$	Curr_M2, Tax_GDP, M2_GDP, InfR, IntR	-0.92***	Co-integrated	10.79***	0.98
$Elec$	Curr_M2, Tax_GDP, M2_GDP, InfR, IntR	-0.45***	Co-integrated	14.54***	0.72

Note: *** indicates significance at 1% level

4.3 Study 5

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Informal Sector Employment and Economic Growth: Evidence from Developing Countries in SDG Perspective

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Abstract: The understanding of the role of informal employment in economic growth is important to facilitate developing countries in safeguarding the decent work, productive employment, and inclusive growth agenda mentioned in Sustainable Development Goals (SDG) 8. The present study attempts to this end by investigating the role of informal employment on economic growth with an aim to assist in fulfilling target 8.3 of SDG. This study utilizes the data available for 20 developing countries for the period 2011–2019. Panel data analysis techniques have been applied, considering the percentage of total employment in the informal sector as the main explanatory variable of the models. The relevant macroeconomic indicators are included in the model as control variables. Empirical findings from Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Dynamic Fixed Effect (DFE) models indicate a positive effect of informal employment on the economic growth of developing countries. The other macroeconomic indicators, per capita income, national expenditure, money supply, and economic freedom, are also found to contribute to the economic growth of the selected countries. This study reveals an important bidirectional causal association between informal employment and economic growth, a unidirectional causal link from per capita income to informal employment and from informal employment to national expenditure. Taking into account the contribution of the informal sector to the economy, this study fosters the need for achieving the targets mentioned in SDG 8 by adopting appropriate policies rather than punishing this sector immediately.

Keywords: informal sector; informal employment; economic growth; macroeconomic policies; developing countries

Citation: Sultana, N.; Rahman, M.M.; Khanam, R. Informal Sector Employment and Economic Growth: Evidence from Developing Countries in SDG Perspective. *Sustainability* **2022**, *14*, 11989. https://doi.org/10.3390/su141911989

Academic Editors: Luigi Aldieri and Jacob Arie Jordaan

Received: 11 August 2022
Accepted: 20 September 2022
Published: 22 September 2022

1. Introduction

Originating in the context of third-world countries, the informal sector constitutes a dominant part of the economy and is identified as an untapped reservoir of opportunities in terms of employment and the entrepreneurial capabilities of developing countries [1–8]; it is often called the subordinate zone of the overall economy that can play a significant role in the growth and socio-economic development of countries across the world [4,9]. The informal sector accounts for almost half of the economic activities in developing countries [2,9,10]. These activities were initially backed by the core assumptions of the classical theory that the informal economy would wither away after achieving persistent growth [10–12]. However, the new view of the informal economy features it as contemporary growth that should proceed as a result of the changed economic context of countries [11]. The prevalent feature of the informal economy around the globe provides support to the new view of informality, mentioned as a dichotomist's approach, which indicates that the informal economy will not wither away; rather, it will be contested in an arrangement of interdependent coexistence with distinctively different conditions, notably in terms of employment arrangements [12–15]. Therefore, it is important to investigate the long-run prospect of informal employment on economic growth with an aim to formulate

appropriate strategies for this sector aligned to the targets of the Sustainable Development Goals (SDG) mentioned by the United Nations.

The new view of informality anticipates that the internal heterogeneity of the informal economy makes it a resilient feature of modernization and economic growth [12]. Moreover, informal activities have the potential to affect sustainability, since they arise due to the improper functioning of the formal system [16]. Therefore, a comprehensive and holistic understanding of the features of the informal sector is important to pursue economic growth by avoiding the undesired effects of economic policy measures [17]. This provokes researchers around the globe to undertake more research on the informal economy to find the reliable and consistent drivers of the informal sector and its relation to economic growth [18], while economic growth itself remains a topic under investigation and debate [19]. The present study has contributed to this end by investigating the significance of the informal sector to the economic growth in terms of employment since informal employment constitutes a persistent structural pillar of the labor market in low-income and developing countries and is identified as a thematic area in at least two sustainable development goals (SDG-8.3 and SDG 10.2) by International Labor Organization (ILO).

In developing countries, employment in the informal sector is increasing over the years [20,21] and it is considered to be a resort against unemployment despite its significant low wage, as compared to the formal sector [21,22]. Informal employment includes the self-employed, paid workers in informal enterprises, unpaid workers in family businesses, casual workers without fixed employers, and sub-contract workers connected to both formal and informal enterprises as per the definition mentioned in the ILO guidebook (2018) which provides a detailed overview of the SDG labor market indicators pertain to Goal 8 (sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all). Informal employment is also linked to some extent to the other SDG goals, such as Goals 1, 5, and 10 since a vast portion of workers are pursuing their livelihoods in conditions of informality. Informality issues are addressed in SDG target 8.3 where the promotion of development-oriented policies are suggested to support productive activities, decent job creation, creativity and innovation, and entrepreneurship, along with an encouragement to the growth and formalization of micro, small and medium-sized enterprises [23]. The prospect of an informal economy in productive activities with the viewpoint of economic gains, improvement of physical and human capital, and the extraction of profit from the local economy may motivate to set this target [7].

Under this backdrop, this study aims to contribute to framing the development-oriented policies related to the informal sector, vis-à-vis, informal employment by investigating its impact on economic growth that will assist in fulfilling target 8.3 of SDG. Because informality has raised issues for public health [24,25], as informal laborers often have to work in small and undefined workplaces, and in precarious working conditions. Informal employment is also criticized for its low wages, lack of economic security due to irregularities in income, limited workplace rights and social security, random abuse and exploitation that contribute negatively to the health and wellbeing of workers [26]; These have a negative impact on revenues, fair competition, and the government's scope of action and reliability of institutions [23]. However, since informality is a development issue it must be dealt with caution [27]. Therefore, the contribution of informality to economic growth is needed to be evaluated to put forward the policies addressing justifiably the decent work deficit and productive inefficiency in the informal sector, which create the context of working poverty and economic distortion intimidating sustainable growth in developing countries. Assessment of the role of informal employment in economic growth will make this need more distinct and work for better policy coherence with an integration of social and economic policies that will promote the central aim of the sustainable development agenda: social, economic, and political inclusion of all people.

This study has attempted to this end by considering the broad definition of the informal sector that recognizes not only the enterprises but also the employment relationships in the informal sector following [20] and [28]. Data unavailability and inconsistency are an

inevitable part of the study of the informal sector, especially in developing countries. Taking account of this drawback this study has considered employment in the informal sector as a representation of the informal sector following the existing literature [12,13,29]. It is measured here as the share of informal employment to total employment and has combined with other macroeconomic indicators namely, per-capita income, national expenditure, unemployment, money supply, and economic freedom index of countries to empirically investigate its influence on the economic growth of countries. This study has relied on the UN's classification of developing countries and considers twenty of them on the basis of the availability of informal employment data.

The contributions of this study to the existing literature are as follows. Firstly, to empirically investigate the long-run contribution of informal sector employment to the economic growth of developing countries. This assessment will resonate with informal employment for critically addressing the issues of decent work deficit [23,30] mentioned in SDG 8 that encompasses inclusive and sustainable economic growth. Secondly, to assess the impact of informal employment on growth in a combination of other macroeconomic indicators. This will assist in macroeconomic policy-making that is helpful for informal enterprises to navigate to formality as targeted by SDG through turbulent global market conditions and ensure sustained wealth accumulation and competitiveness for these relatively poor economies by the achievement of formality [31]. Thirdly, to capture the joint influence of property rights, regulation, monetary policy, government intervention, business freedom and other variables in the model, this study has used the composite Economic Freedom Index (EFI) of countries which can be considered as a novel contribution. It is believed that economic freedom facilitates more effective macroeconomic policy formulation that will spur economic growth with sustainability. This study finds it relevant to assess the effect of economic freedom, components of which may influence the growth of the informal sector, on growth. Fourthly, to explore the long-run co-integration relationship of informal employment with economic growth by applying the most suitable econometric methods. Investigating the long-run relationship this study bears the potential to evaluate the prospect of the informal sector from a sustainability perspective. Fifthly, to reveal the causal relationship between informal employment and economic growth both in the short run and long run. This is important for framing policies toward sustainable and inclusive growth. To the best of the authors' knowledge, no study reveals the causal relationship between informal employment, economic growth, and other macroeconomic indicators for a panel dataset of developing countries.

After the introduction, the paper is organized as follows: Section 2 projects the theory and literature review that covers a number of aspects of informality in its nexus to the economic growth of countries, and Section 3 discusses data, methods and econometric approaches. Section 4 presents empirical findings with the help of tables and provides relevant discussion. Section 5 offers concluding remarks with some policy suggestions.

2. Theory and Literature Review

The causes and consequences of the informal sector and its relation to the formal economy is a topic of extensive research to the researchers. Economists are now more aware of the importance of the informal sector and researchers have found it necessary to relate its significance to economic growth [3,18,32]. This study has reviewed such literature and presents below some features of the informal sector that are related to many aspects of the economy, such as productivity, labor market and employment, socio-economic inequality, enforcement, and economic growth of countries, after discussing a brief theoretical background of the study.

2.1. A Theoretical Background of Informal Employment: Socio-Economic Safety Mechanism or Growth Engine

The theoretical background of informal employment particularly urban informal employment, is presented in the seminal paper of Lewis (1954). Later in 1970, Harris

Todaro explained the reason for urban unemployment that serves as an equilibrating force for rural urban migration and provides the foundation for the subsequent theories of informal employment. Field (1975) extended this in several directions by assuming that urban workers can choose to become informally employed rather than search for higher paying formal jobs [33,34].

Informal employment is considered to be a substitute for formal employment and is treated as a residual absorbing surplus, unskilled labor from the formal sector in the dualistic labor market approach. This group views informal employment as involuntary that utilizes traditional production technology, organizes with little to no capital, and provides a subsistence wage; it is seen to be a safety net for unemployed workers in the dualistic framework and incapable of accumulating capital for growth [35]. Based on this approach, poverty alleviation and providing unemployment insurance during the periods of unemployment are the most appropriate policies. However, in the context of developing countries it is hard to provide unemployment insurance or safety nets [27]. On the other hand, informal employment is considered as a voluntary strategy and compliment to formal employment in the neo-liberal approach; they opine that entrepreneurs are capable of establishing new firms and can avoid strenuous and costly labor regulations by adopting a cost-saving strategy. The entrepreneurs can accumulate a substantial amount of capital for their business and can be associated with formal markets through output demand and business relations with the formal firms [35]. In this way the informal sector becomes capable to accumulate capital and contribute to growth that creates a positive impact to the overall economy [36]. In such a situation entrepreneurs and business owners often enter the informal sector to escape excess labor costs that ultimately extends informal employment. Thus, this particular approach sees informal employment as a potential engine of growth [35]

Under such a theoretical debate, Structural Articulation approach, the third theory of informal employment is evaluated which sees the informal sector as heterogeneous and comprising of at least two distinct sub-sectors [37]. Entrepreneurs and small firms those attempt to grow by avoiding costly regulation are represented by one sub-sector and this sub-sector benefits the overall economy by providing lower consumer prices and labor costs since it is driven by labor demand. This is identified as a dynamic sub-sector that demonstrates pro-cyclical behavior with the overall economy. The other sub-sector argued by the Structural Articulation approach is largely detached with the formal economy and projects countercyclical behavior. This is identified as a static sub-sector that represents the involuntary subsistence strategies of surplus and unskilled workers who failed to find employment in the formal sector. As a result, growth policies and poverty alleviation strategies are required to apply discriminately to the appropriate sub-sector [35]. Based on the fact that, it is difficult to accurately identify each sub-sector, this study considers an integration of these two subsectors in informal employment and finds its impact on growth in order to target relevant policies suitable for both groups.

2.2. The Informal Sector, Productivity, Output, and Growth

It wasrevealed by [38] that the structure, nature, and evolution pattern of the economy and structural change in the informal sector could cause a rapid growth of output in the informal sector. [10] observed that the informal sector lacked investment from a government that could promote direct economic growth but promoted growth in entrepreneurship in the sector and thereby spurred economic growth. This study also opined that the growth of the informal sector was required to sustain the growth of the formal sector since agriculture was a part of the informal sector and the economies experiencing economic growth with informality didn't indicate a lack of development, rather they indicated the improved productivity of informal employment due to economic development. The productivity of output was also linked to the informal sector through the economic performances and policies of countries and thereby influenced economic growth in many ways. Productivity differences across countries were found to be important for analyzing the informal sector

by [39]. This study revealed a larger share of output from low-productivity firms of the informal sector in such countries that faced a low degree of debt enforcement and high costs of getting associated with the formal sector. The level of output i.e., GDP per capita of countries was found to be significant in the relationship between informality and growth by [19]. Using a novel data set of 161 countries, the size of the informal sector and the growth of real GDP per capita projected an inverted U relationship in this study. This study indicated that small and large size informal economies were associated with lower growth, and medium size informal economies were linked to a higher level of growth. The decomposition of growth into growth accounts confirmed the nonlinear result by observing the negative association of labor and capital-output ratio, and the positive association of total factor productivity and the large informal economy in this study. Refs. [4,40] also found a commendable and significant impact of the informal sector on growth in Nigeria and Pakistan, respectively. This brief review reveals that there are considerable channels through which informality and productivity can be linked to the growth of countries.

2.3. Enforcement, Informal Employment, and Growth

The conditions of regulations and enforcement were identified as critical to determine the size of the informal sector in both developed and developing countries by [18] and these had an impact on informal sector employment. In the presence of informality, a theoretical relationship between enforcement and the economic growth of society was developed by [41] and this discussion was found to be important by the study as the employment capacity of the formal sector was declining worldwide. When the enforcement level that encompassed the level of security of property rights, the integrity of contracts and checks of corruption, affected the formal and informal activities differently and imposition of taxes reduced the formal activities only, their simultaneous choice entailed growth as well. The growth rate and welfare functions projected inverted U shapes in this study that acted against the enforcement level. [1] found that product market deregulation reduced informality, unemployment, and wage inequality. Contrary to this finding, enhancement of enforcement level reduced informality by the study of [42] without increasing unemployment, allowing the reallocation of workers to more productive jobs that facilitated increases in wages and contributed to a reduction in inequality. Therefore, debate belongs to the nexus between informality, employment and enforcement level that impacts economic growth through the path of public policy and productivity.

2.4. Informal Employment, Income Inequality, and Economic Growth

Precarious employment and poor prospects reproduce and reinforce distinctive territorial inequalities and thus create a stern limitation for sustainable development. Observing this [43] has opined that for pursuing sustainable development, work arrangements have to be fair and stable. Unfortunately, these are absent in the informal sector and the inequality features are observed in informal employment. [20] revealed that increased employment and inequality in the informal sector due to the formal and informal wage gap had links to productivity and output. According to [42] low productivity was found both in the informal and formal sectors and in the transit between the two, but the informal sector paid significantly less than the formal one. The study observed that the movement of the Gini coefficient over time depended on the gap between formal and informal sector wages and therefore employment in the informal sector had the potential to contribute to improving income inequality in developing countries by improving the Gini coefficient value. The changes in the wages of the informal sector created a major impact on the Lorenz curve and the evolution of the Gini coefficient by this study. Ref. [44] also observed the same while investigating the conditions under the inverted U-shaped curve of the income distribution. The study found that the expansion of the informal sector and manual labor migration to this sector were vital for reducing income inequality. Using Gini index [45] observed the past level of inequality as a salient feature to explain the size of the informal economy. He showed countries with larger initial inequality had larger informal economies over time

and not necessarily the informal economy would naturally decline to the same steady state. Improvement in contractual and financial participation of informal firms could increase informal wages along with an expansion of the size of the informal sector according to [32]. These findings indicate that informal firms accessing institutional services and informal employment with a minimum wage gap have the potential to improve income inequality and foster economic growth.

2.5. Informality, Institutions, and Sustainable Development

Informality has been projected as a core aspect of sustainable development in [46] and this study establishes a strong association between the size of the informal sector and the socio-economic indicators. [14] has revealed an overall detrimental role of the informal sector in the sustainable development of developing countries while the working poor is used as a proxy for the informal sector. Acknowledging the informal economy and informal workforce as the broad base of the global economy and workforce [20] suggested a review of all economic and social policies in terms of their impact on the informal economy and its integral parts. The high correlation of informal activities to the level of economic development and institutional quality was revealed in [34,47] and in response to this result [34] pointed to the modern model of the informal sector that put emphasis on small-scale, unskilled labor-intensive, and self-financed activities with the potential to uphold the consequences of pro-growth policies accommodating a large informal sector. Considering informal labor in the form of unregulated and subcontract work [28] argued that decent work in the informal sector and economic growth issues should gain more focus to realize its promise.

From the above discussion, it is observed that there are several pathways through which informality is linked to formal economic processes such as employment generation, economic productivity, output growth, inequality reduction, institutional capacity, and socio-economic development. However, the dynamics of informality related to formality are yet to be understood completely compared to its wider influences on the economy and development of developing countries. Moreover, macroeconomic factors are rarely considered in this connection. Therefore, this study expects to contribute to the gap by establishing the impact of the informal sector on economic growth through the path of most promising informal employment in the presence of other macroeconomic factors. A particular emphasis on the developing countries with their ranking of economic freedom will add new insight to this analysis.

3. Data and Methodology

3.1. Data

This study has analyzed panel dataset of 20 developing countries (Albenia, Armenia, Bangladesh, Bolivia, Bosnia and Herzegovina, Brazil, Colombia, Costarica, Dominic Republic, Ecuador, El Salvador, Guatemala, Mali, Mongolia, North Macedonia, Paraguay, Peru, Serbia, South Africa, Vietnam) for the period 2011 to 2019. The countries and the time period are selected based on the availability of data on the informal employment level since data on the informal sector is usually unavailable especially in developing countries. The details of the data/variables and their expected relationships with the dependent variable are presented in Table 1 below.

Table 1. Description of variables.

Variable	Source	Proxy or Definition	Hypothesis	Expected Sign
Economic Growth (*EG*)	World Development Indicators WB [48] https://databank.worldbank.org/source/world-development-indicators (accessed on 12 March 2021)	GDP growth rate (annual %)		
Informal sector (*IE*)	International Labor Organization [49] https://ilostat.ilo.org/data/ (accessed on 18 March 2021)	Rate of Informal employment (total) in total employment (%)	H1: Informal employment contributes positively to long-run economic growth [12,50,51]	+
Per capita income (*Y*)	WDI, WB [48]	GDP per capita, PPP (constant 2017 international $)	H2: An increase in per capita income increases economic growth.	+
Gross National Expenditure (*GE*)	WDI, WB [48]	Gross national Expenditure as a percentage of GDP (annual %)	H3:An increase in national expenditure increases growth	+
Unemployment (*UN*)	WDI, WB [48]	Rate of Unemployment (annual %)	H4: An increase in unemployment rate decreases growth	-
Money Supply Growth rate (*MS*)	WDI, WB [48]	Broad Money or M2 money growth rate in terms of total GDP (annual %)	H5: An increase in money supply increases growth.	+
Economic Freedom (*EF*)	Index of Economic Freedom, 2021 [52] https://www.heritage.org/index/explore?view=by-region-country-year&u=637509928185688064#top (accessed on 11 March 2021)	The index of Economic Freedom (overall) focuses on economic freedom, prosperity and opportunity by summing 12 economic freedom indices.	H6: An increase in economic freedom of countries increases growth.	+

Note: '+' sign indicates positive association and '-' indicates negative association with the dependent variable (*EG*).

3.2. Method

The empirical model of this study is based on endogenous growth theory that provides insights of the role of productivity in economic growth. This is a long-run economic growth where the rate is determined by the forces internal to the economic system and influenced by economic factors. Influenced by [19,40,53] this study has employed an econometric model which can be represented as follows:

$$EG = \int (IE,\ Y,\ GE,\ UN, MS, EF) \tag{1}$$

Equation (1) implies that Economic growth rate (*EG*) is a function of Informal employment (*IE*), per capita income (*Y*), Government expenditure (*GE*), unemployment rate (*UN*), money supply growth (*MS*) and economic freedom (*EF*). To be more specific this equation can be written as,

$$\begin{aligned} EG_{i,t} = \alpha_0 + \quad & \beta_1 IE_{i,t} + \beta_2 Y_{i,t} + \beta_3 GE_{i,t} + \beta_4 UN_{i,t} + \beta_5 MS_{i,t} \\ & + \beta_6 EF_{i,t} + \varepsilon_{i.t} \end{aligned} \tag{2}$$

Here EG_{it} is the GDP growth rate for country i in period t and is the variable of interest. IE_{it} is the main explanatory variable in this model, which represents the percentage of total employment in the informal sector in country i for the year t. The other important variables that can affect economic growth are also considered in this study as control variables, where $Y_{i,t}$ represents the per capita income and captures the effect of the demographic transition on the economic growth of developing countries [54]; it also reflects the possible link between growth and informality [55]. Following [56] this is used as a proxy of institutional quality in the model. $GE_{i,t}$ represents Gross National Expenditure expressed as a percentage of annual GDP and examined the fact whether higher national expenditure stimulates aggregate demand and economic activities, $UN_{i,t}$ represents the rate of unemployment in the economy, which is measured in percentages, and examines the expectation that a higher unemployment rate reduces economic growth. $MS_{i,t}$ refers to money supply growth rate as a percentage of GDP and is added to the model due to the role of monetary policy to economic growth and stability. $EF_{i,t}$ represents the overall Economic Freedom Index of countries that combines all 12 economic freedom indices and provides a comprehensive set

of facts for understanding the principles of economic growth and prosperity. The Index of Economic Freedom helps to track the advancement of a country in terms of economic freedom, prosperity, and opportunity over the period [52]. Based on earlier literature, this study aims to test the hypothesis (H1) that informal employment contributes to the economic growth of developing countries [10,12,50]. Therefore, the expected sign for the coefficient of informal employment is positive, while the expected signs for the other variables in relation to economic growth are also positive, except for unemployment.

3.3. Econometric Approaches

3.3.1. Cross-Section Dependence

The panel data set used in this study has considered a number of countries that can be integrated in many ways in a globalized world. Ignorance of the cross-section's dependence may lead to unreliable regression results. Therefore, the first task should be to check the statistical dependence among the cross-sections of the selected developing countries. Here the null hypothesis $H_0 : Cov(\varepsilon_{it}, \varepsilon_{jt}) = 0$, which implies that there is no dependency among the cross-section is tested against the alternative hypothesis $H_1 : Cov(\varepsilon_{it}, \varepsilon_{jt}) \neq 0$ implying dependence in at least one pair of cross-sections. In a data context where N is sufficiently large and T is relatively small, the Lagrange multiplier statistics for the cross-section developed by [57] is more suitable, and it is presented in Appendix A.1.

In the case where population-wise correlations are zero, the CD test may suffer from a lack of power. Therefore [58] suggested a bias-adjusted test, the Bias-adjusted LM test, which is also presented in Appendix A.1.

This study has checked both tests for investigating the cross-section dependence in the data.

3.3.2. Panel Unit Root Test

The second step in the econometric methodology is to check the stationary of the variables. Among the available panel unit root technologies, the common unit root test Levin-Lin-Chu (LLC) [59] as well as the individual root tests of Im–Pesaran-Shin (IPS) [60], Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) Fisher test have been checked [61]. The details of all these tests are presented in Appendix A.2.

3.3.3. Panel Co-Integration Test

When it is confirmed that the selected variables are stationary at first difference i.e., I(1), the study is permitted to proceed with the estimation of the long-run relationship among the variables. This study has employed Pedroni (1999) and Kao (1999) panel co-integration test to confirm the long run cointegration in the data [62]. After being confirmed the co-integration, the study has moved to estimate the long-run co-integrating vector using panel Fully Modified Ordinary Least Square (FMOLS) and panel Dynamic Ordinary Least Square (DOLS); these two methods are capable of avoiding bias estimate of small sample size arising in the application of OLS [63]; these methods are advantageous in accommodation of substantial heterogeneity across individual members of the panel. The other advantages of applying these co-integrated panel approaches are that they permit the short-run dynamics to be heterogeneous among the members of the panel and allow for the pooling of the long-run information restrained in the panel [64]. The serial correlation effect and endogeneity issues in the regression arising from the presence of a cointegrating relationship are accounted by FMOLS estimation that can also adjust least squares [65] while DOLS estimation provides better estimate result for small sample sizes [66].

However, in the pooled OLS regression analysis the cross-section and time series natures of the data set may ignore [67]. Since observations are pooled together, they cannot represent the heterogeneity or individuality of the individual variable [68]. All time invariant differences between individuals are controlled by fixed effects and therefore, a dynamic fixed effect model has been estimated in this study to capture the process of adaptation in economic growth during the period with a heterogeneous coefficient of

lagged dependent variable. The estimated coefficients of the Dynamic Fixed Effect (DFE) model tend to be unbiased due to their omitted time-invariant characteristics such as culture, religion, race, and gender [68,69].

3.3.4. Panel Granger Causality Test

This study investigates the causal relationship when the variables are found to be co-integrated. Engel Granger co-integration test that involves Vector Error Correction mechanism (VECM) is analyzed to find the short-run and long-run causal relationship. The Granger causality method, including the error correction term (ECT), is presented in Appendix A.3.

The optimal lag length is decided by Akaika Information Criteria (AIC).

4. Empirical Results and Discussion

At the beginning of the empirical result, descriptive statistics should be reported that will help in getting an overview of the dataset. The summary statistics of the data along with the correlation matrix, is presented below in Table 2.

Table 2. The summary and correlation coefficient between the variables.

	EG	Y	GE	IE	UN	MS	EF
Mean	3.551328	11303.57	107.5252	58.39694	11.17639	9.995592	60.58444
Median	3.214020	11886.73	106.1551	62.00000	7.150000	9.401226	61.50000
Maximum	17.29078	20296.82	131.8372	96.10000	43.30000	37.02960	71.70000
Minimum	−3.545763	1995.158	90.61637	12.40000	1.000000	−20.01024	42.30000
Std. Dev.	2.593877	4171.584	8.460830	21.58810	8.896780	6.559260	6.616078
Skewness	1.038185	−0.412887	0.546829	−0.336231	1.087047	0.115851	−0.434794
Kurtosis	7.416612	2.802238	2.446391	2.186718	3.185076	6.291390	2.389349
Observations	180	180	180	180	180	180	180
Correlation	EG	Y	GE	IE	UN	MS	EF
EG	1						
Y	−0.2237	1					
GE	0.0665	−0.1277	1				
IE	0.3021	−0.7939	−0.1635	1			
UN	−0.2068	0.3888	0.4532	−0.7384	1		
MS	0.4393	−0.2479	−0.1661	0.2128	−0.2354	1	
EF	−0.0090	0.4282	0.2819	−0.3313	0.3246	−0.1701	1

The dataset that has been considered is a short panel and the number of cross-sections (N) is larger than the number of years (T). Since $N > T$, the Pesaran CD and Bias-corrected scaled LM test result will be suitable to determine the cross-section dependence in the data set [57,58]. The non-rejection of the null hypothesis on the basis of p-values of both the Pesaran CD test and the Bias-corrected scaled LM test are sufficient to infer that there is no cross-section dependence in the data. The result of the cross-section dependence test is presented in Table 3.

To prevent any spurious regression, result this study has checked for unit root. Since there is no evidence of cross-section dependence in the data this study has applied all the first-generation unit root tests and the results are presented in Table 4.

Table 3. The results of the Cross-section Dependence Test.

Null: No Cross-Section Dependence (Correlation) in Residuals			
Test	**Statistic**	**d.f.**	**Prob**
Breusch-Pagan LM	242.14	190	0.01
Pesaran scaled LM	2.67		0.01
Bias-corrected scaled LM	1.42		0.15
Pesaran CD	−0.21		0.83
Decision: Null can't be rejected as per Pesaran CD and Bias-corrected scaled LM test			

Table 4. The results of Unit root tests.

Variables	Levin, Lin & Chu Test (Common Unit Root)		Im, Pesaran & Shin (Individual Unit Root)		ADF Fisher Chi Square (Individual Unit Root)		PP Fisher Chi Square (Individual Unit Root)	
	Ind. Effect	**Ind. Effect & Linear Trend**	**Ind. Effect**	**Ind. Effect & Linear Trend**	**Ind. Effect**	**Ind. Effect & Linear Trend**	**Ind. Effect**	**Ind. Effect & Linear Trend**
EG	8.05 *** (0.00)	−8.04 *** (0.00)	−2.42 *** (0.01)	0.09 (0.53)	69.22 *** (0.00)	41.72 (0.39)	71.19 *** (0.00)	58.77 *** (0.00)
ΔEG	−14.54 *** (0.00)	−18.71 *** (0.00)	−5.48 *** (0.00)	−1.97 ** (0.02)	111.56 *** (0.00)	85.57 *** (0.00)	138.11 *** (0.00)	139.82 *** (0.00)
IE	−5.00 *** (0.00)	−14.77 *** (0.00)	−1.22 (0.11)	−0.69 (0.24)	61.10 ** (0.02)	55.86 ** (0.05)	62.97 *** (0.00)	57.00 ** (0.04)
ΔIE	−9.42 *** (0.00)	−11.05 *** (0.00)	−3.29 *** (0.00)	−0.73 (0.23)	80.14 *** (0.00)	58.99 ** (0.03)	112.00 *** (0.00)	108.69 *** (0.00)
Y	14.20 (1.00)	−5.45 *** (0.00)	7.55 (1.00)	−0.54 (0.29)	27.33 (0.94)	70.09 *** (0.00)	51.62 (0.1)	79.87 *** (0.00)
ΔY	−5.41 *** (0.00)	−8.66 *** (0.00)	−1.79 ** (0.04)	−0.22 (0.41)	67.89 *** (0.00)	47.53 (0.19)	69.60 *** (0.00)	99.71 *** (0.00)
GE	−5.80 *** (0.00)	−8.26 *** (0.00)	−1.82 ** (0.04)	−0.75 (0.22)	60.57 ** (0.02)	61.30 ** (0.02)	55.32 ** (0.05)	53.58 * (0.07)
ΔGE	−10.68 *** (0.00)	−12.92 *** (0.00)	−4.72 *** (0.00)	−1.04 (0.15)	101.29 *** (0.00)	69.88 *** (0.00)	103.15 *** (0.00)	129.86 *** (0.00)
UN	−4.26 *** (0.00)	−18.15 *** (0.00)	−1.34 * (0.09)	−1.72 ** (0.04)	73.72 *** (0.00)	73.68 *** (0.00)	64.05 *** (0.01)	48.79 (0.16)
ΔUN	−22.97 *** (0.00)	−11.99 *** (0.00)	−6.33 *** (0.00)	−1.01 (0.15)	112.71 *** (0.00)	67.75 *** (0.00)	94.46 *** (0.00)	130.31 *** (0.00)
MS	−8.37 *** (0.00)	−10.55 *** (0.00)	−2.71 *** (0.00)	−1.85 ** (0.03)	73.44 *** (0.00)	81.23 *** (0.00)	85.52 *** (0.00)	146.91 (0.00)
ΔMS	−14.58 *** (0.00)	−19.41 *** (0.00)	−8.03 *** (0.00)	−3.33 *** (0.00)	148.56 *** (0.00)	116.98 *** (0.00)	238.83 *** (0.00)	208.14 *** (0.00)
EF	−1.21 (0.11)	−6.64 *** (0.00)	0.77 (0.78)	−0.61 (0.27)	32.62 (0.79)	55.35 ** (0.05)	32.35 (0.79)	93.52 *** (0.00)
ΔEF	−10.78 ***(0.00)	−11.18 *** (0.00)	−5.50 *** (0.00)	−0.79 (0.21)	113.86 *** (0.00)	59.24 ***(0.00)	147.93 ** (0.02)	108.08 *** (0.00)

Note: ***, ** and * indicate the significance level, where. *** ≤ 0.01, ** ≤ 0.05 , * ≤ 0.10. *p*-values are presented in the parenthesis.

Table 4 shows that almost all the variables have a common unit root both at their level and first difference according to Levin, Lin & Chu's test for both the individual effect model and the individual effect with trend model. The results of three individual unit root tests (Im, Pesaran and Shin, ADF-Fisher Chi square, and PP Fisher Chi square) have projected the variables as stationary at their first difference in both the individual effect model and the individual effect with trend model. Only a few variables are found stationary at their first differences either in the individual effect model or in the individual effect with the

trend model. The stationary of the data at their first difference prevents the spurious results of the regression analysis.

In the next step this study has moved to check the cointegrating relationship among the variables to find the evidence for long-run relationship. Both [70,71] cointegration test have been employed and the results are presented in Table 5.

Table 5. The result of co-integration tests.

Pedroni Test for Co-Integration		
	Statistic	***p*-Value**
Modified Phillips-Perron t	7.7374	0.0000
Phillips-Perron t	−16.1279	0.0000
Augmented Dickey-Fuller t	−10.5762	0.0000
Kao test for co-integration		
Modified Dickey-Fuller t	−3.0892	0.0010
Dickey-Fuller t	−5.6972	0.0000
Augmented Dickey-Fuller t	−3.7840	0.0001
Unadjusted Modified Dickey-Fuller t	−4.4618	0.0000
Unadjusted Dickey-Fuller t	−6.2325	0.0000

The results from Table 5 imply that the variables considered in the model are co integrated and the model can be used for cointegration regression to find the long-run coefficient values of the regressors.

Table 6 presents the results of empirical estimations based on the FMOLS, DOLS and DFE along with the diagnostic test outcomes. The estimation results of three applied models present similar empirical findings. The detailed result of the estimated models guarantee a positive effect of informal employment on economic growth that satisfies the main hypothesis (H1) of this study; these results are similar to the findings of [72] for the developing countries of South Asia, for emerging countries (Pakistan) by [4,73] since informal employment is considered as a representative of the informal sector in this study. The estimated coefficients of per capita income (*Y*), Gross national expenditure (*GE*), Money supply growth (*MS*) and economic freedom of countries (*EF*) are also found to be statistically significant with their expected signs. This result satisfies the hypotheses H2, H3, H5 and H6, implying that all these indicators contribute positively to the economic growth of these countries. Hypothesis H3 for the unemployment rate (*UN*) has been satisfied with an altered sign implying that an increase in the unemployment rate (*UN*) contributes positively to economic growth. Although this result has opposed the expected outcome of this study, it provides evidence to the contribution of informal sector employment to economic growth since there is no necessity to have a trade-off between informality and unemployment, according to [1]. The Adjusted R squared values indicate that these models are able to explain a significant percentage of the variance of economic growth. The probability value of the F statistic also indicates the validity of the Dynamic Fixed Effect (DFE) model.

This study utilizes the panel Granger causality based on Vector Error Correction Model (VECM) where the directional causal associations among the variables are analyzed. The Granger causality test results are presented in Table 7. The long-run causal relationship is established by the significance of the t-statistic for the ECT coefficient while the short-run causal link is confirmed by the significance of the F-statistic of the lagged variables.

Table 6. The results of FMOLS, DOLS and DFE.

Variables	Regression Model					
	FMOLS		DOLS		DFE	
	Estimate	S.E	Estimate	S.E	Estimate	S.E
EG (−1)	-	-	-	-	0.2735 *** (3.6867)	0.0742
IE	0.1640 *** (3.0588)	0.0536	0.1364 *** (2.5275)	0.0539	0.0874 * (1.6571)	0.0527
Y	0.0007 *** (3.4456)	0.0002	0.0006 *** (3.3600)	0.0002	0.0006 *** (3.1999)	0.0002
GE	0.1074 *** (2.6952)	0.0398	0.1358 *** (3.4307)	0.0395	0.0707 * (1.7131)	0.0412
UN	0.1298 *** (2.9156)	0.0503	0.0798 ** (2.3722)	0.0547	0.1612 *** (3.2919)	0.0489
MS	0.1482 *** (5.4675)	0.0271	0.1347 *** (4.7735)	0.0282	0.0892 *** (3.3791)	0.0264
EF	0.2885 *** (3.1884)	0.0905	0.2174 ** (2.3876)	0.0911	0.1589 * (1.7758)	0.0895
C	-	-	-	-	−29.5814	0.0004
Diagnostic Test Results						
R squared	0.5848		0.6064		0.6475	
Adjusted R squared	0.5073		0.5425		0.5785	
S.E of regression	1.7084		1.7544		1.5801	
Long run variance	2.2425		3.0045		F-statistic: 9.3947 (0.00)	
Mean dep var	3.4088		3.5513		Durbin-Watson stat: 2.2162	

Note: ***, ** and * indicate the significance level, where. *** ≤ 0.01, ** ≤ 0.05, * ≤ 0.10. The *t* values are presented in the parenthesis.

Table 7. The results of the Granger causality test.

Dependent Variable	Short Run							Long Run
	Independent Variables							
	ΔEG	ΔY	ΔGE	ΔIE	ΔUN	ΔMS	ΔEF	ECT
Δ*EG*	-	3.9692 ** (0.0211)	2.3744 * (0.0969)	3.2701 ** (0.0410)	2.6190 * (0.0766)	0.3202 (0.7265)	0.2218 (0.7265)	−0.2353 *** (0.0011)
Δ*Y*	3.4614 ** (0.0342)	-	2.3178 (0.1024)	5.0114 *** (0.0080)	1.2021 (0.3038)	1.0286 (0.3603)	1.7164 (0.1836)	−22.7928 *** (0.0103)
Δ*GE*	3.9901 ** (0.0207)	2.8465 * (0.0615)	-	0.7968 (0.4529)	4.4284 ** (0.0137)	0.7363 (0.4808)	1.0834 (0.3414)	−0.3135 *** (0.0064)
Δ*IE*	3.0350 ** (0.0514)	1.3509 (0.2625)	3.3135 ** (0.0394)	-	1.4778 (0.2318)	0.1972 (0.8211)	2.4063 * (0.0940)	0.2786 (0.0106)
Δ*UN*	0.0405 (0.9603)	1.6626 (0.1935)	0.0852 (0.9184)	0.1401 (0.8694)	-	0.1329 (0.8757)	2.0942 (0,1271)	−0.1553 (0.2696)
Δ*MS*	4.1952 ** (0.0171)	2.0245 (0.1360)	1.2838 (0.2803)	2.9740 ** (0.0545)	0.6479 (0.5247)	-	0.8710 (0.4209)	1.1641 (0.0000)
Δ*EF*	0.0173 (0.9828)	0.5794 (0.5616)	0.0342 (0.9664)	0.5173 (0.5971)	0.1456 (0.8646)	0.2217 (0.8014)	-	−0.0721 (0.2126)

Note: ***, ** and * indicate rejection of null at 1%, 5% and 10% significance levels, respectively. *p*-values are presented in the parenthesis.

The results of the Granger causality reveal a bi-directional causal association between economic growth and informal employment, economic growth and GDP per capita, and economic growth and gross national expenditure both in the short run and long run. This finding is similar to the result of [4] for Pakistan and opposite to the findings to [17] for Spain. One-way causal link moves from GDP per capita to informal employment, from informal employment to gross national expenditure, from money supply growth to economic growth and from gross national expenditure to unemployment rate both in the short run and long run. In the short run unidirectional causality runs from money supply growth to the informal sector.

5. Conclusions

The informal sector has all the potential to contribute to employment generation. Hence, this study has investigated the contribution of informal employment to the growth of developing countries. The ultimate aim of this study is to facilitate policy measures in achieving SDG with avoidance of any undesirable socio-economic consequences by confirming the contribution of informal employment in economic growth. Panel data analysis techniques have been applied, considering the percentage of employment in the informal sector as the core independent variable. Some macroeconomic indicators that usually reflect the level of economic development and the economic performance of countries are used to control the effect of other factors in the model. Empirical analysis has been conducted based on the availability of data for the countries spanning from 2011–2019. Long-run models FMOLS, DOLS, and DFE have been applied and the results have established the hypothesis that informal employment is a significant contributor to the economic growth of developing countries. The other macroeconomic variables incorporated in the model as control factors, per capita income, national expenditure, money supply growth and economic freedom of countries also contribute positively to economic growth, while the result of the unemployment rate indirectly justifies the contribution of informal employment to growth. A two-way causal relationship has also been established between informal employment and economic growth and vice-versa and one-way causal links have been found to run from per capita income to informal employment and from informal employment to the gross national expenditure of the countries for both the short-run and long-run. A short-run causal link has also been established from money supply to informal employment. These results provide evidence of the interdependent existence of the informal sector with the formal sector in terms of employment arrangements. The empirical findings of this study support the notion by [10,20,34] for a new paradigm of a hybrid economy that will assess and incorporate the informal sector in conjunction with other formal sectors through the pathway of informal employment.

The empirical evidence presented herein indicates that informality should be considered a good candidate for policy analysis in developing countries [1]. The present context has become more prone to this since the informal sector is expanding further in new economic restructuring induced by the COVID-19 pandemic [74]. Both the informal economy and informal employment need to be recognized in terms of their contribution to the economy and should be allowed to integrate accordingly to economic planning and legal structure. Measures should be taken to facilitate decent work and congenial employment conditions for informal workers so that the productivity of informal enterprises and workers can be enhanced and extraction of the employment effects of economic growth can be made possible. Extended social protection, expansion of health and safety protection, and availability of legal services for workers working in the informal sector can be the immediate policy approach. The informal workforce needs to be disaggregated by their risk status and should be addressed accordingly in policy prescription. As argued by [75], a distinction should also be made between the marginalized or survivalist informal sector and the productive informal sector, and should be targeted accordingly in policy measures to extract the benefit of informal employment on growth. Policies should be reviewed in terms of their impact on the informal sector because inappropriate policies

will drive informality in a way that may lead to a lack of development in socio-economic life, health, and environmental quality. Macroeconomic instruments can also be applied in the policy framing that aims to a gradual formalization of the informal enterprises as targeted in SDG 8. Efforts should be on to improve the attractiveness of the formal sector rather than taking immediate initiatives on eliminating the informal sector. The two-way causal relationship between informality and economic growth, which is revealed by this study indicates that they reinforce each other. Thus, any direct measure to penalize the informal sector will discourage growth and shut down the escape mechanism of the poor and unemployed in a rigid regulatory environment that hinders the process of economic inclusion. Therefore, considering the role of informal employment on economic growth policymakers should work to diminish the role of informality gradually without losing its benefit and facilitate the countries to strongly uphold the decent work, productive activities, entrepreneurship, and formalization issues of the informal sector for the achievement of United Nations' 30 agenda on Sustainable development.

Author Contributions: Conceptualization, N.S. and M.M.R.; methodology N.S.; software, N.S.; Validation, M.M.R. and N.S.; formal analysis, N.S.; investigation, N.S. and M.M.R.; resources, N.S.; data curation, N.S. writing-original draft preparation: N.S.; writing-review an editing, M.M.R. and R.K. visualization, N.S. and M.M.R., supervision: M.M.R. and R.K. All authors have read and agreed to the published version of the manuscript.

Funding: No funding is available for this study.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data will be available on request under special consequences.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. Cross Sectional Dependence Test

Pesaran CD test:

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho_{ij}}\right) \Longrightarrow N(0,1) \tag{A1}$$

where, $\hat{\rho_{ij}}$ represents the simple estimate of the pair wise correlation of the residuals (Pesaran 2020, 2021).

The Bias-adjusted LM test:

$$LM(\rho)_{adj} = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{i=j+1}^{N}\hat{\rho_{ij}}\,\frac{(T-k)\hat{\rho}_{ij}^{2}-\mu_{Tij}}{\sqrt{v^{2}{}_{tij}}} \Longrightarrow N(0,1) \tag{A2}$$

Here, k is the number of regressors, μ_{Tij} is the exact mean and $v^{2}{}_{tij}$ is the variance of $(T-k)\hat{\rho}_{ij}^{2}$ (Pesaran et al. 2008).

Appendix A.2. Unit Root Tests

Assuming homogeneity of the coefficients of the lagged dependent variables across the cross sections, the Levin-Lin-Chu (LLC) test is based on the following equation:

$$\Delta y_{i,t} = a_i + \rho y_{i,t-1} + \sum_{j=1}^{\rho_i}\theta_{i.j}\Delta y_{i,\,t-1} + \varepsilon_{i,t} \tag{A3}$$

where, $i = 1, 2, \ldots, N,\ t = 1, 2, \ldots, T,\ \varepsilon_{i,t}$ are $iid\ (0,\ \sigma_{\varepsilon}^2)$ across the unit root of the sample. In this model the null hypothesis $H_0 : \rho_i = 0$ is tested against the alternative $H_0 : \rho_i < 0$ for all, $i = 1, 2, \ldots, N$ with the assumption about the individual effects under H_0. Im, Pesaran and Shin (IPS) relax the homogeneity assumption about ρ and consider a linear trend model for each of the N cross-sections; it is based on the following equation:

$$\Delta y_{i,t} = a_i + \rho_i y_{i,t-1} + \sum_{j=1}^{\rho_i} \theta_{i.j} \Delta y_{i,\ t-1} + \varepsilon_{i,t} \tag{A4}$$

In the IPS test, the null hypothesis of unit root $H_0 : \rho_i = 0$ for all i is tested against the alternative $H_0 : \rho_i < 0$ for all, $i = 1, 2, \ldots, N_0$ and $\rho_i = 0$ for, $i = N_0 + 1, \ldots, N$ with $0 < N_0 \leq N$. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) Chi-square tests were proposed by Maddala and Wu (1999). Fisher's (1932) [76] suggestion of combining ρ_i values from the Augmented-Dickey Fuller (ADF) unit root test applied to cross-section unit i is the basis of these two tests. Assuming cross-section independence the statistic proposed by Maddala and Wu (1999) is defined as follows

$$P = -2 \sum_{i=1}^{N} log(\rho_i) \tag{A5}$$

For large N samples, Choi (2001) has proposed similar standardized statistics

$$Z = -\frac{\sum_{i=1}^{N} log(\rho_i) + N}{\sqrt{N}} \tag{A6}$$

In the ADF and PP unit root tests, both the asymptotic chi-square and the standard normal statistics are reported (Chapsa et al. 2018).

Appendix A.3. Panel Granger Causality Test

The Granger causality method can be represented as follows:

$$\begin{aligned}\Delta EG_{it} = \ & \alpha_{1i} + \sum_{p=1} \alpha_{11,ip} \Delta EG_{it-1} + \sum_{p=1} \alpha_{12,ip} \Delta Y_{it-1} + \sum_{p=1} \alpha_{13,ip} \Delta GE_{it-1} + \sum_{p=1} \alpha_{14,ip} \Delta IE_{it-1} + \sum_{p=1} \alpha_{15,ip} \Delta UN_{it-1} \\ & + \sum_{p=1} \alpha_{16,ip} \Delta MS_{it-1} + \sum_{p=1} \alpha_{17,ip} \Delta EF_{it-1} + \theta_{1i} ECT_{it-1} + \mu_{1,it}\end{aligned} \tag{A7}$$

$$\begin{aligned}\Delta Y_{it} = \ & \alpha_{2i} + \sum_{p=1} \alpha_{21,ip} Y_{it-1} + \sum_{p=1} \alpha_{22,ip} \Delta EG_{it-1} \sum_{p=1} \alpha_{23,ip} \Delta GE_{it-1} + \sum_{p=1} \alpha_{24,ip} \Delta IE_{it-1} + \sum_{p=1} \alpha_{25,ip} \Delta UN_{it-1} \\ & + \sum_{p=1} \alpha_{26,ip} \Delta MS_{it-1} + \sum_{p=1} \alpha_{27,ip} \Delta EF_{it-1} + \theta_{2i} ECT_{it-1} + \mu_{2,it}\end{aligned} \tag{A8}$$

$$\begin{aligned}\Delta IE_{it} = \ & \alpha_{3i} + \sum_{p=1} \alpha_{31,ip} \Delta IS_{it-1} + \sum_{p=1} \alpha_{32,ip} \Delta EG_{it-1} + \sum_{p=1} \alpha_{33,ip} \Delta Y_{it-1} + \sum_{p=1} \alpha_{34,ip} \Delta GE_{it-1} + \sum_{p=1} \alpha_{35,ip} \Delta UN_{it-1} \\ & + \sum_{p=1} \alpha_{36,ip} \Delta MS_{it-1} + \sum_{p=1} \alpha_{37,ip} \Delta EF_{it-1} + \theta_{3i} ECT_{it-1} + \mu_{3,it}\end{aligned} \tag{A9}$$

$$\begin{aligned}\Delta UN_{it} = \ & \alpha_{4i} + \sum_{p} \alpha_{41,ip} \Delta UN_{it-p} + \sum_{p} \alpha_{42,ip} \Delta EG_{it-p} + \sum_{p} \alpha_{43,ip} \Delta Y_{it-1} + \sum_{p} \alpha_{44,ip} \Delta GE_{it-p} + \sum_{p} \alpha_{45ip} \Delta IE_{it-p} \\ & + \sum_{p} \alpha_{46,ip} \Delta MS_{it-p} + \sum_{p} \alpha_{47,ip} \Delta EF_{it-p} + \theta_{4i} ECT_{it-1} + \mu_{4,it}\end{aligned} \tag{A10}$$

$$\begin{aligned}\Delta MS_{it} = \ & \alpha_{5i} + \sum_{p} \alpha_{51,ip} \Delta MS_{it-p} + \sum_{p} \alpha_{52,ip} \Delta EG_{it-p} + \sum_{p} \alpha_{53,ip} \Delta Y_{it-p} + \sum_{p} \alpha_{54,ip} \Delta GE_{it-p} + \sum_{p=1} \alpha_{55,ip} \Delta IE_{it-p} \\ & + \sum_{p} \alpha_{56,ip} \Delta UN_{it-p} + \sum_{p} \alpha_{57,ip} \Delta EF_{it-p} + \theta_{5i} ECT_{it-1} + \mu_{5,it}\end{aligned} \tag{A11}$$

$$\begin{aligned}\Delta EF_{it} = \ & \alpha_{6i} + \sum_{p=1} \alpha_{61,ip} \Delta EF_{it-1} + \sum_{p=1} \alpha_{62,ip} \Delta EG_{it-1} + \sum_{p=1} \alpha_{63,ip} \Delta Y_{it-1} + \sum_{p=1} \alpha_{64,ip} \Delta GE_{it-1} + \sum_{p=1} \alpha_{65,ip} \Delta IE_{it-1} \\ & + \sum_{p=1} \alpha_{66,ip} \Delta UN_{it-1} + \sum_{p=1} \alpha_{67,ip} \Delta MS_{it-1} + \theta_{6i} ECT_{it-1} + \mu_{6,it}\end{aligned} \tag{A12}$$

$$\begin{aligned}\Delta GE_{it} = \ & \alpha_{7i} + \sum_{p=1} \alpha_{71,ip} \Delta GE_{it-1} + \sum_{p=1} \alpha_{72,ip} \Delta EG_{it-1} + \sum_{p=1} \alpha_{73,ip} \Delta Y_{it-1} + \sum_{p=1} \alpha_{74,ip} \Delta IE_{it-1} + \sum_{p=1} \alpha_{75,ip} \Delta UN_{it-1} \\ & + \sum_{p=1} \alpha_{76,ip} \Delta MS_{it-1} + \sum_{p=1} \alpha_{77,ip} \Delta EF_{it-1} + \theta_{7i} ECT_{it-1} + \mu_{7,it}\end{aligned} \tag{A13}$$

Here, Δ refers to first difference operator, p refers to lag length, θ refers to coefficient of error correction term (ECT) and μ refers to random disturbance term.

Table A1. A brief summary of recent literature related to the topic is presented in the table below.

Author	Studied Area	Variable	Findings
Duarte, P. (1917) [16]	Spain	GDP, currency, energy, informality	GDP and informal economy has no causal relation.
Alberola, E. and Urrutia, C. (2020) [77]	Mexico	Labor, informality rate, employment rate, unemployment rate	Informality mitigates inflation volatility for various types of shocks and makes monetary policy less effective.
Khuong, N.V. et al. (2020) [4]	Pakistan	GDP, GNP, inflation rate, growth rate of real GDP, foreign currency accounts, demand deposits, currency in circulation, money supply, banking services and total tax revenues.	Informal sector contributes significantly to GDP. The growth rate of real GDP causes GDP.
Ozgur, G. et al. (2021)	160 economies	Informal economy as percentage of GDP, indicators related to health, economy, environment, education, and social variables.	The size of the informal sector is negatively associated to GDP per capita. The effect of larger informal sector size is stronger in less developed economies.
Pham, T.H.H (2017) [78]	Developing countries	Informality, economic and non-economic indicators of globalization	Trade integration, trade diversification and concentration, de facto and de jure financial openness, and social globalization significantly affect informality. The size of the informal sector in developing countries depends not only on some specific aspects of globalization but also on other macroeconomic aspects, i.e., economic growth, working-age population, government policies and regulation.
Elgin, C. and Birinchi, S. (2016) [19]	161 countries	GDP growth rate, Informal sector, GDP per capita, trade openness, government expenditure, inflation, fiscal deficit, financial depth, corruption control, and law and order, indices.	medium levels of the size of the informal economy are associated with higher levels of growth and small and large sizes of the informal economy are associated with little growth.
Yelwa, M. and Adam, A.J. (2017) [40]	Nigeria	official economy nominal GDP, informal economy nominal GDP, currency in circulation, demand deposit, ratio of currency in circulation to demand deposit, narrow money, informal economy as percentage of official economy	A commendable impact of informal sector economy on economic growth.
Lv, Z. (2020) [9]	96 countries	Informality, tourism, GDP per capita, Govt. size, unemployment, corruption, credit market regulation, labor market regulation	Tourism establishes a u-shaped relationship with informality
Gutierrez-Romero, R. (2021) [45]	138 countries	Informal sector, Gini index, instrumental variables	Past levels of inequality are salient feature to explain the size of informal sector.
Ruiz, M.E. et al. (2017) [24]	Chile	Employment profiles, self-rated health, socio-demographic variables (sec, age, educational level, occupation, economic activity)	Consistent relation between informal employment and self-rated physical and mental health.
Sultana, N. et al. (2022) [14]	50 developing countries	Sustainable development indices, informal sector (working poor), economic growth, national expenditure, economic freedom.	Informal sector plays a detrimental role to sustainable development of developing countries.

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4.4 Links and Implications

In this chapter, empirical findings suggest a reduction in the relative contribution of the informal sector to GDP in Bangladesh. The outcome of **Study 4** explores that a decrease in size of the informal sector can lead to more prominent growth in GDP of Bangladesh. However, the outcome of **Study 5** reveals that informal employment has the potential to generate economic, social, and environmental values to the economies of developing countries, which can contribute to the realization of the SDGs. **Study 4** provides suggestions about macroeconomic policy tools that can help stabilize and integrate the informal sector in Bangladesh as well as other countries in similar contexts, while in **Study 5**, policies are suggested for improving the working conditions in informal employment so that it can be considered a key conduit for reducing poverty and inequality. To provide better policy recommendations for improving the health and wellbeing of informal sector workers, which in turn enables them to work more productively, this research focuses on investigating the socio-economic aspects of the workers employed in the informal sector enterprises. Specifically, the next chapter focuses on the workers' food security status and explores its impact on their health outcomes.

CHAPTER 5: SOCIO-ECONOMIC INSECURITY IN THE INFROMAL SECTOR

5.1 Introduction

In developing countries with high unemployment rates, a significant portion of employment is found in the informal sector (Schneider & Enste, 2000; Chen, 2016). This research reveals the positive impact of informal employment towards achieving the SDGs, as discussed in the previous chapter. However, the poor health status of informal workers can have a negative impact on employment rates, leading to higher job separation and longer periods of non-employment. This creates a vicious cycle, as unemployed individuals are more likely to become ill than their employed counterparts (Albertini et al., 2021) due to limited access to food, which can result in diet-related chronic diseases (Himmelgreen et al., 2020).

This research investigates the food security status of informal workers and assesses its impact on their health outcomes, recognizing that food insecurity can cause social and public health problems in developing countries (Jebena et al., 2017). Additionally, the expansion of informal employment can drive down the wages of informal workers, which in turn can increase the number of households in poverty (Sinha & Kanbur, 2012). Individuals from these households often struggle to consistently obtain adequate food to maintain their dietary requirements due to limited economic resources, leading to recurrent spells of bad health. This can result in exclusion from the labor market and perpetuate the cycle of poverty (Albertini et al., 2021). Besides, work conditions, occupational health and safety issues, and decent work conditions (Chen, 2016) are also critical factors to consider when

assessing the health of informal workers. These factors are essential for the socio-economic well-being of the workers and are analyzed with empirical evidence in **Study 6** presented in section 5.2.

5.2 Study6

Sultana *et al. BMC Public Health* (2023) 23:722
https://doi.org/10.1186/s12889-023-15655-2

BMC Public Health

RESEARCH Open Access

Food insecurity and health outcome nexus: empirical evidence from the informal sector enterprises in Bangladesh

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Abstract

Background Food insecurity indicates the difficulty of constantly obtaining adequate food because of limited economic resources. Food insecurity challenges the desired health outcomes. Although extensive literature has examined the associations between food security and health, low-wage informal sector workers have been less frequently addressed in this topic. The present study has focused on food insecurity among the workers working in the informal sector enterprises who experienced entrenched disadvantage during COVID-19 and examines the relationship between food insecurity and health status as measured by self-reported physical and mental health conditions.

Methods This study has utilized cross-sectional data collected from workers working in informal manufacturing and business enterprises in Dhaka city of Bangladesh. The Food Insecurity Experience Scale (FIES) with eight items is used to screen for food insecurity, and the Short Form 12v2 (SF12v2) scale with 12 questions, and validated for use with Bengali respondents, is used to measure the health status of the informal workers. A health production function has been constructed where the health status (both physical and mental) of workers is associated with food insecurity and other socio-economic and health care factors. Empirical analyses of the study have included descriptive statistics, mean score comparisons, and multivariate regression analyses to identify the predictive factors of the physical and mental health status of the workers.

Results A moderate to severe food insecurity is found to be responsible for the poor health status (both physical and mental) of the selected working group population. Moreover, age over 40 years, having a large family, dissatisfaction with the work place, and the prevalence of occupational health risks are linked to lower physical health, while dissatisfaction with the work place and the incidence of severe diseases contribute to poor mental health status along with food insecurity.

Conclusions Extending social and economic protection towards health coverage and basic consumption is suggested as an immediate action to save lives and ensure productivity of the informal workers. Besides, an increase in income and ensuring decent working conditions are also recommended for the health, safety and satisfaction of workers working in informal sector enterprises.

Keywords Food insecurity, Self-assessed health status, Informal workers, COVID-19

JEL classification I18, I31, J46

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Background

Food insecurity has been recognized as an important social determinant of health [45, 53]. It occurs due to a lack of adequate economic, social, and physical access by people to sufficient, safe, and nutritious food that can satisfy their dietary needs and food preferences for a healthy and active life [22, 43]). It often leads to cycles of fasting and stress, resulting in nutrient deficiencies and weight loss [59]. Food insecurity has significant short-term as well as long-term impacts on physical health and socio-economic participation [13]. It is mostly faced by underprivileged communities, and it affects their health and wellbeing, making them increasingly vulnerable to the risks of starvation, malnutrition, chronic diseases, poor mental health, social conflicts, and inequalities in socio-economic life with an increased probability of hindering the overall developmental activities [13, 40, 69]. Hence, food insecurity has been identified as a multifaceted phenomenon by the United Nations Food and Agriculture Organization (FAO, 2021), which needs to be investigated in light of its complicated impacts. The present study has contributed to this by examining the link between food insecurity and the health status of a susceptible low-income working community operating in the informal sector of Bangladesh.

The informal sector has been accepted globally as a perpetual and significant aspect of urban life [4, 47]. However, the unregulated and unregistered characteristics of informality, precarious working conditions, lower wages, and the involvement of informal enterprises in labor market turnover are suggested as detrimental to health [5, 48, 62]. Informal enterprises are frequently associated with vulnerability and poverty due to the consistent presence of food insecurity and financial crisis [29, 32]. Employment in the informal sector faces a lack of economic security due to irregularities in income, low productivity, health and safety issues, abuse, and exploitation [52]. Workers in informal manufacturing enterprises are exposed to airborne particles, hazardous chemicals, and perilous machinery that lead to a higher prevalence of respiratory diseases [17, 28]. Therefore, informal employment is considered a social determinant of health and embodies a serious problem for public health in terms of poor physical and mental outcomes [48, 62].

The outbreak of the COVID-19 pandemic put 3.3 billion global workforces at risk of losing their livelihoods [33], and it was severe for the informal sector that encompassed a large share of employment in developing countries [5, 17, 77]. Workers in the informal sector were one of the most affected groups in the COVID-19 context, recounting their inability to afford food for sustenance [4, 26]. Informal sector enterprises do not have access to government support programs or formal bank loans [30, 33] and in extreme cases, these enterprises were forced to close their business and production units either momentarily or permanently, which led to job losses and a surge in poverty [30, 33]. Therefore, the informal sector workers were more likely to suffer severe income losses [9, 55, 65]. Since they have limited or no buffers such as savings or access to government support programs, many of them were unable to feed themselves and their families after losing their means to earn an income in the COVID-19 context [55]. This impacted their livelihood and undermined their food security [30, 33]. Food insecurity exacerbated health conditions for these workers with financial challenges due to the known trade-off between purchasing food and meeting health care needs [45]. Workers in this sector are susceptible to a lack of social protection and have poor access to public health care [77]. To this group of people, no income means no food or, at best, less food and less nutritious food [33, 77]. They live with this uncertainty throughout the years, which takes a toll on their health and is one of the worst consequences they have faced during the COVID-19 years.

In the pandemic period, public health issues and their impact on urban informal enterprises became critical, particularly for cities with poor public health systems, the undocumented presence of rural migrants, and the dominance of informal settlements [54]. The financial collapse, permanent closure of many medium and small manufacturing enterprises (MSMEs) and formal absence of income replacement pushed numerous people to resort to the informal sector by making a living as microbusiness owners, own-account workers or service providers, mostly in low and lower-middle-income countries, which often suffer from weak social protection systems and low social coverage. Some formal MSMEs were also pushed into informality [33]. Under such a context, the International Labor Organization (ILO) called for policies to provide income, food support, and adequate health support to the poor and vulnerable informal workers [33]. By conducting an investigation on the workers of the informal sector, this study expects to contribute to policy measures with the suggestions based on empirical evidence. This investigation on urban informal sector workers will also contribute to the effort of diminishing hunger and food insecurity by identifying a food insecure sub-population, while identification of such groups through their demographic characteristics and geographic location is felt necessary for the achievement of the Sustainable Development Goals (see [21]).

In developing countries like Bangladesh, economic lockdown measures carry a serious trade-off in terms of economic welfare, poor nutrition, and hunger [3, 60]. This study, which has investigated the nexus between

food insecurity and the health outcomes of workers in the informal sector, was conducted in Bangladesh for some reasonable facts. First, 99% of industrial units in Bangladesh are either micro, small, or medium-sized enterprises, and a large number of those are informally operated [2]. Informal jobs dominate in all sectors of the Bangladeshi economy. Among the broad sectors, the agriculture sector contains 95%, and the industry sector contains 90% of jobs classified as informal [30, 35, 52]. According to the ILO, 57% of total employment in Bangladesh is in a delicate category due to a lack of formal contracts [30]. In urban areas of Bangladesh, around 13.1 million jobs are informal [30]. However, the surge of the pandemic has diminished the employment opportunity in this sector and pushed the unskilled informal wage workers into the constraints of their purchasing power [8, 19, 39, 41, 49, 51]. Second, the agricultural production and employment in Bangladesh are vulnerable to a multitude of shocks since it belongs to the group of countries that are most at risk of weather-related hazards in the Asia and Pacific region. Economic and social progress are uneven among income groups and geographic regions of the country. The latest estimate based on the year 2018–2020 suggests that, on average, 31.9% of the population is experiencing moderate or severe food insecurity, while the prevalence of undernourishment is still 9.7%. The COVID-19 pandemic has added adverse consequences to food consumption and nutrition in Bangladesh [20]. Third, in the historical context of poor food security standing of households in Bangladesh, the adverse effects of the pandemic and countrywide lockdown have extended beyond income shocks and affected people's food security [3]. Bangladesh is ranked 84 out of 113 countries globally and scored the lowest among the South Asian countries as per the Global Food Security Index 2021 [31]. By shedding light on hunger and food insecurity among workers in urban informal settlements of Bangladesh, this study aims to suggest policies after confirming its association with worker health.

Methods

Study design and data collection

The present study has to follow a cross-sectional design because the required data on informal sector enterprises and informal sector workers are unavailable in official sources. A cohort ($n = 267$) of workers employed in medium and small informal enterprises registered with local authorities (but not with a national body) and comprised of labor without any formal contract, was selected for the interviewer-administered survey. The workers are classified as informal depending on their contractual status. The study was conducted in August-December 2021 in urban areas of Dhaka, Bangladesh. A purposive sampling technique was followed for the study, where workers were selected randomly from three types of manufacturing enterprises: leather and leather products, plastic and small machinery, and dyeing, fabrics, and clothing. Informal enterprises under these three categories of industries are infamous for their polluting activities and unhealthy work environments and have been found to be clustered in three areas of Dhaka city in Bangladesh. Hemayetpur area was selected to survey workers informally employed in the leather factories, Lalbugh (including Islambugh) area was selected to survey informally employed workers in firms within the plastic and small machinery industries, and Keraniganj area was selected to survey informal workers in firms within the dying and clothing industries. Workers were randomly sampled from each enterprise, based on the relative proportion of the workers working in the firm and the overall targeted sample size for each industry. The total sample size was 267 (90 from each industry, of which 3 had to be dropped due to incomplete information). A structured questionnaire was developed in English and translated back into the local language (Bengali) for the survey. A paper based survey was conducted face-to-face among the workers, following all the health and safety rules imposed by the COVID-19 pandemic. After signing the consent form, the potential respondents participated in the interviewer-administered survey. Attending surveyors provided assistance to the respondents who had faced difficulty in reading and answering the survey questions due to a lack of education. Each survey session lasted for about 40–45 min and began with the surveyors reading a verbal consent statement explaining the purpose and potential use of the research, under the supervision of research assistants. The cases where surveyors assisted the respondents by reading consent form and survey questions due to their lack of education were recorded, and all the survey information was transferred to the password-protected software (KOBO Toolbox) on the computer after being translated back into the English language. The saved information in software, from which information could be easily converted into usable data format, was then transferred and stored on a secured drive of the University of Southern Queensland (UniSQ), Australia. During the translation and data entry processes, care was taken to maintain the accuracy of the answers and the error-free entry of quantitative data. The completeness and quality of the data input were cross-checked by the research assistants and the researchers.

Research participants and ethical considerations

The research protocol was thoroughlyreviewed and finally approved by the ethical board of the UniSQ, Australia (UniSQ HREC ID: H21REA014). It followed rigorously all

the steps of data collection guided by the National Statement on ethical conduct in human research 2007 (updated 2018) involving human participants. A local team for data collection was constructed, headed by academic members from the Department of Economics of Jahangirnagar University, Dhaka, Bangladesh (also the co-authors of this article), who were completely aware of the ethical norms of data collection involving humans. The team closely monitored the application of the research protocol, which was approved for this study after ensuring its compliance with international standard. During the information sessions, potential participants were provided with consent forms, where the aims and objectives of the project were mentioned, and the interviewers/surveyors explained verbally the objectives, procedures, risks, and benefits of the study. The survey questionnaire was supplied only to the workers who gave their consent to taking part in the survey after having all the information about the project. The interview team obtained both verbal and written consent from the participants, and the verbal consent statement was read to the participants at the beginning of the survey session who were uneducated. Interviews were conducted outside of the enterprise premises (e.g., a tea-stall, a river bank, or an open space). Participation in this study was completely voluntary, and participants had the complete freedom to withdraw from the survey at any time they wanted without any penalties. The participants were also informed that the data would be kept confidential and used only for research purposes by the researchers. A contact number was provided to each participant of the survey so that measures could be taken in case participants needed any post-interview supportive counseling or assistance.

Empirical strategy

Asking people directly about their experience of food insecurity has been used for more than a decade by many countries as a tool to collect information and monitor food insecurity. This study has followed this technique applicable to the reference country, Bangladesh, to assess food insecurity, while the self-reported health status (both physical and mental) of workers has been used for assessing health outcomes. Following [14, 70] this study has conducted a multivariate analysis where the association between food insecurity and health outcome was investigated after controlling for other socio-demographic, economic, and health related factors.

The health production function for the study can be presented as below:

$$H_i = f(F_i, E_i, S_i, HC_i, WE_i, e_i) \quad (1)$$

where, Hi is the health status (Physical and mental) of workers and is a function of food insecurity (F_i) and other economic factors (E_i), Social factors (S_i), health care factors (HC_i), environmental factors (WE_i), and unobserved factors (e_i) for individual i who work in informal enterprises. The study includes economic factor monthly expenditure besides food insecurity, F_i. Various socio-demographic variables like age, gender, marital status, family size, education, and working hours are included to represent social factors, while having any of the major diseases is included to represent health care factors. Finally, satisfaction in the workplace, which reflects the workers happiness about the work environment (about job certainty, work relation, and a decent work environment), and occupational health risks, which reflect the risk of exposure to pollution or the possible risk of facing accidents due to a lack of adoption to health safety measures, are included to represent the working environment factors.

Measurement of health status

Taking insight from Wang et al. [75], Wan et al. [74], Blanco-Reina et al. [11] this study has used the SF12v2 [76] health survey to measure the health-related quality of life (HRQoL) of informal workers around Dhaka city. This study uses the translated and culturally adapted Bengali version of SF12v2 which proves to be a reliable, acceptable, and valid instrument for measuring health-related quality of life by Islam et al. [34]. The SF12v2 provides a broader picture of health status that includes eight domains: physical functioning, role physical, bodily pain, general health perception, vitality, social functioning, role emotional, and general mental health [76]. The interviewer-administered Bengali SF 12v2 questionnaire contains 12 questions items about health perception on two different subscales: Physical Component Summary (PCS), which assesses physical health perception (about general health, physical functioning, role-physical and bodily pain), and Mental Component Summary (MCS) which evaluates the perception of mental health (about role emotional, mental health, vitality and social functioning). Scores are calculated through Likert's method of summed ratings. In this method the algebraic total of the item scores is used to calculate a score for each question item [34]. Some of the items' scores had to be recoded so that they were all scored in the same direction. The raw scores are added together and linearly transformed into a 0–100 scale, with higher scores denoting greater health [34]. In the current investigation, the Cronbach's alpha for SF12v2 was 0.80, indicating that the scale has strong internal consistency.

Measurement of food insecurity

Food insecurity that indicates a difficulty in constantly obtaining adequate food because of limited economic resources for food is evaluated by administering the

interview with eight questions. FAO [21] has proposed the Food Insecurity Experience Scale Survey Module (FIES-SM), which relies on the yes/no answer of the respondents to eight brief questions regarding their access to adequate food, works as a global reference scale of individual food insecurity. This is a quantitative tool to measure the prevalence of food insecurity (at a moderate to severe level) by statistically analyzing the eight questions that enable estimation of error (confidence intervals around the measures produce) and has been used since 2014 as a survey module [21]. This is also an official tool for measuring access to food within the Sustainable Development Goals (target 2.1), and proves its validity and reliability in socially-backward communities in the context of South Asia [56]. FIES recommends that each country arrive at a categorization of food insecurity (FI) that is meaningful to its context. This study defines the status of food security following FAO [21] and frames the questions accordingly. It provides a raw score-based categorization, while high food insecurity (FI) is categorized with a raw score of 0, marginal FI with a raw score of 1–3, moderate FI with a raw score of 4–6 and severe FI with a raw score of 7–8 [16, 67]. According to the FAO [19] report, mild food insecurity is defined as 'at times during the year, households reduced the quality, variety, and desirability of their diets due to a lack of resources for food, but the quantity of food intake and normal eating patterns were not substantially disrupted' and moderate to severe food insecurity is defined as 'at times during the year, eating patterns of one or more household members were disrupted and food intake reduced because the household lacked money and other resources for food' [19]. In the present investigation, the Cronbach's alpha for FIES was 0.91, indicating that the scale has strong internal consistency.

Variables and categories

Age was classified into four categories: 18–30, 31–40, 41–50, and 51 and older, while 18–30 years was chosen as the reference group for the regression analysis. Gender was divided into male and female, with male being the reference category, and marital status was divided into single and married, with unmarried being the reference category. There are two types of families: those with four or fewer members and those with more than four members, with the first serving as the reference category. Working hours were divided into three categories: less than 8 h, 8 h, and more than 8 h, with less than 8 h being the reference category, and monthly expenditure was divided into three categories: less than BDT 15,000, BDT 15,001–30,000, and more than BDT 30,000, with less than BDT 15,000 being the reference. The participants were asked to rate their level of happiness at work, with the options being feeling happy, feeling somewhat happy, and feeling unhappy. Feeling happy was designated as the reference category. Regarding health issues at work, a dichotomous response was included, with the reference category being none at all. The experience of food insecurity was divided into two categories: food secure or mild food insecure and moderate to severe food insecure, with the first one serving as the reference category. Finally, occurrence of any or more of the major diseases, namely, 1. hypertension, 2. heart disease (including coronary heart disease and other heart condition), 3. stroke, 4. hyperlipidemia, 5. liver disease, 6. diabetes mellitus and other endocrine disease, 7. respiratory disease, 8. urinary and reproductive disease, 9. musculoskeletal disease, 10. gastrointestinal disease, 11. dermal diseases, and 12. dental caries or other dental disease [57], was reported into one of three categories: There is no major disease, one major disease, or multiple major diseases. There is no major disease is set as the reference category. Based on the reference categories, it is expected that aged, female, and married workers with a large family size and lower monthly expenditure, feeling unhappy at work, experiencing moderate to severe food insecurity, facing health risks at work, and having one or more major diseases will have a lower health status than their counterparts.

Data analysis

Data were coded in Excel and all survey data were doubled-entered, checked for missing values, outliers, normality assumptions before data analysis. Statistical analysis were performed by using econometric software STATA version 15.0. First the descriptive statistics of all the variables, including mean, standard deviation, frequency, and percentages were used to summarize and describe the demographic characteristics of the sample. A multivariate regression analysis was used to identify the predictive factors of PCS and MCS. The level of significance of all statistical tests performed was set at $p < 0.05$ and two-tailed.

Results

Table 1 presents the details of SF12v2 score values. The mean scores of SF12v2 PCS is 46.89 (SD = 7.80) and MCS is 41.34 (SD = 8.03). While the mean score for general health is 39.78 (SD = 9.87), physical function 47.43 (SD = 10.99), role physical 50.11 (SD = 7.12), bodily pain 43.36 (SD = 8.55), role emotional 46.22 (SD = 8.33), mental health 41.21 (SD = 8.75), vitality 41.34 (SD = 8.03), and social functioning 39.28 (SD = 11.05). The mean scores for general health and social functioning are found lower among the informal workers.

Table 1 Mean and standard deviation of SF12V2 scoring

Variables	Mean (Std. Dev.)
Physical Component Summary (PCS)	46.89 (7.80)
General Health (GH)	39.78 (9.87)
Physical Functioning (PF)	47.43 (10.99)
Role-Physical (RP)	50.11 (7.12)
Bodily Pain (BP)	43.36 (8.55)
Mental Component summary(MCS)	41.34 (8.03)
Role Emotional (RE)	46.22 (8.33)
Mental Health (MH)	41.21 (8.75)
Vitality (VT)	41.34 (8.03)
Social Functioning (SF)	39.28 (11.05)

The baseline characteristics of the study subjects are summarized in Table 2 along with the mean score of SF12v2. Among the 267 participants, 59.55% are in the age group of 18–30 years, 22.10% are in the age group of 31–40 years, 9.74% are in the group of 41–50 years, and 8.61% are in the group older than 51 years. Among the total participants, 89.51% are men; 62.55% are married; 64.79% have more than four family members; 11.61% have no formal education, 55.06% have a primary education, and 30.34% have a secondary education. Additionally, 87.27% of participants work more than eight hours per day; 59.93% have a family income of less than BDT 15,000; and 30.34% have an income between BDT 15,000 and 30,000. About 83.46% of workers have reported that they face health risks at work, 18.73% report having one major disease, 49.06% have multiple major diseases, and 66.29% have moderate to severe food insecurity.

In Table 2, findings with both PCS and MCS have revealed the significance of all variables considered in the model, i.e., age, gender, marital status, family size, education, working hours, monthly expenditure, satisfaction in the workplace, occupational health issues, major diseases, and food insecurity all are related to the physical and mental health of the sample.

The outcomes of the estimation of multivariate linear regression for physical health components are presented in Table 3. When compared to workers in the reference group of 18 to 30 years, workers who are 41 to 50 years old have a mean score that is 3.5989 [SD = 1.56; 95% CI = -3.79 to 0.80] units lower, and workers over 51 years have a mean score that is 8.44 [SD = 1.65; 95% CI = -11.69 to -5.20] units lower. This leads to the conclusion that for the selected workers working in the informal manufacturing sector, the mean score for physical health declines with age. Besides, when controlling for all other variables, it is revealed that female workers typically have a mean score of physical health that is 4.8686 [SD = 1.35; 95% CI = -7.52 to -2.21] units lower than that of male workers. Furthermore, the family size variable's slope coefficient was found to be negative and significant at the 5% level of significance. According to the estimates, families with more than four members tend to have a mean score of physical health that is 2.2584 [SD = 0.89; 95% CI = -4.00 to -0.51] units lower than families with four or fewer members.

When all other variables are taken into account, the slope coefficient of food insecurity variable is found to be negative and statistically significant at a level of significance lower than 1%. This result reports that workers who experience moderate to severe food insecurity have a mean score of physical health that is 6.0370 [SD = 1.09; 95% CI = -8.19 to -3.88] points lower than the workers who have perfect food security or mild food insecurity. Besides having food insecurity, those who are somewhat happy with their workplace have 2.3423 [SD = 1.39; 95% CI = -5.09 to 0.40] units lower mean score, and those who are unhappy with their workplace have 3.6209 [SD = 1.77; 95% CI = -7.10 to -0.14] units lower mean score in their physical health status. The results of this study also reveal that workers who face health risks at the work have 2.7282 [SD = 1.15; 95% CI = -5.00 to -0.45] units lower mean score in their physical health status compared to their counterpart. However, the effects of marital status, education, work hours, monthly expenditure, and having a major disease on physical health are found to be statistically insignificant in this study.

The outcomes for mental health components are presented in Table 4. According to the outcome of this study, participants' mental health scores increase with age. Comparing to those workers who are in the 18–30 year age group, workers in the 41–50 year age group have a higher mean score of mental health by 2.5476 [SD = 1.45; 95% CI = -0.32 to 5.42] units, and workers in the age group greater than 51 years have a higher mean score by 3.0691 [SD = 1.55; 95% CI = 0.03 to 6.11] units. At a 10% level of significance, the slope coefficient of family size is revealed to be statistically significant and positive. It implies that workers with a family size of more than four have a mean mental health score that is 1.4474 [SD = 0.83; 95% CI = -0.19 to 3.08] units higher than the workers with a family size of four or fewer. Result also implies that, mean mental health score is 3.2418 [SD = 1.38; 95% CI = 0.52 to 5.97] units higher (on average) for families with monthly family expenditure exceeding BDT 30,000. When controlling for all other variables, it is found that there is a statistically significant and detrimental effect of food insecurity on mental health. Those who reported moderate to severe food insecurity on average had a lower mean score in mental health status by 3.5794 [SD = 1.03; 95% CI = -5.60 to -1.56] units.

Table 2 SF mean score comparisons by socio-demographic and health related variables

Variables	n (%)	PCS-12 mean score (Std. Dev.)	Prob > F	MCS-12 mean score (Std. Dev.)	Prob > F
Total sample	267 (100)				
Age					
18–30	159 (59.55)	48.79 (6.29)	< 0.001	41.41 (8.35)	< 0.001
31–40	59 (22.10)	47.19 (7.91)		40.97 (8.10)	
41–50	26 (9.74)	42.71 (7.01)		41.41 (6.98)	
≥ 51	23 (8.61)	37.70 (9.81)		41.76 (7.07)	
Gender					
Male	239 (59.51)	47.40 (7.49)	< 0.001	41.51 (8.12)	< 0.001
Female	28 (10.49)	42.49 (9.09)		39.89 (7.14)	
Marital Status					
Unmarried	100 (37.45)	49.23 (5.73)	< 0.001	41.27 (8.29)	< 0.001
Married	167 (62.55)	45.49 (8.53)		41.39 (7.89)	
Family size					
≤ 4	94 (35.21)	48.10 (7.04)	< 0.001	39.67 (7.56)	< 0.001
> 4	173 (64.79)	46.23 (8.13)		42.25 (8.15)	
Education					
No education	31 (11.61)	43.93 (8.33)	< 0.001	42.07 (9.30)	< 0.001
Primary	147 (55.06)	47.73 (7.95)		41.01 (8.42)	
Secondary	81 (30.34)	46.56 (6.89)		41.05 (6.79)	
≥ Higher secondary	8 (3.00)	46.11 (10.04)		47.51 (4.75)	
Working Hours					
< 8 h	7 (2.62)	52.17 (2.83)	< 0.001	43.20 (9.88)	< 0.001
8 h	27 (10.11)	46.63 (9.41)		43.95 (9.55)	
> 8 h	233 (87.27)	46.76 (7.67)		10.98 (7.75)	
Monthly expenditure					
≤ 15,000 BDT	144 (53.93)	46.20 (7.58)	< 0.001	39.07 (7.17)	< 0.001
15,001–30,000 BDT	81 (30.34)	46.46 (8.87)		41.05 (7.31)	
> 30,000 BDT	42 (15.73)	50.08 (5.38)		49.71 (6.67)	
How do you feel at your workplace? (Satisfaction with workplace)					
Happy	27 (10.11)	51.14 (6.22)	< 0.001	49.97 (8.27)	< 0.001
Moderately happy	207 (77.53)	46.97 (7.39)		40.60 (7.54)	
Not happy	33 (12.36)	42.92 (9.56)		38.96 (6.44)	
Health risk at workplace					
No	222 (83.46)	47.71 (6.90)	< 0.001	41.95 (8.38)	< 0.001
Yes	45 (16.54)	42.66 (10.48)		38.41 (5.10)	
Major Diseases					
No major disease	86 (32.21)	48.56 (6.63)	< 0.001	47.59 (8.47)	< 0.001
One major disease	50 (18.73)	46.65 (6.42)		41.20 (5.33)	
More than one	131 (49.06)	45.88 (8.80)		37.30 (5.65)	
Food insecurity					
Food secure or mild	90 (33.71)	51.29 (4.82)	< 0.001	46.39 (8.91)	< 0.001
Moderate to Severe	177 (66.29)	44.65 (8.08)		38.77 (6.13)	

In this study, the coefficient of workplace satisfaction was found to have a negative sign with statistical significance. This result implies that, those who are somewhat happy with their workplace have a 3.8684 [SD = 1.31; 95% CI = -6.44 to -1.29] unit lower mean score, and those who are unhappy with their workplace have a 5.6789 [SD = 1.66; 95% CI = -8.94 to -2.42] unit lower mean score of mental health than those who are happy with their workplace. Finally, after adjusting for other variables, it is reported that having one or more

Table 3 Result of Multivariate linear regression for physical health components (PCS-12)

Variables	Coefficient	Std. Err	*p*-value	95% CI	
Age	Ref. 18–30 Years				
31–40	-1.4942	1.1635	0.200	-3.7859	0.7976
41–50	-3.5989[b]	1.5554	0.022	-6.6624	-0.5353
≥ 51	-8.4421[a]	1.6463	< 0.001	-11.6848	-5.1993
Gender	Ref. Male				
Female	-4.8686 [b]	1.3484	< 0.001	-7.5245	-2.2127
Marital Status	Ref. Unmarried				
Married	-1.6768	1.0680	0.118	-3.7804	0.4268
Education	Ref. No education				
Primary	0.8027	1.3078	0.540	-1.7732	3.3786
Secondary	-0.9959	1.3889	0.474	-3.7317	1.7397
≥ Higher secondary	-1.6688	2.5729	0.517	-6.7364	3.3988
Family Size	Ref. ≤ 4				
> 4	-2.2584 [b]	0.8868	0.011	-4.0051	-0.5117
Working hours	Ref. < 8 h				
8 h	-3.7015	2.6990	0.171	-9.0176	1.6146
> 8 h	-2.4721	2.4496	0.314	-7.2969	2.3527
Monthly expenditure	Ref. ≤ 15,000 BDT				
15,001–30,000	0.9306	0.9556	0.331	-2.8128	0.9517
> 30,000	-1.5936	1.4733	0.280	-4.4955	1.3083
Moderate to severe food insecurity	Ref. No				
Yes	-6.0370 [a]	1.0934	< 0.001	-8.1907	-3.8834
Workplace Satisfaction	Ref. Happy				
Somewhat happy	-2.3423[c]	1.1576	0.094	-5.0857	0.4012
Not happy	-3.6209 [b]	1.0180	0.041	-7.0981	-0.1436
Health risk at workplace	Ref. No				
Yes	-2.7282 [b]	1.1537	0.019	-5.0007	-0.4558
Major Diseases	Ref. No				
One	-0.7703	1.1576	0.506	-3.0503	1.5098
More than one	1.2314	1.0180	0.228	-0.7737	3.2367
Diagnostic check					
R-Square	0.4103				
RMSE	6.2305				
F-Stat	9.0076 (*p*-value < 0.001)				

[a] represents significance at 1% level, [b] represents significance at 5% level and [c] represents significance at 10% level

serious illnesses has a statistically significant negative impact on the mental health of workers. In comparison to workers without a major disease, those with any one major disease have a lower mean score of 4.7755 [SD = 1.09; 95% CI = -6.92 to -2.64] units (on average), and those with more than one major disease have lower mean score of 8.3633 [SD = 0.96; 95% CI = -10.25 to -6.48] units (on average). In this study, the effects of gender, marital status, education, working hours, and workplace health risks on mental health are found to be statistically insignificant.

Discussion

This study has explored food insecurity among workers from informally operated enterprises who belong to low-income and socially disadvantaged community. The empirical investigation of this study has found that workers experiencing moderate to severe food insecurity are more likely to face poor health status (physical and mental) than their food secure counterpart. This finding is congruent with past research that showed food insecurity to be associated with multiple health outcomes, e.g., poor sleep outcomes [18], cardio metabolic risk

Table 4 Result of Multivariate linear regression for mental health components (MCS-12)

Variables	Coefficient	Std. Err	*p*-value	95% CI	
Age	Ref. 18–30 Years				
31–40	-0.4954	1.0920	0.651	-2.6463	1.6555
41–50	2.5476[c]	1.4598	0.082	-0.3274	5.4232
≥ 51	3.0691[b]	1.5451	0.048	-0.0257	6.1126
Gender	Ref. Male				
Female	1.2255	1.2655	0.334	-1.2672	3.7182
Marital Status	Ref. Unmarried				
Married	0.4349	1.0024	0.665	-1.5394	2.4092
Education	Ref. No education				
Primary	-0.3241	1.2274	0.792	-2.7417	2.0935
Secondary	-0.3808	1.3036	0.770	-2.9484	2.1868
≥ Higher secondary	3.1381	2.4148	0.195	-1.6181	7.8944
Family Size	Ref. ≤ 4				
> 4	1.4474[a]	0.8323	0.083	-0.1919	3.0867
Monthly expenditure	Ref. ≤ 15,000 BDT				
15,001–30,000	-0.7046	0.8969	0.433	-2.4712	1.0619
> 30,000	3.2418 [b]	1.3827	0.020	0.5182	5.9654
Working hours	Ref. < 8 h				
8 h	0.9367	2.5331	0.712	-4.0527	5.9262
> 8 h	-0.3428	2.2991	0.882	-4.8711	4.1855
Moderate to severe food insecurity	Ref. No				
Yes	-3.5794 [a]	1.0262	0.001	-5.6007	-1.5581
Satisfaction in workplace	Ref. Happy				
Moderately happy	-3.8684 [a]	1.3072	0.003	-6.4433	-1.2934
Not happy	-5.6789 [a]	1.6569	0.001	-8.9424	-2.4154
Health risk at workplace	Ref. No				
Yes	0.8037	1.0828	0.459	-1.3291	2.9365
Major Diseases	Ref. No				
One	-4.7755 [a]	1.0865	< 0.001	-6.9155	-2.6356
More than one	-8.3633 [a]	0.9554	< 0.001	-10.2452	-6.4813
Diagnostic check					
R-Square	0.5085				
RMSE	5.8476				
F-Stat	13.3938 (*p*-value < 0.001)				

[a] represents significance at 1% level, [b] represents significance at 5% level and [c] represents significance at 10% level

factors [63], hypertension [66], and cost-related underuse of medication [1]. Conversely, low-income working community with lack of job security can face financial hardships in managing their health conditions, which increases the subsequent risk of their food insecurity [36]. However, the cross-sectional nature of this study limits the understanding of the causal direction of the association, although both directions seem reasonable. The observed relationship between poor mental health status and severe to moderate food insecurity among workers in this study is supported by Jones [38]. The findings of this study are also in line with the studies of Brucker [14], Alvarez et al. [7], and Ziliak and Gundersen [79] that were conducted on adult populations with different characteristics. Besides, a few studies that were carried out in Bangladesh are also noteworthy in this context. Examining 176 informal waste workers in Bangladesh, Haque et al. [27] found that 81% of the participants went through psychological distress amid the COVID-19 pandemic. This study has also reported that during the pandemic many households were severely affected by a food crisis, which ultimately put them under mental strain with an increased risk of developing symptoms of poor mental health. The study by Rahman et al.

[58] also revealed the deteriorating food insecurity statistics during the pandemic period which increased stress levels in Bangladesh. However, to the best of our knowledge, this is the first study to demonstrate an association between food insecurity and health status among low-income informal manufacturing workers, who are the severely affected section of the economy in the COVID-19 pandemic.

Aged workers (over 40 years) in the sample experience low mean score on the physical health component, implying that aging is negatively associated with workers' physical health status. Older people are more likely to suffer from chronic diseases that require medication and more frequent medical visits. Low-income working adults hardly can afford that, and their physical health status deteriorates with age. However, it has been found that age positively correlates with workers' mental health. This result is in line with the research by Lau et al. [44] and Shamshirgaran et al. [68]. According to the findings of Lau et al. [44], older people had poorer physical health than those aged 18 to 34 years, but older people had better mental health related quality of life. Similarly, the findings of Shamshirgaran et al. [68] supported the notion that physical health deteriorated with age while mental health improved. Numerous empirical studies have supported the paradox of declining physical health but improving mental health with age, as was discussed by Thomas et al. [72]. Because older people are typically better at controlling their emotions and making complex social decisions, that improves mental health with age [12, 25]. Older people are also better able to cope with stressful changes [12, 37, 61]. Additionally, aging leads to an increase in wisdom and better mental health in later life [50, 78].

The study has found female workers to be more susceptible to weak physical health conditions. Informal women workers are more vulnerable with low incomes and high levels of food insecurity, increasing the risk for poor health, which is consistent with the finding of Horwood et al. [29]. However, Haque et al. [27] have found that female informal waste workers experience significantly more psychological distress than males in the context of Bangladesh. The study by Lau et al. [44] revealed that women scored worse on both physical and mental health. Family size of more than four members is strongly negatively associated with physical health, while it is weakly but positively associated with the mental health of workers. In low-income countries, early marriage, misconceptions about family planning, lack of access to health services, religious beliefs are connected to larger families and are often responsible for lowering health status. It is often seen in low-income families, in which parents live with hunger to feed their kids in days of extreme food crisis. However, in these social structures, children carry the family legacy and usually support their families' livelihoods. Children may enter the labor force illegally and earn money for the family. In some cultures or communities, it is thought that the larger the family, the more blessed the family is. Besides, larger families may provide more opportunities for social support and caregiving, which can benefit mental health [10, 15, 71].

Monthly expenditures of more than BDT 30,000 can't ensure physical health but can ensure mental health. The risk of developing mood and anxiety disorders is inversely correlated with disposable income and expenditure levels. Increased income and consequently increased expenditure may ease financial strain and give people a sense of security and control, which can act as a protective barrier against the damaging effects of stress on mental health as mentioned by Sareen et al. [64], Li et al. [46] and Thomson et al. [73]. Dissatisfaction with the work environment deteriorates both the physical and mental health related quality of life. Workers in the informal manufacturing sectors often report job dissatisfaction due to reasons such as low pay, working more than 8 h a day, job insecurity, unhealthy working conditions, abusive and exploitative environment. This finding is consistent with the finding of Fisher et al. [23] that reported job dissatisfaction with a strong correlation with symptoms of anxiety and depression. Besides, occupational health risks such as accidents while working or illness due to coming across poisonous chemicals contribute significantly and inversely to the physical health status of workers. Finally, the prevalence of major diseases is strongly and negatively related to workers mental health. This is in line with the findings of Alessi et al. [6] and Khandaker et al. [42] that stated any major disease such as heart disease and diabetes as increasing risk factor for mental health issues.

While empirical investigations have confirmed the objective of this study- association between food insecurity and health status- the results should be interpreted with caution given the limitations of this study concluded here. The first limitation is data constraint. The national datasets rarely provide information on the economic activities of micro businesses, especially of those that are not registered with the Industry and Commerce Department. While collecting primary data, the study faced movement restrictions and enterprise closure due to lock down and the pandemic context. This constraints the study to find a sufficient number of samples to make it more representative. The second limitation is the cross-sectional nature of this study, which precludes making causal inferences. The third limitation is that the predictor and outcome measures are based on self-report, which may be subject to response bias. The fourth

limitation is the possibility of unmeasured confounders, although this study has tried to add a number of potential confounders, including age, sex, marital status, education, family size,, and health hazards related to the work place.

Conclusions and policy suggestions

The present study adds insight to the existing literature on the nexus between food insecurity and the health status (both physical and mental) of working adults in informal settlements. The study uses a cross-sectional research method with primary data on workers from three categories of informal enterprises operating in three different areas of Dhaka city, Bangladesh. The food insecurity index is constructed from the collected data following FAO guidelines and SF12v2 mean scores are calculated to assess health status of informal workers based on self-reported PCS and MCS. The multivariate regression analysis has been applied, confounding with some socio-demographic and health-related factors, and the results show that moderate to severe food insecurity is a significant risk factor for the physical and mental health of informal sector workers. Moreover, age over 40 years, gender (female), a large family size, workplace dissatisfaction and health risks at work all negatively impact physical health status. Besides, age over 40 years, dissatisfaction with the work place, and the prevalence of one or more major diseases impact mental health status negatively, while a sufficient monthly expenditure positively impacts the mental health of the workers.

Given the overwhelming dominance of informal activities in developing countries, skills and productivity improvement of workers in the informal sector is a significant concern, for which ensuring a good health status is imperative. According to the ILO [33], pandemic circumstances require an immediate response to recovery, which cannot separate health from economic issues and to compensate for the loss of or reduction in economic activity, providing income and food support to individuals employed in informal settlements and to their families is the immediate policy response. Because food support for individuals in informal enterprises can ensure health and enhance productivity of workers by reducing their need to access health care services that are already limited for informal workers [33]. The outcome of this study has empirically confirmed these needs by establishing an inverse relation between food insecurity and health outcomes for informal sector workers in urban Bangladesh. This study expects to contribute to the argument in favor of the informal sector similar to the ILO. Such contribution will aid in containing the proliferation of pandemic-led economic meltdown as the informal sector is expected to incorporate strongly in post-pandemic economic restoration due to its potential to grow faster in periods of economic crisis with relative ease in creating new jobs (see [4, 48]). The outcome will also contribute to the Sustainable Development Goal 2 (SDG 2), where countries are committed to ending hunger and achieving food security by the year 2030 through the fulfillment of SDG target 2.1 (ensuring access to sufficient, safe, and nutritious food for all people, especially for the poor and people in vulnerable states all year round).

To address the urgent need to protect lives and livelihoods in a COVID-19 affected world, it is crucial to extend social and economic protection such as, universal health coverage and income support, to those most affected. This includes youth, women, older, and migrant workers in informal jobs who are poorly protected and low-paid [33]. Food insecurity issues among workers should be addressed carefully by the social community, local authorities, and enterprises. They should provide sufficient income and operate under a care system linking nutrition assistance and food support. Workers should take under routine health care practices. Enterprise-based food banks may aid in improving food insecurity among workers, particularly the elderly. Consumption support through transfers can also be helpful. It can be in cash if food markets are working and in kind, if they are not. The existing stigma of receiving food assistance might have increased mental stress and despair for those who were not food insecure before. This can be an argument for why food insecurity is associated with mental health. Therefore, measures should be taken to introduce food assistance as a social support system that may reduce the stigma and shame associated with accepting food support, either in cash or kind. Enterprise owners should come forward and address the physical and mental health status of workers carefully, as it is linked to productivity. The finding of this study- the identification of food insecurity as a determinant of health status from individual-level demographic and economic characteristics of a particularly vulnerable community- can assist the government and other organizations in targeting assistance and strategies. The findings of this study also emphasise on the need for randomized safety inspections in informal enterprises that can reduce injury rates, ensure health safety, and encourage a decent work environment. The formation of labor unions and their active role in the informal sector can boost the voice of workers, push for the prioritization of minimizing the formal-informal wage gap, and ensure health and safety issues in the workplace.

In the food availability category, Bangladesh scored the highest, 64.4 [24]. Still, it needs to develop its food supply and distribution adequacy by improving road, air, port, and rail infrastructures, modernization of

food policy, corruption minimization, and political stability. Bangladesh should enhance the operation of the food safety net programs. In the post-pandemic economic context, effective measures and policies to save workers and bring back economic productivity must combine healthcare efforts with consumption support. Moreover, protecting workers' rights, following workplace safety rules and other health practices, and ensuring access to decent work in all enterprises are decisive in addressing the health dimension of the ongoing crisis.

Acknowledgements
The authors thank to all the participants of the survey for their valuable contribution to the study. Thanks to the anonymous reviewers for their valuable contribution to the work that helps to the qualitative improvement of this manuscript.

Authors' contributions
Nahid Sultana has planned for the study, prepare the questionnaire, coordinated the project and has written the main manuscript; Mohammad Mafuzur Rahman has revised the first and second draft, provided corrections and suggestions; Rasheda Khanam has revised the second draft and provided corrections that are incorporated in the final manuscript; Istihak Rayhan has contributed to the planning, questionnaire, data curation, software handling and result preparation; Roni Hossain has supervised data collection process and coordinated the project. All authors read and approved the final manuscript.

Funding
This research has received no funding.

Availability of data and materials
The datasets generated and analyzed during the current study are not publicly available since it is a part of an ongoing research project. However, data can be available from the corresponding author on reasonable request with the consent of UniSQ.

Declarations

Ethics approval and consent to participate
This is a statement to confirm that all the procedures of the interviewer-administered survey for this study were approved by the Human Research Ethics Office (HREC) of the University of Southern Queensland (UniSQ), Australia. The reference number of the approved ethics file is.
UniSQ HREC ID: H21REA014. I can confirm that all methods were performed in accordance with the relevant guidelines and regulations.
This is also to state that informed consent was obtained from all the subjects. Each of the persons who participated in the interview put his/her signature on the approved (by HREC,UniSQ) consent form before commencing the interview as an agreement to take part in the interview.

Consent for publication
Not applicable for this study.

Competing interests
There is no conflict of interest with respect to this article.

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Received: 24 July 2022 Accepted: 11 April 2023
Published online: 20 April 2023

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Publisher's Note

5.3 Link and Implications

This chapter highlights the need for extending social and economic protection to informal sector workers in terms of income support and health coverage, given the issue of working poverty and food insecurity in this sector. The health status of informal workers is closely linked to their productivity and that of informal enterprises, where labor often replaces capital. In addition, social determinants, including food insecurity, can cause health effects through various pathways of environmental exposures. These social determinants are driving forces that put pressures on the environment, leading to changes in its state, and creating exposures that cause health effects. For instance, urban informal workers with low incomes and inadequate social protection are more likely to live and work in an unhealthy environment and be exposed to pathogens and disease vectors. Unfortunately, there is a lack of research on many of these inter-linkages, which impedes the quantification of their impact (Kjellstrom et al., 2007). Therefore, to address this knowledge gap, the next chapter examines the environmental burden arising from the growth of informal manufacturing, which can be considered as pressure on environment, and analyzes the environmental health risks on the production prospects of informal firms.

CHAPTER 6: ENVIRONMENT AND INFORMAL SECTOR

6.1 Introduction

The societal impacts of industrial pollution caused by economic activities have become a global concern due to their adverse impact on the environment and human health (Song et al., 2017). In South Asian countries, the joint effect of urbanization and informal activities has led to a significant increase in environmental degradation (Qayyum et al., 2021). The relationship between informal industrial activities and environmental pollution is complex and multifaceted. To gain a deeper understanding of this topic, this research investigates the pollution (metallic pollution) load caused by informal industries in urban areas. **Study 7** under Section 6.2 presents the details of the scientific investigation on pollution components, and empirical analysis to assess the impact of pollution on the economic efficiency level of selected informal manufacturing firms. This analysis aims to understand the green growth prospects of the informal sector in urban areas and identify pathways to promote eco-efficiency in informal manufacturing enterprises that will lead to cleaner production. Eco-efficiency is an index of sustainability (Liu et al., 2017) and this study aims to contribute to its promotion. The impact of informal economic activities on environmental degradation is an insufficiently addressed topic in the literature. **Study 8** in Section 6.3 explores the nexus of informal economic activities with environmental degradation for emerging economies in the presence of formal, institutional, and other factors where the findings justify the need for cleaner production in informal enterprises.

6.2 Study7

Heliyon 9 (2023) e14583

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Investigating the prospect of cleaner production in informal enterprises: A scientific assessment of environmental burdens and economic efficiency

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ARTICLE INFO

Keywords:
Informal sector
Cleaner production
Eco-efficiency
Metalloid pollution
Pollution load index
Data envelopment analysis

ABSTRACT

The present study aims to assess the prospects for cleaner production (CP) and sustainable development (SD) of informally operated small manufacturing enterprises, which are frequently blamed for uncontrolled waste disposal and causing pollution to the environment. The economic efficiency level of these firms has been explored to this end, and the metallic pollution loads in the surrounding environment have been scientifically analyzed to investigate the nexus between these two. DEA (Data Envelopment Analysis)-Tobit analysis has been employed, and a pollution load index (PLI) of heavy metal pollution comprising two environmental compartments (soil and water) has been constructed based on the concentration level of metalloid pollutants in the samples collected from the surrounding areas of the studied informal firms in Bangladesh. The study disproves CP practice in majority of the informal firms in Bangladesh by observing a positive relationship between firm-level efficiency and pollution load sourced from their production activities. Afterwards, this study estimates the eco-efficiency level of firms by considering pollution load as an undesirable output and minimizing its impact in an input-oriented DEA model. Applying the eco-efficiency scores in censored Tobit regression analysis, the outcome endorses the prospect of CP for informally operated enterprises in Bangladesh. However, the CP prospect can only materialize if and only if firms are provided with adequate technical, financial, and strategic support for achieving eco-efficiency in their production. The informal and marginal nature of the studied firms restricts them from getting access to the facilities and support services needed for implementing CP and moving towards sustainable manufacturing. Therefore, this study recommends green practices in informal manufacturing and limiting the informal firms by bringing them gradually under the coverage of formalization, which is in line with the achievement of the targets mentioned in Sustainable Development Goal 8.

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https://doi.org/10.1016/j.heliyon.2023.e14583
Received 8 December 2022; Received in revised form 9 March 2023; Accepted 10 March 2023
Available online 15 March 2023

1. Background

Industrial pollution appears to be a global concern since it is not only associated with earth heating and environmental degradation but also imposes a significant impact on human health [1,2]. It generates health nuisance materials that affect people's health by causing various chronic diseases contributing to premature mortality, and lowering fertility rates that ultimately hinder the economic growth of a country [1,3,4]. Therefore, research on industrial pollution becomes crucial in the fight against global environmental degradation [5]. At the same time, a modification in industrial economic structure from unsustainable to sustainable has also become important as a target to make it more meaningful [6,7]. Cleaner production (CP) has emerged as a strategy to this end by promoting less polluting industrial processes that lower risks to humans and the environment. CP focuses on the implementation of waste and pollutants minimization by eliminating the use of toxic raw materials and reducing the quantity of toxic wastes and products through efficiency improvements in the production process [8–10]. CP is important for firm management as it enhances profit, reduces resource use and pollutant emissions, and ensures workplace safety [8], which attributes to the achievement of sustainable development (SD) [10]. Improvement in existing production efficiency through the implementation of clean technology is a way to develop CP [9,11] that aids efforts towards SD [12]. Therefore, more and more researchers are now advocating for efficiency improvement based on environmental judgments that hold an important role not only in CP but also in sustainability studies [7,13,14]. The present study has contributed to this by considering the industrial productions under the informal sector since they often become pollution-intensive, which fosters a number of environmental problems in some emerging and developing countries [15,16].

The informal sector, which captures three interlinked dimensions: informal units, informal activities, and informal employment [16], was officially recognized by the International Labor Organization (ILO) at the International Labor Conference in 2002. This study has considered the ILO definition of the informal sector, which takes account of all production activities taking place in the informal settlements [17]. These activities are imperfectly regulated and not subject to government scrutiny [18,19], but they become important from the perspective of employment generation and revenue earning [20–22]. Activities in this sector induce environmental degradation as they impose a serious challenge to the implementation of environmental regulations and weaken the regulatory effects on countries [15,16,23–25]. Moreover, they use low-cost modes of production and cheap labor-based technology that generate pollution and impose social costs see Refs. [26,27]. Informally operated manufacturing or metal finishing operations (such as galvanometry, electroplating, metal cleaning, leather and mining industries, dyes and pigment industries) often discharge untreated industrial wastes containing considerable amounts of heavy metal ions into nature that creates environmental pressure. Their continuous deposition in the soils and water bodies make them toxic due to high exposure duration and damage the relevant eco-system [28–30]. When informal production relocates formal sector production, augmented non-compliance with environmental regulations by informal enterprises increases pollution that needs to be addressed in the study on environmental degradation [27,31].

Under such a context, this study aims to explore the CP performance of informal manufacturing enterprises through efficiency analysis since efficiency in resource use is one of the main areas of CP, while inefficiency in the production process leads to many byproducts and wastes [32]. The study also investigates the metalloid pollution caused by informal firms in this regard, as metal-based industrial activities (in the face of rapid industrialization and urbanization), and the leaching of metals from different sources (due to various anthropogenic activities, such as landfills and waste dumps) have become a concern for the researchers. It creates environmental load and biological and physiological complications in humans along with toxicity in cases of high concentration [2,30,33]. The non-biodegradable and bio-accumulative nature of metallic pollutants has turned the research on minimizing their effects on the environment and avoiding their adverse effects on humans a top priority in these days [29,30]. The present study has contributed to this by constructing a composite Pollution Load Index (PLI) comprising two environmental compartments guided by the idea that heavy metal concentrations in water and soil sediment can be used to evaluate the anthropogenic and industrial impacts and risks caused by wastewater discharges in the soil and water bodies [34]. This study has also investigated its minimization effect by estimating eco-efficiency, which is an index of sustainability [35] and contributes to resolving the key problem in achieving SD [14].

National data on informal sector enterprises is not available. As a result, an interviewer-administered survey was conducted on informally operated firms, and soil and water samples were collected from the surrounding areas of the surveyed enterprises to identify pollution by heavy metals, specifically, lead (Pb), nickel (Ni), and chromium (Cr). Bangladesh was considered for this study because it is a densely populated country with increasing metalloid exposure and heavy metal poisoning case reports. Already, groundwater arsenic (As) contamination becomes a major public health problem in this country and causes the biggest disaster in the world [33]. Moreover, Bangladesh facilitates the indiscriminate installation of industrial units in its development process [36] that are mostly informally operated, employ 80% of the labor force, and contribute 30% of Gross Domestic Product (GDP) [37]. These micro, small, or medium-sized enterprises are found to be located in the surrounding areas of the capital city, Dhaka, and other major cities and become responsible for unplanned urbanizations and environmental crises in urban areas [36,38]. Besides, environmental regulations are routinely violated in Bangladesh due to a lack of enforcement by the relevant agencies, which appear to be corrupt, ineffective, and weak [39]. This provides an undue opportunity to firms in informal manufacturing sector, that account for two-thirds of the total informal contribution to Bangladesh's GDP [40], to cause serious heavy metal pollution through their uncontrolled waste disposal into nearby soil and water bodies [41]. This needs to be investigated for the sustainability prospects of urban development. However, there has been no formal research on the performance evaluation of informal enterprises that incorporates their link to worsening environmental crises. Overlooking this issue of the informal sector in the formulation and implementation measures of environmental policy may lead to misleading outcomes [42,43].

This study contributes to the literature in several ways. First, the economic efficiency assessment of three types of manufacturing enterprises operating in the informal sector will characterize the development of informal industrial enterprises in Bangladesh see Ref. [44]. Second, an assessment of the efficiency of informal production units and its relationship to pollution will inform

policymakers about their role in achieving eco-efficiency and their potential contribution to sustainable production. This evaluation is significant in the prospect of achieving strategic objective 'green growth' in Bangladesh, as World Bank (2004) has recognized the informal sector as a source of alternative services for the poor and crucial for inclusive development [45]. Third, the efficiency and performance assessment of informal enterprises will provide directives for the formal sector's development, as these two are positively linked in Bangladesh's economy [46]. Fourth, estimation of the unaccounted load to the environment by the construction of PLI and its inclusion in the eco-efficiency analysis. This inclusion is relevant to socio-economic and safety concerns, which were integrated into the CP concept in 1998 b y the United Nations Environment Program (UNEP).

2. Literature review

There is not much literature on the advancement of knowledge about the adoption of cleaner production (CP) practices in informal sector industries and its contribution to the Sustainable Development Goals (SDGs) from a holistic perspective. Despite having a large volume of literature on SDG, a further understanding is required to link the adoption of CP principles in informal firms with the achievements in the economic, environmental, and social dimensions of SD. Recent research works are focusing to this end. Significance of CP as an aided effort to achieve SD by conservation of raw materials and energy, removal of toxic raw materials, and reduction of the amount and toxicity of all wastes was discussed in a study by Refs. [10,12]. Economic and environmental gains resulting from the implementation of CP in small enterprises in the metal and machine industries are evaluated by Ref. [10]. According to the findings of this study CP practice through the implementation of waste water treatment stations in the manufacturing process leads to l economic gains, promotes efficient use of raw materials and environmental improvements [47]. reviewed the cleaner production concepts in the electroplating industry. They opined on the efficient use of natural resources and energy and the reduction of risks for humans and the environment throughout the lifecycle of a product, which are the core principles of CP. In a similar review [8] has stated that CP can be implemented by reducing waste and pollutants, increasing production efficiency and lowering risks to humans and environment. Based on the lessons learned from the setbacks due to the occurred incidents [7] found it necessary to upgrade the efficiency models as the negative effects of industrialization on the environment, human survival, and further production improvement became more visible with the deepening of industrialization.

Efforts to increase efficiency in manufacturing process by adopting clean technologies, replacing hazardous raw materials, improving management, initiating intensive research and development are highlighted by Ref. [9]. Using eco-efficiency of the Data Envelopment Analysis (DEA) and comparing desirable output with undesirable output [14] showed that most efficient countries in EU member states had higher economic growth and per capita income [48]. first evaluated industrial eco-efficiency in Chinese provinces using DEA and then identified the determinants of the resulting eco-efficiency scores. Technological deficits and weak environmental policies were identified as the reasons for lower industrial eco-efficiency in this study. Eco-efficiency analysis was also conducted on coal industries in China by Ref. [13], on coal industry ecosystem in China by Ref. [49], on the heavy pollution industries of China by Ref. [5], on European Railways by Ref. [50] using a network DEA model. All these studies were based on secondary data and projected efficiency trends.

The potentiality of the informal sector as a key element in the struggle towards sustainability was explored by Ref. [51]. This study focused on how the informal economy could encourage the sustainable use of resources and could offer an alternative to the regulated market economy. However, a significant relationship between informal economies and higher level of pollution was evident in a number of studies [19,49,52–58]. The findings by Ref. [27] have revealed that the environmental regulations are not effective in the informal sector and it relies on conventional energy sources. The results also revealed a mixed picture for South Asian countries in terms of their contribution to emissions. The informal sector was shown to be a long-term driver of ecological footprint levels when it was linked to formal economies in an investigation by Ref. [58] on Turkey [59]. found the positive influence of the informal sector on emissions of local pollutants and no significant impact on global pollutants, i.e., CO_2. They pointed out that since the informal sector in developing countries mostly relied on labor-intensive production techniques and utilized less energy, it led to lower levels of emissions. An inverted U-shaped relationship between the informal sector and environmental pollution was also revealed by Ref. [19] for 152 countries and for China by Ref. [60]. [55] opined that the nexus between the informal sector and environmental management should be considered the bedrock for the sustenance of urban areas in low-income countries.

Considering the diverse impact of the informal sector on environmental pollution, which can be explained by their low productive efficiency, it appears critical to assess the potential of this sector in CP, which is a significant parameter in the SDG. However, no study has been found so far that captures the performance of informal firms in CP either by efficiency or by eco-efficiency analysis. In the African context, research towards generating quality information on assessing the informal SME's potential was stressed by Ref. [21] since urban precincts of the informal sector were considered to be the root cause of many problems. In urban areas of Bangladesh [57], conducted a study on the brick kiln industries under the informal sector, and those were found to be unprofitable after incorporating the health impact and other social costs of pollution associated with this industry.

Reviewing the available literature, this study has been convinced that there exists a lack of research on CP prospects and progress towards attaining SDG targets. Firms in the informal sector are neglected in this, particularly in environmental efficiency analysis to offer quantitative evidence in the CP prospect. To fill this gap the present study subscribes to the importance of CP for informally operated firms in different industries by assessing empirically their efficiency-pollution nexus. It can provide an important insight into policy measures for moving forward with the CP agenda, particularly in the face of informal sector growth and environmental degradation.

3. Material and methods

3.1. Data

This study is conducted for informal manufacturing firms, and primary data is collected at the enterprise level from three different areas of the capital city, Dhaka, Bangladesh. The enterprises were selected based on the criteria provided by ILO (2018): unincorporated private firms with no permanent premises, registered at the local level (not at the national industrial authority), not maintaining accounts (no formal bookkeeping), no social security contribution, and no tax on wages [61]. A structured questionnaire was used to collect information from 90 enterprises (in total) that were operating informally during the period between August and December 2021. Therefore, the used data set was cross-sectional. Three types of small manufacturing industries were chosen using a stratified sampling technique. The selected industries are: leather and leather products; plastic and small machinery; dyeing and clothing. Survey areas were selected based on the information of cluster setup of the particular type of firms in the area. Hemayetpur area was selected for interviewing firms in the leather and leather products industries, Lalbagh (including Islambagh) area for plastic and small machinery, and Keraniganj area for the dyeing and clothing industries. Each area was divided into small zones for the collection of environmental samples, and firms for the interview were selected from the zones in a nearly equi-proportional manner. A total of 30 firm owners/managers were interviewed from each area, and firms with no more than 10 full-time workers were qualified for the interview [following [62]]. Before the interview, the enumerators provided sufficient information to the respondents regarding the aims and objectives of the study to avoid any bias in answering questions. Each interview began after the respondents signed the consent forms that were supplied. During data collection, researchers as well as the enumerator follow all the ethical norms considered by the University of Southern Queensland (USQ), Australia (USQ HREC ID: H21REA014).

The survey questionnaire began with the demographic information of the respondents and then moved on to the questions about the average volume of total output per month, price per unit of output, number of workers (full-time and part-time), wage per workers, average cost of raw materials. The questionnaire also enquired about firms' engagement with emission control technology, subcontracting and its type, and access to and availability of loans for business purposes. Following [63,64], this study considers labor and raw material costs (yearly) needed for the production as input variables, while output variables are divided into desirable output and undesirable output. Revenue of firms (annual sales expressed in monetary units) is considered a desirable output, and the metallic pollution load generated by indiscriminate emissions discharge from the production units in the surrounding area is considered an undesirable output variable in this study. Cost and revenue data are calculated in BDT (One Bangladeshi Taka [BDT] = US$ 0.0099 approximately as of 13th November 2022). Econometric software packages STATA version 15, DEAP version 2.1 and EVIEWS version 10 have been used for the analysis of data.

For an understanding of how polluting these industries are, a Pollution Load Index (PLI) has been constructed in this study for two environmental compartments following [28,30,65]. Samples were collected for this from the soil and water of each area [based on the study by Refs. [34,38]]. The heavy metals Chromium (Cr), Nickel (Ni), and Lead (Pb), which have been identified as the most toxic elements in the environment by the US Environment Protection Agency (EPA) [28] and are claimed to discharge to the environment at different stages of industrial production due to the untreated nature of wastewater and dumping of solid waste, are considered for investigation.

3.1.1. Construction of pollution load index (PLI)

PLI is an integrated approach that assesses soil and water quality. This process aims to investigate the metal contaminants into the surrounding environment of the studied firms due to indiscriminate effluent discharge and solid waste dumping. PLI calculation procedure was adopted from Ref. [28]. Contamination of hazardous materials (Cr, Ni, and Pb) was investigated in the surface soils and water either released from firms or stored in nearby water bodies. PLI was calculated for soil and water sample using the following formula:

$$PLI = (CF_1 \times CF_2 \times \ldots\ldots \times CF_z)^{\frac{1}{z}}$$

Where, CF represents the Contamination Factor and z is the number of samples collected from each studies area. CF is an essential tool to monitor heavy metal contamination. It is individual for each heavy metal as it is the ratio between the concentration of heavy metal (C_{hm}) and the background value of that heavy metal (C_b).

$$CF = \frac{C_{hm}}{C_b}$$

The background value of the metals are mentioned in the Appendix. All the chemical diagnosis were done in a chemical laboratory for the determination of total concentration of selected heavy metals (Pb, Zn, Cu) in both soil and water. The Pollution Load Indices (PLIs) was derived from the obtained concentration level of heavy metals in soil and water for each sample and then combined together associating with an equal weight to find a composite PLI. All the instrumental and technical supports for this scientific analysis were provided by Dr. Wazed Mia Science Research Center (WMSRC), Bangladesh and the Department of Environmental Science, Jahangirnagar University, Dhaka, Bangladesh. The details of study area, sample collection and data processing methodology for PLI construction are presented in the Appendix.

4. Methods

Data Envelopment Analysis (DEA), a non-parametric approach, is applied in this study for empirical analysis. It is a mathematical optimization technique to measure the relative efficiency of each studied unit, named a decision-making unit (DMU), that converts the input into output under the conditions of multiple inputs and outputs [66–69]. DEA (BCC) model based on variable returns to scale (VRS) [70] has been applied to this study, which is a radial model, and is widely used to evaluate environmental issues [66]. This input-oriented DEA model is a cost-saving representation of the production process that serves as an explicit measure of efficiency change even when undesirable outputs are integrated into the analysis. The decision to choose this orientation is also influenced by the probable control of the managers over input quantities see [71], in the context of the present study. DEA perceives an efficiency frontier by accepting the most efficient DMU as a reference point and calculating the other DMUs' efficiencies in a relative sense based on their distances to this reference point [66,72].

This study assumes that there are n DMUs and m inputs are used by each of them to produce Q outputs. M is the (mxk) input matrix and Q is the (qxk) output matrix where $j \in I_N : I_N = \{1, 2, \ldots, n\}$, an index of set of firms. The inputs and output vectors of the firms are expressed as $x_j \in R^m$ and $y_j \in R^q$ respectively. Economic efficiency is obtained by ensuring maximum benefit from a given cost or minimizing the cost of a given benefit. In this study efficiency (allocative) describes the use of two inputs namely, labor and raw materials by DMUs in the proportion that minimizes the cost of production when input prices are given [73]. The model (model-1) can be stated as follows:

$$Min\ \vartheta_e$$

s.t.

$$\sum_j v_j y_{qj} - s_q^+ = y_{qe}, q = 1, 2, \ldots, Q$$

$$\sum_j v_j x_{mj} - \vartheta_e x_{me} + s_m^- = 0, m = 1, 2, \ldots, M$$

$$\sum_j v_j = 1$$

$$\mathrm{v_j} \geq 0, \mathrm{j} = 1, 2, \ldots, \mathrm{n}$$

$$\mathrm{s_q^+} \geq 0, \mathrm{s_m^-} \geq 0, \forall \mathrm{q, m}$$

Where, DMU e is the unit under evaluation and ϑ_e is the efficiency scores.

4.1. Tobit regression model

Tobit regression, a variable limited model, is used to investigate how environmental and production management factors affect firm efficiency level. In Tobit regression, the dependent variable is modelled as the censored data, where the observation of compliant drivers can be clustered at a threshold value of zero (left censored in Tobit literature). Non-compliant drivers are kept as continuous data for representing the magnitude of non-compliance [35,74]. Tobit regression can be expressed as

$$Y_i^* = \alpha + \beta X_i + \varepsilon_i i$$

$$Y_i = Y_i^*, if\ Y_i^* > 0$$

$$Y_i = 0, if\ Y_i^* \leq 0$$

Where, Y_i is the dependent variable calculated using a latent variable Y_i^* for positive values and censored otherwise. X_i is a vector of independent variables, α is the intercept vector and β is the coefficient vector. ε_i is the error term where $\varepsilon_i \sim (0, \sigma^2)$. Maximum likelihood (ML) method is more appropriate in this cases since the ordinary least squares (OLS) regression projects biased result where the dependent variable is partial continuous. Here the dependent variable is the efficiency index that is bound between 0 and 1 values and derived from DEA. The firm level efficiency function can be written as:

$$E_i = \alpha + \beta_{1i} PLI_i + \beta_{2i} Tech_i + \beta_{3i} Loan_i + \beta_{4i} Subcont_i + \varepsilon_i$$

Here, E_i represents DEA VRS efficiency scores, i indicates the number of DMUs, The independent variables considered in this model are pollution (*PLI*), use of pollution reducing technology (*Tech*), access to loan (*Loan*) and engagement of firms in subcontract arrangement (*Subcont*). Since it is difficult for informally operated production units to unveil the exact level of emissions and the pollution damage estimate values for each DMU, indexed values of metalloid pollution load (PLI) in soil and water are used as the main explanatory variable by allotting those to the relevant firms. Use of pollution reducing technology [64], access to loans, and engagement of firms in subcontract arrangements that may influence business strategy [mentioned by Ref. [75]] are also considered as

influencing factor of economic efficiency along with PLI [35,64,76]. The selection of these explanatory variables is guided by a disregard for environmental practices, such as waste reduction and proper dumping, minimum resource use, and recycling [77,78], as well as limitations in capital and labor performance, firm management, and technology adoptions by informal SMEs [77,78] that provoke the assumption of the presence of undesirable outputs (i.e. pollution) in the production process of informal firms [7].

Since the solution of the ecological problems is the key to achieving sustainable economic, social, and ecological development, this study has applied DEA for environmental analysis and estimated eco-efficiency in the next stage, where undesirable (bad) outputs such as pollution or emissions also come into consideration apart from inputs and desirable (good) outputs [13,79–81] Production process improvement was the first of four basic approaches to eco-efficiency proposed in WBCSD (1992), and the present study attempts to focus on that through eco-efficiency assessment for the achievement of SD. Schaltegger and Sturm (1990) first proposed the concept of eco-efficiency in 1990 which involved the creation of more economic value with less environmental impact [7,82]. The current study adheres to Li and Luo's (2016) definition of environmental efficiency, where it is implied by a certain area that uses fewer environmental resources and produces less ecological impact to provide products and services targeting to meet human needs [5,11]. Eco-efficiency deals with the key problem in achieving SD by progressively working with the aim of obtaining more economic benefit with least environmental damage [14].

At this stage, $y_j = (y_j^g, y_j^b)$, which indicates the total output vector is separated into two sub-output vectors, where, $(y_j^g : q \in I_g : I_g = \{1, 2, \ldots, k\})$ is the k output vector of desirable outputs, and $y_j^b : q \in I_b : I_b = \{k+1, k+2, \ldots, Q\})$ is the remaining $(q-k)$ output vectors that are undesirable (bad) outputs i.e. environmental load (PLI) created by unaccounted pollutant discharge but remain unaccounted. Undesirable outputs can be treated as inputs, and the idea was proposed by Ref. [83]. [84,85] applied this to calculate environmental efficiency [16]. This method infers a negative effect of undesirable output levels on efficiency, and hence it is non-decreasing in desirable outputs and non-increasing in undesirable outputs. In this study, the eco-efficiency of firms is captured by reducing resource usage and decreasing environmental damage [84]. Taking insight from Refs. [67,80,86,87] the input oriented model (model-2) with undesirable output (as input) can be stated as,

$$Min\ \vartheta_e$$

s.t

$$\sum_j \nu_j y_{qj}^g - s_q{}^g = y_{qe}^g, q = 1, 2, \ldots, Q^g$$

$$\sum_j \nu_j y_{qj}^b - \vartheta_e y_{qe}^b + s_q{}^b = 0, q = 1, 2, \ldots, Q^b$$

$$\sum_j \nu_j x_{mj} - \vartheta_e x_{me} + s_m{}^- = 0, m = 1, 2, \ldots, M$$

$$\sum_j \nu_j = 1$$

$$\nu_j \geq 0, j = 1, \ldots\ldots\ldots, n$$

$$s_q^g \geq 0, s_q^b \geq 0, s_m^- \geq 0, \forall q, m$$

5. Results

5.1. The results from the estimation of PLI

The summary statistics of the concentration factor of selected heavy metals in soil and water samples collected from the studied areas are presented in Table 4 of the Appendix. Environmental samples were collected in the period August–December 2021 (a juncture of wet and dry seasons) and the scientific investigation found a base level of contamination for most of the studied metals in

Table 1
Results of Contamination Factor (CF) analysis and PLI.

Location	Soil					Water				
	Pb	Ni	Cr	Degree of Concentration	PLI	Pb	Ni	Cr	Degree of concentration	PLI
Hemayetpur	0.01	0.16	1.29	1.45	0.05	0.05	0.38	50.16	50.69	0.95
Lalbagh	2.34	0.53	0.12	2.98	0.52	0.45	0.22	0.01	0.67	0.02
Keraniganj	6.41	0.17	0.05	6.63	0.39	0.01	0.51	4.23	4.23	0.10

Note: Background value of the metals: Pb 20, Ni 49 and Cr 97 [Sources [28,98]].
PLI = 0 => Perfection, PLI<1 => Baseline Level Contaminants.
PLI> 1 => Progressive deterioration of soil due to metal.

the collected soil and water samples. Only a few samples of soil and water projected a high contamination factor score. The results of concentration factor analysis and area wise PLI scores are presented in Table 1. These results are also presented graphically in Figs. 1 and 2 for soil samples and in Figs. 3 and 4 for water samples. Flow diagram of environmental parameter analysis is presented in Fig. 6 of the Appendix. The applied procedures of water and soil samples digestion for metal detection are presented diagrammatically in Figs. 7 and 8 of the Appendix, respectively.

Table 1 projects that the levels of metal contamination in soil and water samples of all three studied areas are low (less than the first cutoff value 8), except for Cr in the water sample from Hemayetpur and for Pb in soil sample of Keraniganj. The contamination factor (CF) was the highest for Cr in water samples collected from Hemayetpur area. Its CF value for soil was 1.29, indicating a moderate level of contamination, and for water it was 50.16, indicating a very high level of contamination. Other heavy metals (Pb and Ni) were found to be at a low level in the areas. As leather tanning industries, where chrome tanning is used in the tanning process, are located in the Hemayetpur area, tannery industries can be identified as a possible source of Cr pollution. Workers, entrepreneurs, and residents of this area remain at high health risk due to Cr pollution in the area since Cr is mutagenic and carcinogenic to humans [88].

At Lalbagh, the CF value of Pb in soil was 2.34 and in water was 0.45, indicating moderate and low-levels of contamination, respectively. The CF values of Ni in soil and water samples of the Lalbagh area were 0.53 and 0.22 respectively, which indicated a low-level of contamination. Ni is commonly used as a major alloying element [89], so the likely sources of Ni in the studied samples were the machinery industries nearby. Pb stabilizers such as Pb sulfate, Pb stearate, etc., are used as common additives [90–92], and the probable sources of Pb in the samples are the nearby plastic industries. Dermal absorption of Pb and Ni into the human body may impose an important risk for developing cancer [60,93].

At Keraniganj, the CF value of Pb in the soil was 6.41, indicating a very high level of contamination, and the CF value of Cr in the water was 3.71, indicating a considerable level of contamination. As an individual metal, the CF value of Ni was highest in the water samples of Keraniganj (0.51), although it indicated a low-level contamination. Pb and Cr are widely used in the production of color pigments for textile dyes [94]. Hence, nearby textile dyeing industries were the probable sources of Pb and Cr discharge that are mutagenic and carcinogenic to humans [88,93].

5.2. Result of efficiency analysis

The summary of the utilized DEA model is presented in Table 5, and the summary of input and output variables used in efficiency estimation is presented in Table 6 of the Appendix. The relative efficiency scores of firms under each category of industries (the DMUs) are obtained from the estimation of an input oriented DEA model where pollution load has been ignored (model 1). The result (obtained from using econometric software DEAP version 2.1) is presented in Table 7 of the Appendix. Variable Returns to Scale (VRS) represents the measure of the amount by which all inputs can be reduced to produce the same output as the DMUs move from the variable returns to scale frontier to the constant returns to scale frontier. However, the VRS scores in the DEA outcome reveal a very low level of efficiency for all categories of informal enterprises, which is quite expected due to their informal organizational structure. Under the assumption of VRS, the average CRS efficiency score of selected firms in the leather industry is the lowest at 8.6%, and the average VRS efficiency score is 13.8%, which implies that on average, leather firms are highly inefficient in economic considerations. For scale efficiency, the average score is found to be 67.9%, which indicates that the actual scale of production has diverged by 32.1% on average from the most productive scale size in leather industries. The average CRS score for studied firms under plastic and small machinery is 33.9%, and the average VRS score is 44.2%, while their average scale efficiency is 77.5%. Selected firms in the dyeing and clothing industries project an average CRS score of 24.7% and a VRS score of 37.7%, although their scale efficiency score is 77.3%.

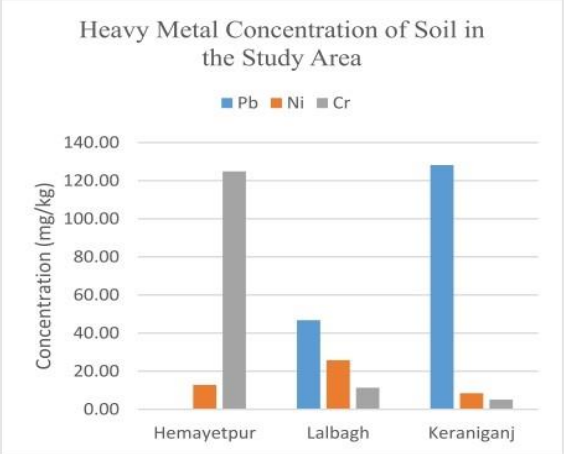

Fig. 1. Heavy metal (Pb, Ni, Cr) concentration in soil.

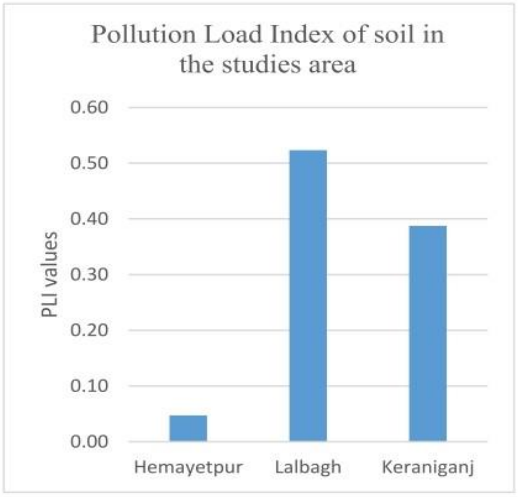

Fig. 2. PLI for soil sample in three studies area. Source: Author's own calculation.

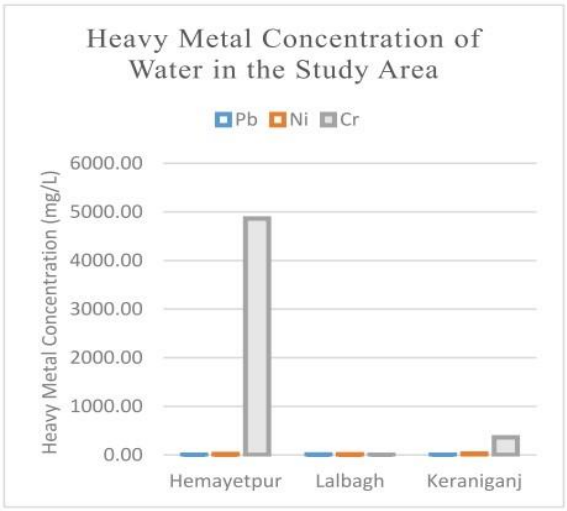

Fig. 3. Heavy metal (Pb, Ni, Cr) concentration in water.

5.3. Result of tobit regression

The Tobit regression result is presented in Table 2. The outcome reports that the economic efficiency levels of two out of the three categories of informal firms are significantly linked to the pollution generated by the firms.

The efficiency levels of firms in the leather, and dyeing and clothing industries are positively associated with the pollution level of the surrounding area, for which the firms themselves are responsible. The positive and significant correlation between these two variables reveals the fact that a high level of pollution is the inevitable cost of efficiency for informally operated firms in these two industries. This indicates, economic efficiency can be achieved or enhanced in these firms at the cost of the environment due to their dependency on low-cost environmentally harmful inputs and/or production technology, unskilled cheap labor, indecent work conditions, and poor waste disposal practice as the cost-minimizing strategy. The PLI Coefficient for firms in the plastic and small machinery industries has come up with a negative sign (which is expected in an ideal context), and projects no significant relationship with efficiency. The low level of pollution concentration in the surrounding area of the plastic and small machinery firms and the comparatively higher level of efficiency scores may contribute to this relationship. This result has confirmed that informal firms in the

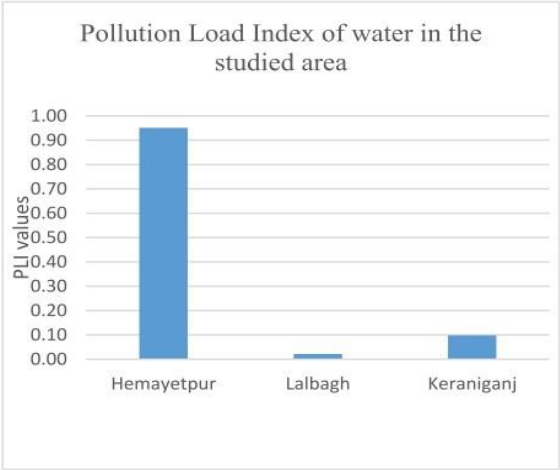

Fig. 4. PLI for water sample in three studies area. Source: Author's own calculation.

Table 2
Result of Tobit regression.

Explanatory variables	Leather industries			Plastic and small machinery industries			Dyeing and clothing industries		
	Coeff	SE	t-score	Coeff	SE	t-score	Coeff	SE	t-score
PLI	0.015***	0.005	3.02	−0.010	0.008	−1.16	0.025***	0.006	4.40
Tech	0.037	0.037	0.41	−0.097	0.149	−0.76	−0.161	0.102	−1.58
Loan	0.136	0.088	1.55	−0.109	0.144	−0.65	−0.038	0.098	−0.39
Subcont	−0.016	0.082	−0.20	0.051	0.133	0.38	−0.058	0.091	−0.63
Cons	−0.069	0.102	−0.68	0.574***	0.167	3.44	0.303	0.114	2.66

Note: *** represents statistical significance at 1% level, ** represents statistical significance at 5% level and * represents statistical significance at 10% level.

leather, and dyeing and clothing industries are polluting and operating far from CP practices in their production, whereas the firms in the plastic and small machinery industries pose no threat to CP.

5.4. Result of Eco-efficiency analysis

This study attempts to find the future CP prospects of informal firms by estimating efficiency scores after addressing environmental issues in the model, having confirmed the positive correlation between pollution and economic efficiency of informal firms in two industries. Fig. 5 depicts the average economic and environmental efficiency scores of informal firms operating in three industries.

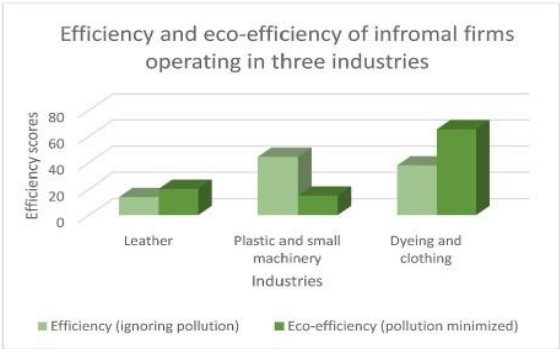

Fig. 5. Average economic and environmental efficiency of informal firms operating under three industries.

In the eco-DEA model, pollution load, which is an undesirable output of informal production, has been minimized with other inputs considered. The average VRS efficiency scores are found to be increasing in the eco-DEA model estimation outcome for two categories of industries that are polluting. Average efficiency increases by 6.3% for firms in the leather industry and by 27.6% for dyeing and clothing industries after minimizing the pollution load like other inputs. However, efficiency decreases by 29% for the plastic and small machinery industries, may be due to observed insignificant pollution load in the environmental components of the surrounding area of these firms. The scale efficiency of firms in all industries decreases after minimizing pollution load in production. This indicates the high cost of pollution abatement, which enhances the economic vulnerability of firms in the prevailing context and is the ultimate reason for not approaching towards eco-efficiency. The details of the eco-efficiency estimation outcomes (obtained from using econometric software DEAP version 2.1) are presented in Table 8 of the Appendix, while the results of Tobit analysis incorporating eco-efficiency outcomes with the same independent variables are presented in Table 3 below in order to confirm the pollution-eco-efficiency nexus.

The results in Table 3 show that the correlation between pollution and eco-efficiency becomes insignificant for the informal firms in most of the industries (Plastic and machinery, and dyeing and clothing) and it projects a significant negative relationship for the firms in leather industry, which is expected in general. Access to loans increases eco-efficiency for the firms in leather industry whereas access to loans and subcontract agreements both contribute to increase the eco-efficiency of firms in plastic and small machinery industries.

5. Discussion

In the prevailing scenario, metallic pollution, for which informal manufacturing firms are responsible, is significant in its relation to economic efficiency of informal firms for most of the categories under study (the leather and dyeing and clothing industries). The higher the level of pollution, which is sourced from their own production practices, the greater the economic efficiency for firms in these industries. However, this nexus can be altered along with efficiency improvement if firms move to achieve eco-efficiency by minimizing their pollution load. Only these practices and measures taken by informal firms for pollution reduction and control can help materialize the CP agenda in informal industrial units and lead to the achievement of SDG targets. However, a reduction in scale efficiency in an attempt to minimize pollution indicates that environmental considerations drag firms further away from the optimal operation since firms have to face technical and financial constraints to bear the expenses associated with minimizing pollution load. This will make firms less competitive unless they receive any external support.

The environmental efficiency estimated in this paper is relative. These efficiency results are in line with the findings of [95,96] for China. The increase in efficiency levels of polluting firms after their pollution minimization may be due to the fact that environmentally legitimate firms can attract customers and utilize labor and resources more successfully than poor performers [39]. Another reason may be that a less polluted work environment helps to promote sound health and increases the productivity of workers and entrepreneurs. The eco-efficiency outcome of this study finds the future prospect for CP in informal sector enterprises in the urban areas of Bangladesh if and only if enterprises and other stakeholders take adequate measures to address firm-level pollution issues. In the present scenario, achieving eco-efficiency in informal firms is a far-reaching goal since they are not financially and technologically capable enough to carry out CP practices in their production process. They needs considerable attention from policymakers, governments and non-governmental organizations for the realization of sustainable manufacturing, Otherwise, it will take a toll on the surrounding environment and people's health in the neighborhood of the informal firms. This result justifies Target 3 under SDG 8 for the productivity improvement and gradual transformation of informal firms towards formalization since they impose a threat to the environment and human health that should be prevented with proper attention.

6. Conclusion and policy suggestions

This study has estimated the economic efficiency level of firms operating in the informal sector of urban Bangladesh by adopting an input-oriented DEA method and has explored pollution as a plausible factor affecting the efficiency level of informal firms. With an ultimate aim of investigating the prospect of informal firms in SD through the achievement of CP, this study captures the metallic pollution load generated particularly by these firms. Cr contamination is found to be high in water samples around firms in the leather industry (in Hemayetpur area), and Pb contamination is found to be alarming in a soil samples around firms in dyeing and clothing

Table 3
Result of Tobit analysis for eco-efficiency outcome.

Explanatory variables	Leather industries			Plastic and small machinery industries			Dyeing and clothing industries		
	Coeff.	SE	z-score	Coeff.	SE	z-score	Coeff.	SE	z-score
PLI	−0.004**	0.002	−1.926	−0.038	0.039	0.958	0.001	0.006	0.146
Tech	−0.100	0.136	−0.737	−0.314***	0.121	−2.592	−0.045	0.125	−0.390
Loan	0.387**	0.164	2.369	0.289**	0.129	2.242	0.008	0.113	0.076
Subcont	−0.018	0.128	−0.144	0.378***	0.133	0.107	3.523	0.106	−0.409
Cons	0.221	0.156	1.409	0.005	0.141	0.036	0.841***	0.131	6.419

Note: *** represents statistical significance at 1% level, ** represents statistical significance at 5% level and * represents statistical significance at 10% level.

industry (in Keraniganj area), although the other metallic ingredients are seen at a tolerable level for rest of the collected samples. The empirical results obtained from Tobit regression analysis have revealed a significant positive correlation of pollution on firm-level efficiency for these two above mentioned industries, which evident the polluting nature of the informal firms operating in these two industries. This result reveals a lack of CP practice in these two categories of informal firms under the existing economic arrangements.

In this a context, the current study has investigated the CP prospects of these firms by minimizing undesirable output (pollution load) in the DEA model. Estimating the eco-DEA models, the result implies that firms can enhance their efficiency even after their pollution minimizing efforts, compared to the situation where pollution burdens are ignored. Thus, by taking care of pollution in production, informal enterprises can contribute to CP and sustainability and alter the positive pollution efficiency nexus. However, SMEs that are operated under informal arrangements, face constraints in accommodating pollution in their production process due to the high cost associated with it. Firms become less competitive in price if they take measures to minimize pollution or produce environment-friendly outputs. Therefore, the relevant authority should come forward to materialize CP arrangements in informal firms since the application of conservative command and control regulation to those small and medium firms seems to be difficult in its implementation, although very rational [26,56]. According to ILO (2010), if a decent environment is created in informal sector firms, it could be a part of greening the economy [97]. However, the present context of the informal manufacturing firms that has been revealed by this study is not impressive, although perceives future potential with the precondition of achieving technical, financial, and managerial improvements. Bringing the informal firms under formal coverage can be the first step in improving the scenario. Benefits provided under formal arrangements can address the inefficiency of most of the informal firms, which has been realized by the outcome of the DEA analysis of this study, and the impact of pollution, which has long-term disadvantages for humans and the ecology. This study also states the need for the substitution of raw materials, the improvement of the production technology, and the use of more efficient production methods that can be important initiatives for CP development in these enterprises.

The findings of this study will justify policy measures proposed by global bodies to limit the size of informal industrial enterprises in Bangladesh and other developing countries from both economic and environmental considerations. Meanwhile, the strategy of implementing indirect environmental regulations, adopting financial and/or technological support policies, utilizing social capital, and implementing information-based policy such as educational programs that publicize information about pollution to build awareness can put forward to uphold CP. Firms can also be encouraged to invest in innovative technologies to achieving this. Rigorous environmental stewardship campaigns to create inclusive and environment-friendly economic activities in urban areas can also be carried out. Due to the inapplicability of direct environmental regulatory instruments to informal sector enterprises, enterprise owners' awareness of adopting eco-efficient technology and using environmentally friendly products, as well as more efficient resource management, can help to achieve a decent work environment in informal sector firms and prevent pollution to the surrounding environment. Thus, the practice of corporate social responsibility (CSR), which is based on three pillars; economy, environment, and society, will be ensured and help in pursuing SD. Implementation of CSR by informal firms will make them socially and environmentally responsible [see Ref. [78]]. Simultaneously, at the national level, targeted policy measures on challenges faced by informal SMEs, such as access to credit and finance, proper location and networking, the legal and regulatory framework, and technological development, can be addressed to facilitate green development concepts in urban areas by ensuring CP in informal production and business. Since small-scale production in the informal sector continues to exist in the economy due to slower absorption mechanism into the modern, formal economy [see Ref. [17]], proper planning, motivation, and adequate support for informal production and business throughout the process of formalization will make them committed to meeting social and environmental needs, which underpin CP concepts. This will also ensure economic returns that will safeguard not only the quality of economic growth but also social welfare and environmental sustainability.

Author contribution statement

Nahid Sultana: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Mohammad Mafizur Rahman: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Rasheda Khanam: Conceived and designed the experiments.

K.M.Zahidul Islam: Analyzed and interpreted the data.

Md. Rayhanul Islam Rayhan: Performed the experiments.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors have no competing interest to declare.

Supplementary content related to this article has been published online at [URL].

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e14583.

Appendix

Brief description of the studies areas

Hemayetpur area consists of several small-scale tanneries and leather product-producing firms. The tannery industry uses a lot of water for leather processing purposes. The wastewater is designed to disperse into a central treatment plant (CETP) and after treatment discharges into the nearby river Dhaleshwari. However, some untreated wastewater is seen to overflow from the drains before reaching CETP and logs onto the surface due to a poor drainage system. These untreated effluents impose a crucial public health concern. A total of 5 water samples were collected from the nearby areas of interviewed enterprises where they were found to overflow from the drainage water and transported to the environmental compartment either by logging or by surface runoffs. A total of 3 soil samples were also collected from the periphery area of interviewed firms. The Lalbagh (including Islambag) area is located on the bank of the river Buriganga. A large number of small-scale plastic and machinery firms are situated in this area. The ultimate destination of the effluent from these plastic and metallic industries is the nearby Buriganga river. There is a drainage channel through which industrial effluents are discharged into the river. A total of 5 water samples were collected from the effluent discharge of surveyed farms. A total of 3 soil samples were also collected. Keraniganj, another area on the river Buriganga where many dying, fabrics and clothing industries are located. Untreated effluents from these industries are also discharged into the Buriganga river stream through the poorly maintained drainage channel. A total of 4 water and 4 soil samples were collected from this area. All the samples were transported, preserved safely following due procedure and tested in a well-equipped and well-recognized laboratory to find the metallic concentration levels. The details of the PLI construction utilizing these concentration values are presented in the following sub-section.

Scientific Procedure for the assessment of metallic concentration in soil and water samples.

Flow Diagram of Environmental Parameters Analysis (Fig. 6).

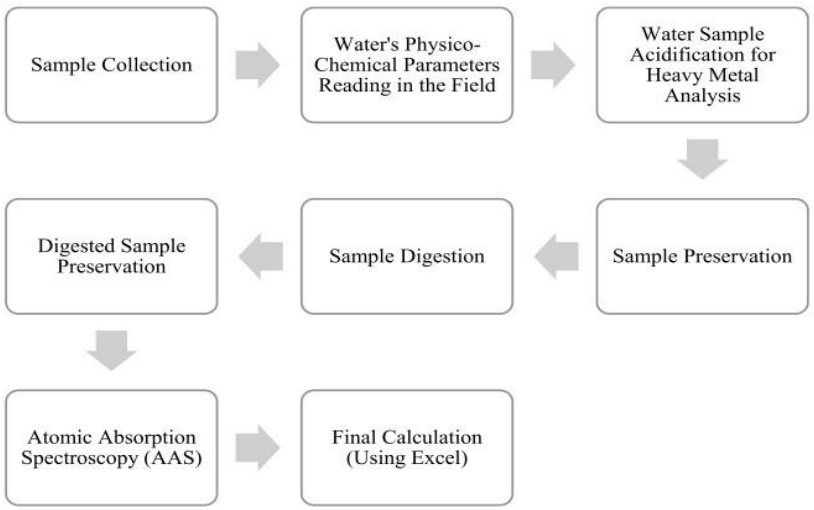

Fig. 6. Environmental Parameters Analysis.

Sample preservation

A gross total of 14 water and 10 soil samples were collected from the studied area. The water samples were collected in cleaned plastic bottles, pre-washed with 20% nitric acid (HNO_3) [99] and double-distilled water. Two 250 ml bottles were used in each sampling point. One is for physicochemical parameters analysis another is for heavy metal analysis. To measure the heavy metal concentration, 65% concentrated HNO_3 was added to each sample by dropper immediately after collection to keep the pH below 2 to minimize precipitation & adsorption onto container walls [100]. The physicochemical parameters (pH, EC) were measured at the field. The samples were then transported using an icebox to the laboratory of Environmental Sciences, Jahangirnagar University, Savar, Dhaka-1342. Samples were labeled correctly and preserved in the refrigerator at below 4 °C.

The soil samples were collected using an excavator to dig the soil at (0–40 cm) depth [101]. After digging up, almost 250 g m of soil was collected in the zipper polybag. The collected soil samples were transported to the abovementioned laboratory & preserved in the refrigerator at below 4 °C.

Sample Digestion Procedure

Samples are digested to reduce interference by organic matter and to convert metals associated with particulates to a form that can be determined by atomic absorption spectrophotometer (AAS).

Surface water sample digestion

Water samples were digested with concentrated HNO_3 acid for heavy metal determination as described by Ref. [100].
Apparatus:
The required apparatuses were.

1. Beaker
2. Hot plate (Model MS300 H s, MTOPO, Korea)
3. 100 ml volumetric flasks
4. Pipette
5. Glass rod

Reagent:
The required reagents were.

1. 65% conc. HNO_3 acid, analytical or trace-metals grade had been used
2. HCl acid

Procedure:
100 ml distilled water and 5 ml 65% concentrated HNO_3 acid was added for digestion. The solution was heated at 105^0c in a digital hot plate in a fume chamber. Then the solution was slowly boiled and evaporated on a hotplate to the lowest volume possible. Continue heating until digestion was completed as shown by a light-colored, clear solution. After cooling, beaker was washed down with distilled water and transferred solution into volumetric flask to make 50 ml. Then the solution was filtered by Whatman (0.41 μ m pore size) into the plastic bottle and finally taken the sample for analysis by AAS. Along with the water samples, a blank sample was digested. The total procedure is given in (Fig. 7).

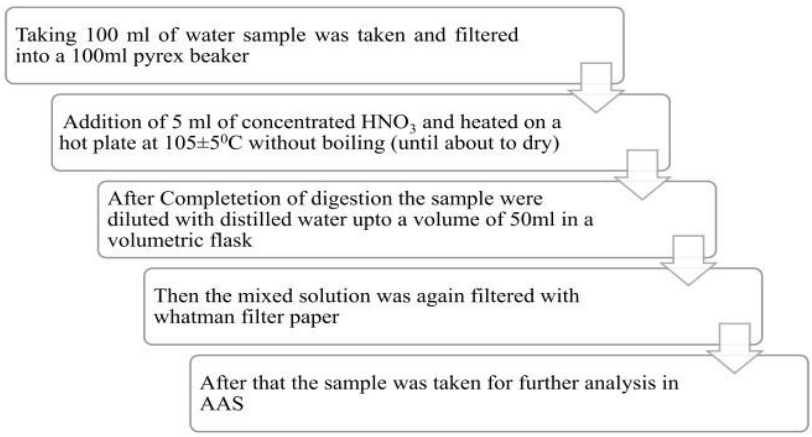

Fig. 7. The procedure of water sample digestion used for metal detection in AAS.

Soil Sample Digestion
Soil sample were digested with concentrated HNO_3 acid for heavy metal determination as described by [102].
Apparatus:
The required apparatuses were.

1. Beaker
2. Hot plate (Model MS300 H s, MTOPO, Korea)

3. 50 ml volumetric flasks
4. Pipette
5. Glass rod
6. Digital Balance (Model JJ224BCE, SI NO. 142417043025)

Reagent:
The required reagents were.

1. 65% conc. HNO_3 acid, analytical or trace-metals grade had been used
2. HCl acid
3. 80% concentrated $HCLO_4$ acid

Procedure:
At first soil sample was mashed by mortar and sieved by a 1 mm sieve. 1 g soil sample was taken into a clean beaker by a balance, and 10 ml 65% concentrated HNO_3, and 2 ml of $HCLO_4$ acid were added for digestion. Then the solution was heated at 140^0c in a digital hot plate in a fume chamber. Then the solution was slowly boiled and evaporated on a hotplate to the lowest volume possible. Continue heating until digestion was completed. After cooling, the beaker was washed down with distilled water and transferred solution into a volumetric flask to make 50 ml (4:1): 40 ml distilled and 10 ml conc. HCl. Then the solution was filtered by Whatman (0.41 μ m pore size) into the plastic bottle and finally taken the sample for analysis by AAS. Along with the soil samples, a blank sample was digested. The total procedure is given in (Figs. 3 and 8).

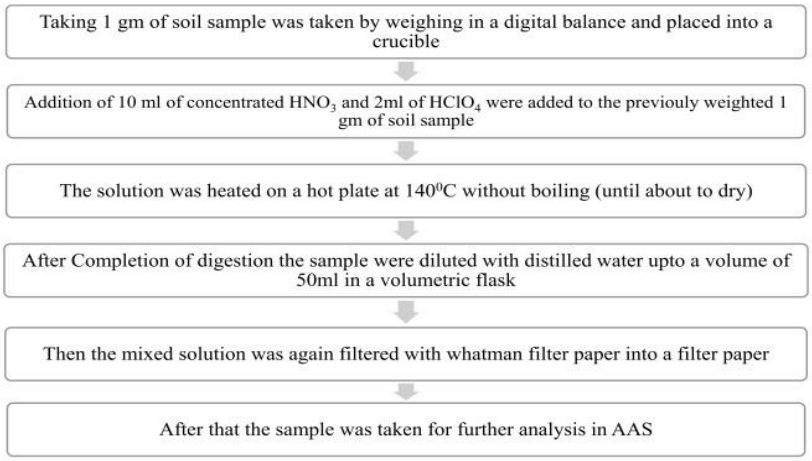

Fig. 8. The procedure of soil sample digestion used for metal detection in AAS0.

Atomic Absorption Spectroscopy

After completing the digestion process, the digested samples were preserved in the refrigerator at below 4 °C temperature. The metal was analyzed using Atomic Absorption Spectroscopy (Model-AA-7000; Shimadzu) in the South-Asian largest scientific laboratory named Wazed Miah Scientific Research Center.

Final Calculation:
After taking the reading from the AAS, the collected data was analyzed using Microsoft Excel. The following formula was used to determine the actual concentration of heavy metal in the water samples.

$$C_w = \frac{W \times 50 \times 1000 \times 1000}{1000 \times 100}$$

Where,
C_w = Metal's Concentration in water in μg/L.
W = Metal's Concentration derived from AAS reading in ppm - Metal's Concentration in ppm from blank prepared.
Standard permissible limit of metal concentration in inland water was adopted from Ref. [103].
The following formula was used to determine the actual concentration of heavy metal in the soil samples.

$$C_s = \frac{S \times 50 \times 1000}{1000}$$

Where,

C_s = Metal's Concentration in soil in mg/kg.

S = Metal's Concentration derived from AAS reading in ppm - Metal's Concentration in ppm from blank prepared.

Standard permissible limit of metal concentration in soil was adopted from Ref. [104].

Table 4
Concentration of Heavy Metal in Soil and water samples from the studied area.

Location	Statistics	Soil (mg/kg)			Water (mg/L)		
		Pb	Ni	Cr	Pb	Ni	Cr
Hemayetpur (n = 3)	Mean	0.01	12.80	124.83	0.91	18.50	4865.93
	Max	0.01	18.50	341.23	4.50	39.80	15349.00
	Min	0.01	8.07	13.10	0.01	5.35	0.01
	SD	0.00	5.28	168.91	2.01	12.74	6801.76
Lalbagh (n = 3)	Mean	46.77	25.78	11.30	8.99	10.76	0.01
	Max	93.54	35.82	18.82	22.45	24.75	0.01
	Min	2.70	14.31	0.01	0.01	0.01	0.01
	SD	45.48	10.83	9.96	12.29	9.75	0.00
Keraniganj (n = 4)	Mean	128.17	8.42	5.13	0.01	25.00	360.29
	Max	512.65	12.16	20.48	0.01	32.25	998.15
	Min	0.01	2.58	0.01	0.01	18.30	110.25
	SD	256.32	4.12	10.24	0.00	5.77	426.51

Table 5
Summary of DEA Models.

Total DMUs	90
Leather and leather products (located in Hemayetpur area)	30
Plastic and small machinery (located in Lalbagh and Islambugh area)	30
Dyeing and clothing (located in Keraniganj area)	30
Input used	2
Desired output used	1
Undesirable output used (as impact value)	1
Orientation for model	Input Oriented Model
Incorporation of undesirable output into the Model	As input As ratio of desirable output
Returns to scale	Variable Returns to Scale
Slack computation stage	One- stage

Table 6
The summary statistics of input and output variables

Area	Variable	Obs	Mean	Min	Maxi
Hemayetpur	Worker (full time)	30	11.28	4	20
	Wage (monthly in BDT)	30	10483.33	7000	15,000
	Raw material cost (yearly in BDT)	30	1,639,600	168,000	5,400,000
	Revenue (yearly in BDT)	30	28,300,000	450,000	3,000,000
Lalbagh	Worker (full time)	30	7.45	3	17
	Wage (monthly in BDT)	30	11216.87	7500	16,000
	Raw material cost (yearly in BDT)	30	461233.3	8000	6,552,000
	Revenue (yearly in BDT)	30	6,265,770	104,750	42,500,000
Keraniganj	Worker (full time)	30	8.95	2	18
	Wage (monthly in BDT)	30	11644.67	6000	17,000
	Raw material cost (yearly in BDT)	30	882,800	50,000	4,800,000
	Revenue (yearly in BDT)	30	14,200,000	650,000	86,600,000

Table 7
The results of efficiency analysis of informal enterprises.

DEA result for informal enterprises												
DMU	Efficiency level (Leather industries)				Efficiency level (Plastic and small machinery industries)				Efficiency level (Dyeing and clothing industries)			
1	CRS	VRS	SE	RTS	CRS	VRS	SE	RTS	CRS	VRS	SE	RTS
1	0.042	0.139	0.301	+1	0.105	0.187	0.564	+1	1	1	1	–
2	0.032	0.033	0.972	−1	0.035	0.099	0.353	+1	0.331	0.436	0.76	+1
3	0.012	0.014	0.875	−1	0.354	1	0.354	+1	0.058	1	0.058	+1
4	0.064	0.092	0.7	−1	0.181	0.184	0.982	−1	0.424	0.523	0.811	+1
5	0.038	0.04	0.938	−1	0.051	0.055	0.92	+1	1	1	1	–
6	0.188	0.233	0.808	−1	0.03	0.034	0.869	+1	0.322	0.349	0.923	+1

(continued on next page)

Table 7 (*continued*)

DEA result for informal enterprises												
DMU	Efficiency level (Leather industries)				Efficiency level (Plastic and small machinery industries)				Efficiency level (Dyeing and clothing industries)			
7	0.16	0.3	0.533	−1	0.866	1	0.866	−1	0.039	1	0.039	+1
8	0.058	0.065	0.894	+1	0.099	0.106	0.93	−1	0.043	0.11	0.394	+1
9	0.143	1	0.143	+1	0.593	0.612	0.97	−1	0.076	1	0.076	+1
10	1	1	1	–	0.133	0.158	0.841	+1	0.13	0.151	0.859	+1
11	0.026	0.042	0.625	−1	0.053	0.112	0.472	+1	0.051	0.053	0.974	−1
12	0.036	0.048	0.75	−1	0.302	0.363	0.831	−1	0.134	0.163	0.817	+1
13	0.034	0.037	0.934	+1	0.178	0.189	0.94	−1	0.3	0.414	0.725	+1
14	0.015	0.035	0.437	−1	1	1	1	–	0.265	0.28	0.949	+1
15	0.007	0.018	0.404	−1	1	1	1	–	0.1	0.105	0.958	+1
16	0.1	0.125	0.8	−1	0.45	0.566	0.795	+1	0.092	0.106	0.868	+1
17	0.105	0.14	0.75	−1	0.235	0.44	0.534	+1	0.183	0.195	0.941	+1
18	0.019	0.027	0.709	+1	0.242	0.247	0.979	−1	0.248	0.248	1	–
19	0.024	0.025	0.968	+1	1	1	1	–	0.352	0.392	0.897	+1
20	0.195	0.256	0.761	−1	0.205	0.272	0.754	+1	0.243	0.259	0.938	+1
21	0.013	0.026	0.515	−1	0.155	1	0.155	+1	0.135	0.383	0.353	+1
22	0.018	0.018	0.972	−1	0.178	0.448	0.396	+1	0.12	0.129	0.93	+1
23	0.019	0.042	0.444	+1	0.182	0.239	0.762	+1	0.042	0.056	0.756	+1
24	0.033	0.034	0.972	−1	1	1	1	–	0.115	0.123	0.935	+1
25	0.072	0.096	0.75	−1	0.48	0.696	0.69	+1	0.129	0.151	0.854	+1
26	0.056	0.058	0.968	+1	0.1	0.11	0.905	+1	0.265	0.304	0.872	+1
27	0.039	0.089	0.444	+1	0.091	0.102	0.892	+1	0.631	0.708	0.89	−1
28	0.022	0.077	0.288	+1	0.455	0.512	0.889	+1	0.097	0.106	0.907	+1
29	0.004	0.011	0.365	+1	0.173	0.241	0.72	−1	0.318	0.329	0.968	+1
30	0.003	0.009	0.353	+1	0.246	0.274	0.897	−1	0.18	0.243	0.737	−1
Mean	0.086	0.138	0.679	–	0.339	0.442	0.775		0.247	0.377	0.773	–

Table 8
The results of eco-efficiency analysis of informal enterprises (pollution minimization)

DEA result for informal enterprises									
DMU	Leather industry (Efficiency level)			Plastic and small machinery product industries (Efficiency level)			Dyeing and clothing industries (Efficiency level)		
	crs	vrs	scale	crs	vrs	scale	crs	vrs	scale
1	0.042	0.139	0.301	0.016	0.018	0.845	1	1	1
2	0.032	0.033	0.972	0.005	0.012	0.439	0.331	0.436	0.76
3	0.012	0.014	0.875	0.057	1	0.057	0.058	1	0.058
4	0.064	0.092	0.7	0.018	0.018	1	0.424	0.523	0.811
5	0.037	0.04	0.937	0.008	0.009	0.829	1	1	1
6	0.188	0.233	0.808	0.004	0.005	0.909	0.322	0.349	0.923
7	0.184	0.3	0.613	0.09	0.157	0.571	0.039	1	0.039
8	0.058	0.065	0.894	0.011	0.011	0.995	0.043	0.11	0.394
9	0.143	1	0.143	0.069	0.07	0.984	0.076	1	0.076
10	1	1	1	0.021	0.042	0.504	0.13	0.151	0.859
11	0.098	1	0.098	0.008	0.013	0.651	0.155	0.173	0.896
12	0.112	1	0.112	0.035	0.043	0.8	0.249	0.382	0.652
13	0.034	0.037	0.934	0.02	0.02	0.995	0.447	1	0.447
14	0.023	0.035	0.646	1	1	1	0.62	0.651	0.954
15	0.012	0.018	0.646	0.067	0.133	0.5	0.25	0.274	0.914
16	0.1	0.125	0.8	0.067	0.074	0.896	0.175	0.225	0.775
17	0.105	0.14	0.75	0.036	0.044	0.824	0.462	0.491	0.94
18	0.019	0.027	0.709	0.028	0.028	0.984	0.787	0.885	0.889
19	0.024	0.025	0.968	0.153	0.164	0.936	1	1	1
20	0.195	0.256	0.761	0.022	0.024	0.909	0.462	0.511	0.905
21	0.013	0.026	0.515	0.019	1	0.019	0.418	1	0.418
22	0.018	0.018	0.972	0.028	0.066	0.419	0.204	0.413	0.494
23	0.019	0.042	0.444	0.028	0.04	0.709	0.07	1	0.07
24	0.033	0.034	0.972	0.161	0.247	0.651	0.225	0.246	0.915
25	0.072	0.096	0.75	0.048	0.048	0.99	0.279	0.413	0.675
26	0.056	0.058	0.968	0.007	0.01	0.667	0.535	1	0.535
27	0.039	0.089	0.444	0.006	0.009	0.684	1	1	1
28	0.022	0.077	0.288	0.07	0.086	0.814	0.287	1	0.287
29	0.004	0.011	0.365	0.003	0.035	0.073	0.793	1	0.793
30	0.003	0.009	0.353	0.03	0.03	0.99	0.344	0.344	1
Mean	0.092	0.201	0.658	0.071	0.149	0.722	0.406	0.653	0.683

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6.3 Study 8

Heliyon 8 (2022) e09569

Contents lists available at ScienceDirect

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Research article

Environmental quality and its nexus with informal economy, corruption control, energy use, and socioeconomic aspects: the perspective of emerging economies

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ARTICLE INFO

Keywords:
CO_2 emissions
Ecological footprints
Economic growth
Informal economy
Renewable and non-renewable energy
Corruption control

ABSTRACT

This paper explores the impacts of informal economic activities and institutional capacity, particularly, corruption control on the environmental quality degradation of emerging economies under the prevailing socio-economic conditions and energy use patterns of the countries. The study utilizes key environmental degradation indicators: Carbon dioxide (CO_2) emissions, ecological footprints (EFs), and Nitrous Oxide (NO) emissions, and a panel dataset of 15 emerging countries for the period 2002–2019 to undertake an empirical investigation. The pooled mean group (PMG)-ARDL estimator, Fully Modified OLS (FMOLS), Dynamic OLS (DOLS) and Augmented Mean Group (AMG) methods have been applied as empirical investigation techniques. The empirical findings reveal that in the long-run informal economic activities positively affect the environmental quality with fewer recorded emissions of CO_2 and EFs while these activities affect negatively to NO emissions. This study has also found that corruption control improves environmental quality by reducing EFs and NO emissions but works to the opposite by increasing recorded CO_2 emissions. An increase in economic growth and renewable energy consumption improves environmental quality in emerging countries, while consumption of non-renewable energy degrades the environmental quality. The robust empirical findings advocate policy initiatives for intense monitoring of informal activities and implementation of indirect tax policy to regulate informal activities and the pollution they cause. Careful measures of corruption control and initiatives to bring the informal economic activities into a formal framework are suggested to reduce CO_2 and NO emissions. An increase in economic growth with more focus on renewables and phasing out non-renewables can ensure green growth in emerging countries.

1. Introduction

Emerging countries are increasing economic growth by enhancing their industrial activities. The energy-intensive industrial development that is taking place in these countries has turned them into the largest producer of Carbon dioxide (CO_2) in recent decades (Bilgen, 2014; Nguyen and Kakinaka, 2019; Oh et al., 2021). These countries are typically dependent on fossil fuel in their industrialization process due to its low cost. However, the use of fossil fuel-based energy is posing environmental challenges to these countries (Pata and Yilanci, 2020a, 2020b; Li et al., 2021; Le and Sarkodie, 2020; Reilly, 2015). In addition, the increased economic activity encourages the unsustainable use of natural resources that affects bio capacity, increases the countries' ecological footprints (EFs), and poses a threat to the environment (Pata, 2021; Danish and wang, 2019; Oh et al., 2021). To avoid far-reaching consequences on ecology and the environment, these countries are under pressure (both internal and external) to reduce environmental damages (Ahmad et al., 2021b).

Environmental pollution is a multinational concept, and it has links to social issues (e.g., health, education, unemployment, women's employment, electrification rate, and accessibility to energy at fair prices), and governance (e.g., corruption, institutional capacity) in addition to economic growth, energy use, and industrialization (Mohr et al., 2015; Bauer et al., 2016; EIA, 2018). In emerging countries informal economic activities are important aspects that need to be investigated in the context of environmental quality assessment. These countries generally have large informal sector and hence it is suggested to be considered as an economic tool for maintaining energy demand and economic

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https://doi.org/10.1016/j.heliyon.2022.e09569
Received 11 January 2022; Received in revised form 22 March 2022; Accepted 24 May 2022

development (Medina and Schneider, 2019; Benkraiem et al., 2019; Huang et al., 2020; Elgin and Oztunali, 2014[1]). However, economic activities in this sector are often unregistered, marginal and geographically dispersed in nature that give them the opportunity to be noncompliant with environmental regulations (Elgin and Oztunali, 2014; Pang et al., 2021). Literature shows that the informal economy has largely been ignored into understanding its relationship with environmental quality despite the fact that its expansion increases the discharge of pollutants (Wang et al., 2019).

Under such a backdrop, the present study has focused on the informal economy and related institutional capacity along with economic, social and energy consumption aspects to understand their impact on environmental quality of fifteen (15) emerging countries.[1] Emerging countries are targeted since they have achieved remarkable economic growth in the last two decades and at the same time become liable for worsening the environmental quality, which is evident by their increased ecological footprints up to 3.18 (global hectares per capita) in the year 2017 from 2.36 in the year 1984. These countries have achieved the potentials to influence the global market since they represent 40% of total GDP and almost 60% of total population of the world (Ahmad et al., 2021b). The recent trend of environmental quality degradation (CO_2 emissions and Ecological Footprints) of these selected countries are presented in Figures 1 and 2. The trends of economic growth, informal sector performances and energy consumptions (non-renewable and renewable) of these emerging countries are also presented in Figures 3, 4, 5, and 6.[1]

This paper will add to the literature in several ways; Firstly, this study will provide an insight into environmental quality degradation by employing three indicators: CO_2, EFs, and Nitrous Oxide (NO) to capture the various dimensions of the environmental degradation (see Almeida and das, 2017). Apart from air pollution indicators, CO_2 and NO, of which CO_2 is the most prominent Green House Gas with growth rate 72% and NO with growth rate 42% in last decade (Shokoohi et al., 2022; Sinha and Bhattacharya, 2016), an anthropogenic consumption-based environmental degradation indicator ecological footprints (EFs) is also employed for a comprehensive assessment of total environmental damage. It measures the impact of human pressure on nature in terms of build-up land, cropland, forest products, fishing ground, CO_2 emissions, and water pollution which is capable to assess the sustainability of lifestyle of people, consumption of goods and services, business and production activities, regions and cities (GFN, 2021; Pata and Yilanci, 2020a; Pata and Yilanci, 2020b). Inclusion of EF is important to identify its determining factors since more than 80% of the total population of this world lives in countries with ecological pressure where consumption of natural resources exceeds their ecological reproductive capacity (Pata, 2021). Secondly, the informal sector is utilized in this study as an indication of the level of regulation and governance that an economy experiences (Swain et al., 2020; Goel et al., 2013) to evaluate its impact on environmental quality. Thirdly; since informal economic activities might work through corruption (Goel et al., 2013; Goel and Saunoris, 2020), the corruption control index is accommodated in the study as an institutional capacity indicator to evaluate its role in ensuring environmental quality. Fourthly, this study has added the socioeconomic conditions of emerging countries to understand its influence on environmental quality. Goel et al. (2013) underscores that socioeconomic conditions such as education, employment and demographic characteristics of an emerging economy can impact environmental quality by influencing decision making. Fifthly, the use of empirical investigation technique PMG-ARDL which is robust in finding the common coefficient for the long run and helpful to suggest mutual strategies for the emerging countries.

[1] Argentina, Bangladesh, Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, Turkey, Poland, Egypt, Pakistan (Source: https://worldpopulationreview.com/country-rankings/emerging-countries; https://en.wikipedia.org/wiki/Emerging_market).

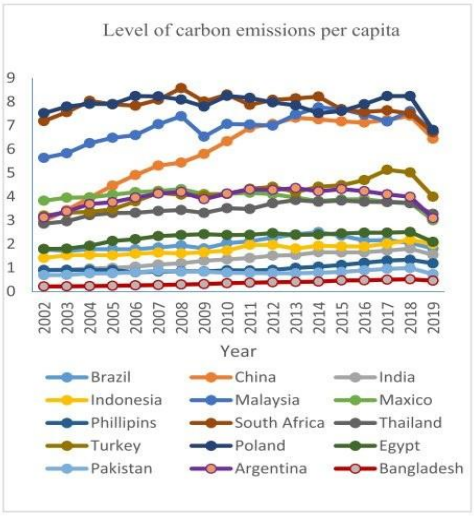

Figure 1. Level of carbon emissions (Source, WDI, 2021).

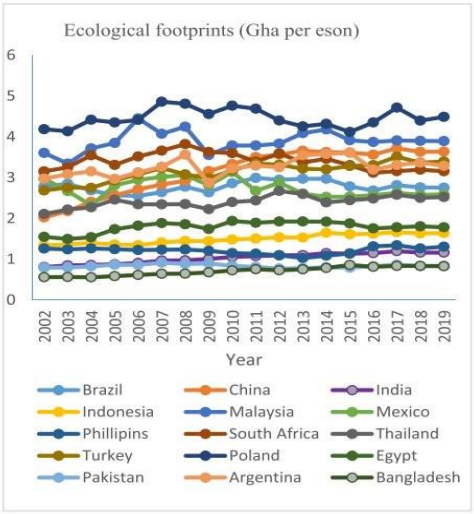

Figure 2. Ecological footprint of countries (Data source: GFN, 2021).

This paper is organized as follows: section 2 presents a brief review of recent literature that links environmental quality measured by various degradation indicators with the variables under investigation in this study. Section 3 describes the data and methodological steps followed in the study to obtain the outcome. Section 4 presents the results in a systematic manner and section 5 discusses the results in brief. Section 6 concludes the study with final remarks and policy suggestions.

2. Literature review

In previous studies, environmental degradation, economic growth and energy consumption were the three most common factors that were investigated. However, this study has extended the analysis by including

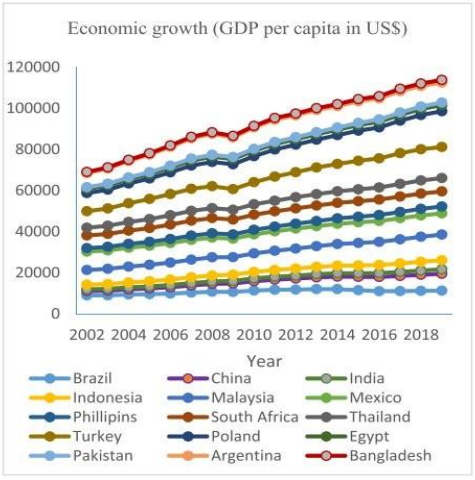

Figure 3. Economic growth in emerging countries (Data source: WDI, 2021).

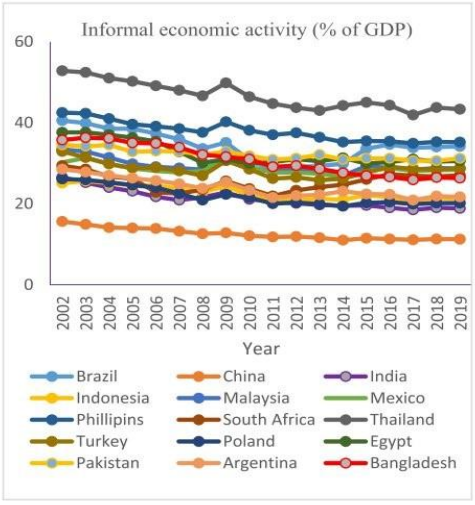

Figure 4. Informal economic activities as percentage of GDP (Data source: Medina and Schneider, 2019).

informal economic activity, corruption control, and socioeconomic conditions. The review of the most recent studies capturing the selected factors mentioned above and their nexus to environmental degradation has been presented below under four sub-sections.

2.1. Environmental quality and economic growth

The relationship between environmental quality and economic growth can be explained by the economic theory widely known as the Environmental Kuznets Curve (EKC) hypothesis. This hypothesis accepts that environmental degradation increases along with an increase in per capita income since more attention is paid to economic growth than environmental quality management at a lower level of income. When the country is at the peak of its development and reaches a certain threshold point, the government pays attention to improving the environmental quality. As a result, environmental degradation declines and form an

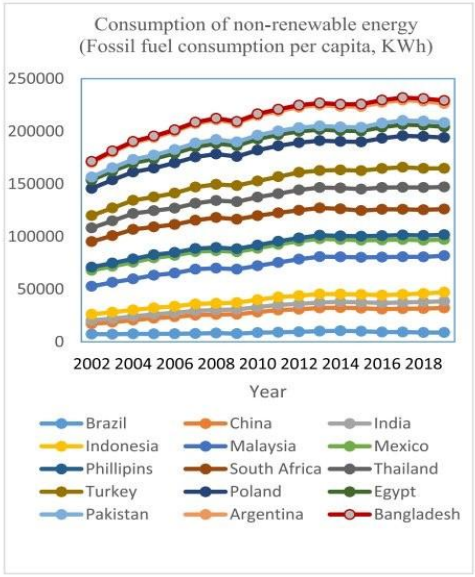

Figure 5. Consumption of non-renewable energy (KWh) per capita (Data source: WDI, 2021).

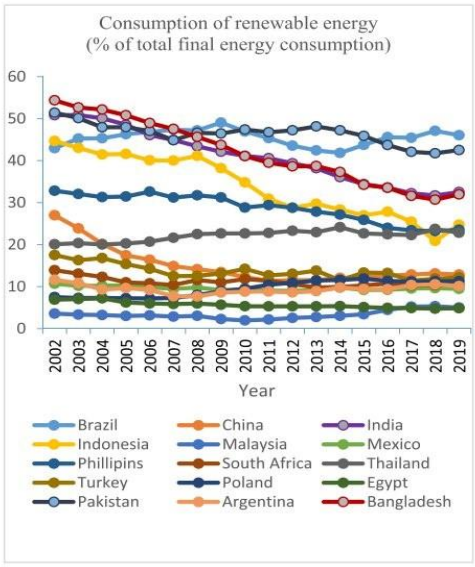

Figure 6. Consumption of renewable energy as percentage of total energy consumption (Data source, WDI, 2021).

'inverted U' shape (Ozcan and Ozturk, 2019; Lawson et al., 2020; Suki and Mohd, 2020; Wen et al., 2021). The phenomena attributed to this shape are the scale, composition, and technique effects through which economic growth contributes to the environmental performance level (Ozcan et al., 2020). Many recent studies have established the validity of the EKC hypothesis by employing both time series and panel data. Rahman (2020) for top 10 electricity consuming countries, Usama et al. (2020) for Ethiopia, Erdogan et al. (2020) for OECD countries, Gü ng ö r

et al., 2020 for 9 selected countries, Ahmad et al. (2021a) for 5 China provinces, Suki and Mohd (2020) for Malaysia, Sultana et al. (2021) for Bangladesh all validated the 'inverted U' hypothesis. At the same time, the opposite results U-shaped relations are also found between economic growth and environmental pollution in the recent literature of Usman et al. (2021) for 12 Middle East and North American (MENA) countries, Pontarollo and Serpieri (2020) for Romania, Halliru et al. (2020) for west African countries, Pata and Aydin (2020) for China, and Zhang (2019) for five Central Asian countries. A positive contribution of GDP on environmental degradation indicators was revealed by Taiwo Onifadea et al. (2021) for E7 countries and Ozcan et al. (2020) for OECD countries while increased GDP was found to improve environmental performances in a large panel of countries by Alhassan (2021). A contrast to this result was noted by Danish and wang (2019) for 9 Newly Industrialized (Next-11) countries after integrating economic growth with urbanization. Narayan and Narayan (2010) also found decreasing impact of emissions on economic growth in developing countries.

For emerging countries contradiction prevails in the role of economic growth to Environmental quality. An inverted U-relation between economic growth and EFs has been revealed by Ahmad et al. (2021b) while for Newly Industrialized (Next-11) countries, Destek and Sarkodie (2019) revealed an inverted U relation for Mexico, Philippines, Singapore, and South Africa, and a U-shaped relation for China, India, South Korea, Turkey, and Thailand. A positive impact of increased CO_2 emissions on economic growth was projected by Le and Sarkodie (2020) in their study on emerging markets and developing countries while Acheampong et al. (2021) reveals a negligible effect of CO_2 emissions on economic growth for Sab-Saharan countries.

2.2. Environmental quality and energy consumption

The choice of energy resource of a country depends on a balance between economic growth and environmental degradation (Nguyen and Kakinaka, 2019). In emerging economies, the energy demand is sharply rising for economic development resulting in severe environmental problems (Oh et al., 2021). The negative relation between fossil fuel based energy consumption and environmental quality is revealed in the bulk of energy literature with all its adverse impacts (Ahmad et al., 2021a; Khan et al., 2021; Li et al., 2021; Ozcan et al., 2020, Martins et al., 2019; Destek and Sarkodie, 2019). Sharma et al. (2021) has noticed that energy consumption leads to environmental pollution at a lower income level, whereas its harmful effect becomes weak at a higher level of income.

Given the negative environmental impacts of fossil fuel based energy for economic development, renewable energy has been considered an alternative to those and a potential solution to limit sea-level rise or other climate change problems (Irandoust, 2016; Gani, 2021). Degradation in environmental quality triggers a shift towards renewable energy and energy-efficient technology according to the study of Ibrahiem and Hanafy (2021). The importance of the generation of renewable energy as a less carbon-emitting source is pointed to in a number of studies (Khan et al., 2021; Ingleso-Lotz and Dogan, 2018; Asongu and Odhiambo, 2019; Destek and Aslan, 2017; Wang et al., 2020). Nguyen and Kakinaka (2019) revealed that the relationship between renewable energy consumption and carbon emissions usually associated with the country's level of development. The stimulating role of renewable energy consumption in shaping environmental quality was identified by Zafar et al. (2020) for OECD countries.

By disaggregating energy into renewable and non-renewable categories, many studies reveal that renewable energy is environmentally friendly while non-renewable energy is damaging to the environment (Ahmad et al., 2021; Djellouli et al., 2021 for selected African countries, Khan et al., 2021 for OECD countries, Pata, 2021 for USA). In the study of emerging markets and developing countries (EMDEs), Le and Sarkodie (2020) have revealed that the exploitation of renewable energy offers double dividends by providing economic growth and reducing CO_2 emissions. However, no effect has been found for renewable energy consumption on environmental quality degradation in China by Pata and Caglar (2021).

2.3. Environmental quality and informal economy

While there are ample studies on the influence of the formal economy on environmental quality, the investigation on the impact of the informal economy on environmental quality is largely ignored and unknown although the informal sector includes many pollution-intensive activities and intensifies environmental impact (Wang et al., 2019; Blackman, 2000). Karanfil and Ozkaya (2007) found a link between environmental pollution and informal economic activities. Benkraiem et al. (2019) also found a significant relationship between unrecorded economy, environmental quality, and energy consumption. Elgin and Oztunali (2014) investigated this in a global context and revealed an inverted U relation between the informal economy and environmental pollution in terms of energy use. Their findings suggested that the small and large size of informal sectors were accompanied by a lower level of pollution, and medium-sized informal sectors were linked to a higher level of pollution. The model that was developed in the study identified two channels of informality that might affect environmental pollution: scale effect and deregulation effect. Since these two effects worked in opposite directions, an inverted U relation was created based on the altered relative strength of one with respect to informal sector size.

Literature has identified some features of informal economy that work behind its relation to environmental quality. Canh et al. (2021) underscored that since the activities of the shadow economy are almost free from environmental regulations, the shadow economic activities can be more energy-intensive and less green-oriented. Compliance with official requirements is generally weaker in the informal sector compared to the formal sector. Therefore, the formal sector avoids the costly regulations by outsourcing part of its production to the informal sector. Baksi and Bose (2016) modeled this process and analyzed how stringent regulations affected the size and regulatory compliance status of an endogenous informal sector through the outsourcing decision of formal firms. This study also identified the conditions under which a partially compliant informal sector acted as a source of leakage by permitting the formal sector to outsource polluting production. Bento et al. (2018) showed that energy tax could create welfare gains by allowing substitution from the informal sector. They mentioned two mechanisms through which the informal sector could lower the costs of environmental and energy tax policy: first; an energy tax would impose an indirect tax on the informal sector since informal firms buy energy from the formal sector, such as electricity, natural gas, gasoline, and secondly; a revenue-neutral shift in tax base towards energy that could decrease the tax burden on goods substituted by the informal sector. These mechanisms were found to have considerable potential in welfare-enhancing substitution of informal labor into the formal sector. Therefore, well-judged policies are required to address the damaging impact of informal economy to the environmental quality.

2.4. Institutional arrangements and environmental quality

Institutional arrangements, including policies, acts, and regulations in a jurisdiction, are crucial for protecting environmental quality. The outcome of the study by Ahmad et al. (2021b) has indicated that institutional quality promotes environmental sustainability by moderating the interconnection between economic complexity and ecological degradation. The virtue of institutions for environmental protection in developing countries has been noted by Azam et al. (2021). However, this depends on the enforcement of environmental rules and regulations (Momtaz and Kabir, 2018). The prevalence of corruption often creates difficulties in effectively enforcing the rules and regulations and protecting environmental quality (Du, 2021). Illegal rent seekers are key actors who may influence the implementation of environmental rules and

cause environmental degradation during the development of a country. Their illegal activities may make economic development unsustainable as there is a potential to release carbon emissions, degrade forests and land resources, and cause water pollution (Du, 2021; Dogan et al., 2020). Ren et al. (2021) have shown how corruption influences environmental pollution and emphasize the importance of understanding the relation between corruption and carbon emissions for the formulation and implementation of public policies focusing on corruption control and carbon emissions reduction. Paying special attention to MENA countries, Goel et al. (2013) showed with empirical evidence that both more corrupt nations and nations with large shadow sectors projected similar effects in yielding fewer recorded emissions. Their study revealed the negative impact of these two on the recorded pollution level.

From the review of recent literature, it has been observed that the role of the informal sector, corruption control, and the prevailing socio-economic condition of the countries were not investigated in environmental degradation studies of emerging countries. Moreover, contradictions still prevail in the outcome of economic growth-environmental degradation nexus. This study has been initiated to fill these gaps and find some new insights into the economic mechanism of emerging countries that need to be addressed to continue their economic growth at a minimum environmental cost.

3. Data and methodology

3.1. Data

To accomplish the objectives of this study, 15 (fifteen) emerging countries[1] of the world have been selected and panel data set spanning 2002–2019 is used. The details of the used variables are presented in Table 1.

3.2. The method

This study follows the modified STRIPAT (Impact = Population X Affluence X Technology) framework proposed by Rosa and Dietz (1998) to identify the stochastic impact of population, affluence, and technology on environmental issues. Since STRIPAT model allows some additional factors that might influence the environment apart from affluence and demographic characteristics to associate with T (York et al., 2003), the study adds informal sector activities and corruption control in the model to satisfy the aim of this study. The basic form of the STRIPAT model with a required modification can be stated as follows:

$$I = \alpha EG_{it}^{\beta_1} RE_{it}^{\beta_2} NRE_{it}^{\beta_3} SEC_{it}^{\beta_4} IE_{it}^{\beta_5} CC_{it}^{\beta_6} \varepsilon_{it} \quad (1)$$

Here, in Eq. (1), I represents environmental impacts in terms of CO_2 emissions, Ecological footprints, and NO emissions. α refers to the constant, $\beta_1, \beta_2, \beta_3, \ldots\ldots, \beta_6$ are the exponents of A, T, P and two additional variables IE and CC. This study captures affluence by Gross Domestic Product per capita (*EG*), demographic variable is captured by their socioeconomic conditions (*SEC*) and Technology is captured by a disaggregated form of energy (see Appiah et al., 2019), Renewables (*RE*) and Non-renewables (*NRE*) since the use of energy facilitates technological diffusion. This study considers informal economic activities (*IE*) and corruption control (*CC*) that are identified as institutional factors with T to assess their impact on environmental degradation. The variables are transformed into log form, aiming to reduce the heteroscedasticity and to obtain the elasticity of the explanatory variables to the explained variable directly. The model can be specified in the logarithmic model as follows:

$$lnED = \alpha + \beta_1 lnEG_{it} + \beta_2 lnRE_{it} + \beta_3 lnNRE_{it} + \beta_4 lnSEC_{it} + \beta_5 lnIE_{it} + \beta_6 lncc_{it} + \varepsilon_{it} \quad (2)$$

In Eq. (2), impact (I) is replaced by environmental degradation (ED) measured by CO_2 emissions, EFs, and NO emissions. Specifically, the study estimates the following three models.

$$lnCO_2 = \alpha + \beta_1 lnEG_{it} + \beta_2 lnRE_{it} + \beta_3 lnNRE_{it} + \beta_4 lnSEC_{it} + \beta_5 lnIE_{it} + \beta_6 lncc_{it} + \varepsilon_{it} \quad (3)$$

$$lnEF = \alpha + \beta_1 lnEG_{it} + \beta_2 lnRE_{it} + \beta_3 lnNRE_{it} + \beta_4 lnSEC_{it} + \beta_5 lnIE_{it} + \beta_6 lncc_{it} + \varepsilon_{it} \quad (4)$$

$$lnNO = \alpha + \beta_1 lnEG_{it} + \beta_2 lnRE_{it} + \beta_3 lnNRE_{it} + \beta_4 lnSEC_{it} + \beta_5 lnIE_{it} + \beta_6 lncc_{it} + \varepsilon_{it} \quad (5)$$

Panel econometric approaches have been applied to these models [Eq. (3)-Eq. (5)] that consider the issues of heterogeneity and cross-sectional dependence.

3.3. Pre-estimation investigations

In panel data estimation, the first step is to inspect the 'unobserved common processes' on the error terms and the variables. It may arise from the shocks of unobserved common factors that affect all panel units

Table 1. Description of variables.

Variables	Acronyms	Unit	Source
CO_2 emissions	CO_2	Metric tons per capita	WDI + International energy agency 2020) https://www.iea.org/data-and-statistics
Ecological Footprint	EF	Gha per person	Country trends, Global Footprint Network https://data.footprintnetwork.org/?_ga=2.59590190.2004080785.1636416261-137262501.1627655575#/countryTrends?type=BCpc,EFCpc&cn=9
Nitrous Oxide emissions	NO	Thousand metric tons of CO_2 equivalent per capita	WDI (2021)
Economic Growth	EG	GDP per capita in 2010 constant US$	WDI (2021)
Informal Economy	IE	% share of GDP	Medina and Schneider (2019), Shedding Light on the Shadow Economy: A Global Database and the Interaction with the Official One
Renewable energy consumption	RE	% of total final energy consumption	WDI (2021)
Non-Renewable energy consumption	NRE	Fossil fuel consumption per capita (KWh)	Our World in Data [Ref. Assi et al., 2021] https://ourworldindata.org/fossil-fuels#fossil-fuel-consumption-which-countries-use-the-most-energy-from-fossil-fuels
Socio-economic Condition	SEC	Percentile rank	International Country Risk Guide, WB (2021)
Control of Corruption	CC	Percentile rank	Worldwide Governance Indicator, WB (2021)

and spillover across all panel units (Le and Sarkodie, 2020). It is very likely to have economic assimilation among the countries since they belong to the same economic group. Hence, the study has checked the cross-country interrelationship among the variables by adopting four cross-sectional dependence (CSD) tests: Breusch Pagan LM (1980) test, Pesaran scaled LM (2004) test, Bias-corrected scaled LM (2012) test, and Pesaran (2004) CD test. All these tests provide the yardstick for selecting the next econometric approach suitable for the analysis, i.e., unit root tests and cointegration tests.

To check the stationarity of the variables this study has conducted both the First and Second generation unit root tests. Im, Pesaran and Shin (2003) (IPS) that deals with individual root and Levin et al. (2002) (LLC) that deals with common root problem have been employed as first generation test. The IPS and LLC model can be expressed as follows:

$$\Delta y_{it} = \rho_i y_{i,\,t-1} + \sum_{j=1}^{pi} \delta_i y_{it-j} + \alpha_{mi} d_{mt} + \varepsilon_{it} \tag{6}$$

In Eq. (6), Δ is the first difference operator, j is the optimal lag, α_{mi} and d_{mt} are parameters and vector of coefficients, respectively. The null hypothesis and the alternative hypothesis for LLC and IPS tests can be written as

(Null Hypothesis)	$H_0 : \beta_i = 0$	*for all i*
(LLC)	$H_0 : \beta_i = \beta < 0$	*for all*
(IPS)	$H_0 : \beta_i 0$ *for some i*, $\beta_i < 0$	*for atleast one i*

However, these tests do not take into account the cross-sectional dependence. Hence, the Cross-sectional augmented IPS (CIPS) and Cross-sectional Augmented Dickey-Fuller (CADF) tests developed by Pesaran (2007) are employed where the ADF regressions are improved with cross-section averages of lagged values and first differences for each unit (Westerlund et al., 2016). CADF statistics can be formulated as follows:

$$\Delta y_{it} = \alpha_{it} + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \sum_{j=0}^{p} \theta_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{i,t-j} + e_{it} \tag{7}$$

In Eq. (7), $\bar{y}_t$ represents the average at time T for all cross sections (Salman et al., 2019). The CIPS test is basically the cross-sectional average of the individual CADF test and can be expressed as

$$CIPS = N^{-1} \sum_{i-1}^{N} CADF_1$$

Once stationarity of the variables are confirmed, in the next step, the study moves for Perdoni (1999) cointegration tests and Kao (1999) cointegration test that are the extension of Engel-Granger two-step residual-based cointegration tests to confirm the existence of long-run relationships among the variables. Kao test is based on homogeneous cointegrating vector assumption on the null proposition. The Perdoni (1999) method for cointegration is a robust framework of heterogeneous errors in cross-section dependence and several regressors (Appiah et al., 2019). The Westerlund (2005) cointegration test, which is more appropriate in the presence of CSD and heterogeneity, has also been employed based on the result of the CSD test. The null hypothesis of the Westerlund (2005) test assumes no cointegration and relaxes the assumptions of common factor restrictions. This test uses structural dynamics rather than residual dynamics to identify the long-run relationship among the variables (Arshad Ansari et al., 2020). The statistic is called panel VR statistic. The statistic is derived based upon a model in which the AR parameter is either panel-specific or is the same over the panels (Appiah et al., 2019). This study uses the same over the panel.

3.4. Model estimation

The model specifications of Eq. (3) to Eq. (5) follow the Pooled Mean Group Autoregressive Distributive Lag (PMG-ARDL) estimation technique taking insight from Ibrahiem and Hanafy (2021), Ahmad et al. (2021b), Sarkodie and Strezov (2019); Appiah et al. (2019); Attiaoui et al. (2017). PMG-ARDL is a standard least squares regression model that is advantageous for estimating the long-run and short-run cointegrating relationships and applicability in large and small panels (Khan et al., 2020). This method is also appropriate for variables integrated to I (0), I (1), and a mix of both but not I (2). Pesaran et al. (1999) proposed this approach that combined pooling and averaging of coefficients employed above the cross-sectional units. PMG estimator hypothesizes long-run slope homogeneity and hence it considers the long-run coefficients common but allows the short-run dynamic specification to differ from country to country. It also reveals the dynamics of adjustment from short-run to long-run. This estimation procedure based on the maximum likelihood method seems consistent since it accounts for individual characteristics and provides an improved evaluation of the long-run relationship. It is also robust to outliers and lag order selection (Pesaran et al., 1999).

The ARDL system of equations for time period $t = 1, 2, \ldots\ldots, T$ and number of cross-sections $i = 1, 2, \ldots\ldots, N$ for the Y is shown in Eq. (8).

$$Y_{i,t} = \sum_{j=1}^{p} \delta_{i,j} Y_{i,t-1} + \sum_{j=0}^{q} \gamma_{i,j}^{'} X_{i,t-j} + \varepsilon \tag{8}$$

Here, $X_{i,t-j}$ is the (kx1) vector of regressors for cross-section i. The proposed re-parameterized form of the model by Pesaran et al. (1999) is as follows:

$$\Delta Y_{i,t} = \xi_i \left(Y_{i,t-1} - \theta_1^{'} X_{i,t-1} \right) + \sum_{j=1}^{p-1} \delta_{ij} \Delta Y_{i,t-j} + \sum_{j=1}^{q-1} \delta_{ij}^{'} \Delta X_{i,t-j} + \varepsilon_{it} \tag{9}$$

In Eq. (9), $(Y_{i,t-1} - \theta_1^{'} X_{i,t-1})$ is the Error Correction Term (ECT). Y ($lnED$) denotes the dependent variables, CO_2, EFs and NO respectively and X denote the set of regressors ($lnEG_{it} + lnIE_{it} + lnRE_{it} + lnNRE_{it} + lnSEC_{it} + lnCC_{it}$) with the same number of lags q across i, the cross sectional units in time t. ξ_i represents the error correction coefficients, θ represents the long run coefficients that produces the δ and γ estimates after convergence is reached.

This study further applies Fully Modified OLS (FMOLS) (Phillips and Hansen, 2016) and Dynamic OLS (DOLS) (Stock and Watson, 1993) for long-run panel estimation, based on the results of the cointegration analysis. The estimation of these cointegration regression models using a parametric approach will check the robustness of the long-run coefficients of PMG model. These methods are advantageous with asymptotic properties and free from endogeneity issues (Arshad Ansari et al., 2020). The estimators of these models are efficient in eliminating the autocorrelation problem in residual terms. They are also unbiased with small samples (Zhang, 2019). The results obtained from estimating the three different models (3–5) are also cross-examined with the Augmented Mean Group (AMG) estimators of Eberhardt and Bond (2009) and Eberhardt and Teal (2010) that deal with cross-section dependence, heterogeneity and endogeneity problems (Ahmad et al., 2021b; Pata et al., 2021).

4. Results

Descriptive statistics of the selected variables are presented in TableS1. Results indicate that there are no major differences between mean and median except *RE*. The correlation matrices are presented in Table S2 and the results of four Cross-sectional Dependence (CSD) tests are summarized in Table S3. The results reject the null hypothesis of cross-sectional independence of the variables at 1% significance level. This indicates that a shock arising in one sample country may influence the same to the other countries. In order to address this problem sufficiently and to ensure the efficiency of estimation, the study has applied second generation unit root tests CIPS and CADF in addition to first generation tests IPS and LLC. The results of the unit root tests that incorporate an intercept and trend are presented in Table S4. Results reveal that the unit root problems of the variables are resolved in their

first differences although a few variables are found to be stationary at their levels.

Having confirmed that all series are stationary at the first difference, the panel co-integration tests suggested by Pedroni (1999) and Kao (1999) are conducted. In addition to these two tests, Westerlund (2005) cointegration test has also been performed based on the result of CSD tests. The Cointegration test results for models (3), (4), and (5) are reported in Table 2.

The results of Kao (1999) cointegration tests show that the variables are cointegrated in the models, and hence they have long-run associations among themselves. The results of Pedroni (1999) cointegration tests also reveal the long run association of variables in the models. Since the CD test reveals cross-sectional dependence for model (3), the study has applied the second generation cointegration test Westerlund (2005). Here, the test statistic variance ratio rejects the null theory of no cointegration between CO_2 and the set of explanatory variables in favor of the alternative that all panels are cointegrated in the model.

The results obtained from an estimation of Pooled Mean Group (PMG)-ARDL approach based on the cointegration form of the simple ARDL model are presented in Table 3. Both the short-run and long-run results of the estimated model (3)–(5) are reported in the Table along with their convergence coefficients.

In Table 3, model (3) estimation results reveal that 1% increase in economic growth (EG), consumption of renewable energy (RE), informal economic activities (IE), and socio-economic conditions (SEC) reduce CO_2 emissions in the long run (LR) by 0.48%, 0.88%, 0.07% and 0.13% respectively. As opposed to these coefficient results, a percentage point increase in non-renewable energy (NRE) consumption increases CO_2 emissions by 1.22% while a percentile increase in corruption control (CC) increase CO_2 emissions by 0.11%. The short-run (SR) results project that consumption of non-renewable energy increases carbon emission but controlling corruption can reduce it. The estimation results of model (4) reveal that 1% increase in EG, IE, RE consumption, and CC contribute to improve the ecological footprints (EFs) by 0.31%, 0.34%, 0.1% and 0.06% respectively, while consumption of NRE works to the opposite by increasing EFs 0.75% in the LR. Informal activities are found to be a negatively contributing factor to EFs in the short-run as well. Lastly, the model (5) estimation results have found EG, RE consumption, improvement in socioeconomic conditions (SEC) and CC as improvements over NO emissions, implying 1% increase in EG, RE consumption, SEC and CC decrease NO emissions by 0.42%, 0.23%, 0.05% and 0.04% respectively. Opposing these, 1% increase in IE activity and consumption of NRE deteriorates NO emissions level by 0.12% and 0.63% respectively, in the LR. In the SR, EG increases NO emissions and RE consumption decrease it in a significant manner. The results of Hausman test, which sets the null hypothesis of homogeneity in the long-run coefficients, has justified the selection of PMG-ARDL models. The error correction terms (ECT), presented as convergence coefficients in Table 3, and are found to be negative and statistically significant for all three models.

The long-run results of the PMG model are expected to be identical for the countries and the short-run coefficient results are country-specific. To satisfy the aim, this study emphasizes the long-run outcomes and checks those for robustness with the results of cointegration models estimation presented in Table 4. The FMOLS and DOLS model estimation results report almost similar outcome for EG, RE and NRE and SEC with PMG-ARDL model estimation results. IE activities and CC results are also exactly similar for CO_2 and NO emissions with PMG-ARDL model. IE in FMOLS and DOLS estimation results project negative sign as the main model but CC appears with positive sign for EFs.

The LR regression estimates of AMG model are presented in Table S5. The results reveal that IE activities increase CO_2 emissions and the role of CC is insignificant. For NO emissions, it is weakly significant and negatively associated to IE that contradicts to earlier results. However, the result of IE activities on EFs is similar to the result of PMG-ARDL models. The result for RE, NRE and SEC are also similar in AMG model like other applied models. The slight differences in regression estimates are justifiable and may arise due to the difference in assumptions of the applied models that doesn't nullify the main findings of the study.

5. Discussion

In PMG-ARDL models EG is found to be improving towards environmental quality implying that economic growth reduces all types of emissions in emerging countries. FMOLS and DOLS results have also confirmed that. This result of EG supports the findings of Narayan and Narayan (2010) for the panel of Middle-eastern and South Asian developing countries where long run income elasticities were found to be smaller than the short run income elasticities, suggesting carbon emissions reduction with economic growth. This result is also in line with Alhassan (2021) for 79 countries where economic growth improves environmental performances and Acheampong et al. (2021) for Sub-Saharan African countries where economic growth reduces CO_2 emissions through a mechanism of structural shift towards information industries and services that are less carbon emitting. The result indicates that economic growth is important for reducing emissions since it can bring structural and technological innovations (Acheampong et al.,

Table 2. The results of the test for cointegration.

Test for Cointegration
Ho: No co-integration
H_1: All panels are co-integrated

	Model-3(CO_2)		Model-4 (EFs)		Model-5(NO)	
Kao	Statistic	P-value	Statistic	P-value	Statistic	P-value
Modified Dickey-Fuller t	-4.921	0.000	-4.091	0.000	-1.741	0.041
Dickey-Fuller t	-0.676	0.249	-4.532	0.000	-1.761	0.039
Augmented Dickey-Fuller t	-0.475	0.317	-2.975	0.001	-0.952	0.170
Unadjusted Modified Dickey-Fuller t	-6.004	0.000	-6.674	0.000	-2.828	0.002
Unadjusted Dickey-Fuller t	-1.053	0.145	-5.409	0.000	-2.292	0.011
Pedroni	Statistic	P-value	Statistic	P-value	Statistic	P-value
Modified Variance ratio	-2.431	0.0075	-2.697	0.000	4.192	0.000
Modified Phillips-Perron t	2.996	0.0014	1.500	0.000	-7.751	0.000
Phillips-Perron t	-1.507	0.065	-7.626	0.000	-6.676	0.000
Augmented Dickey-Fuller t	-1.935	0.026	-7.720	0.000	-3.783	0.000
Westerlund	Statistic	P-value	Statistic		Statistic	
Variance ratio	1.538	0.061	-	-	-	-
CD	23.27	0.000	0.781	0.993	0.337	0.736

Table 3. The results of Pooled Mean Group (PMG)-ARDL estimation.

Variables	Model-3(CO_2)		Model-4 (EFs)		Model-5(NO)	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
Convergence coefficient	-0.478***	0.181	-0.516***	0.109	-0.418***	0.049
Long-run coefficient						
lnEG	-0.477***	0.081	-0.307***	0.025	-0.419***	0.047
lnIE	-0.884***	0.162	-0.337***	0.013	0.119*	0.072
lnRE	-0.074***	0.029	-0.100***	0.021	-0.229***	0.050
lnNRE	1.223***	0.055	0.748***	0.019	0.630***	0.045
lnSEC	-0.131***	0.042	0.018	0.013	-0.052*	0.031
lnCC	0.106***	0.017	-0.056***	0.008	-0.045***	0.012
Short-run coefficient						
Δ*lnEG*	0.146	0.475	-0.146	0.241	0.404**	0.180
Δ*lnIE*	0.153	0.476	-0.208**	0.105	-0.141	0.120
Δ*lnRE*	-0.123	0.196	-0.104	0.093	-0.203**	0.092
Δ*lnNRE*	0.515**	0.284	0.009	0.077	0.083	0.107
Δ*lnSEC*	0.049	0.284	0.045	0.066	0.061	0.069
Δ*lnCC*	-0.113***	0.041	0.008	0.041	-0.027	0.041
Constant	-0.687***	0.266	-0.469***	0.109	-2.004***	0.466
Hausman test	Chi-Sq 1.33 (p-value 0.969)		Chi-Sq 0.78 (p-value 0.992)		Chi-Sq 0.51 (p-value 0.944)	
Number of Countries	15		15		15	
Number of Observations	255		255		255	
Log likelihood	787.311		839.252		906.193	
CD test	23.271 (0.000)		7.576 (0.000)		26.318 (0.000)	

Note: AIC criterion is chosen for the lag order.
*** indicates 1%, ** indicates 5% and * indicates 10% significance level.

Table 4. The results of Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS) regressions.

Variables	Model-1(CO_2)		Model-2 (EFs)		Model-3(NO)	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
lnEG	-0.045*** (4.670)	-0.195*** (3.833)	-0.031*** (3.262)	-0.129*** (2.809)	-0.118*** (0.016)	-0.241*** (0.060)
lnIE	-0.077*** (3.411)	-0.203*** (2.586)	-0.142*** (6.325)	-0.189*** (2.473)	0.077*** (0.030)	0.102 (0.103)
lnRE	-0.129*** (8.749)	-0.082*** (2.664)	-0.105*** (7.082)	-0.051* (1.688)	-0.065*** (0.011)	-0.042 (0.033)
lnNRE	0.929*** (50.751)	1.105*** (14.373)	0.511*** (27.863)	0.597*** (8.856)	0.249*** (0.025)	0.456*** (0.086)
lnSEC	0.018 (0.602)	-0.026 (0.949)	0.033 (1.082)	0.043* (1.673)	0.041*** (0.009)	0.060 (0.032)
lnCC	0.053*** (2.670)	0.068*** (2.988)	0.119*** (6.057)	0.008 (0.325)	-0.015* (0.008)	-0.009 (0.026)
R-squared	0.997	0.998	0.991	0.996	0.991	0.996
Adjusted R-squared	0.996	0.997	0.990	0.993	0.990	0.995
S.E of Regression	0.023	0.021	0.025	0.021	0.023	0.016
Long-run variance	0.002	0.000	0.000	0.000	0.000	0.000
Mean dependent var	0.416	0.416	0.323	0.323	-3.462	-3.463
S.D dependent var	0.391	0.392	0.250	0.250	0.235	0.235
Sum squared resid	0.125	0.066	0.144	0.061	0.125	0.046

Note: *** indicates 1%, *8 indicates 5% and * indicates 10% significance level respectively. Std. Errors are reported in the parenthesis.

2021). However, the negative impact of economic growth on CO_2 emission contradicts to the findings of Ahmad et al. (2021b) for emerging countries, Sharif et al. (2020) for Turkey, Danish et al. (2019) for Pakistan.

IE is found to contribute negatively to CO_2 emissions and EFs in LR. However, the result of corruption control that decrease CO_2 emissions in the short run but increase emissions in the long run indicates to the fact that corruption control initiatives encourage polluting firms to swaps their emissions from official to unofficial domain in the long-run. Thus the negative association of informal activities with CO_2 emissions can be justified since informally operated firms can easily pursue the polluting activities even under strict regulations and able to hide them by taking the advantage of their non-compliance nature (Goel et al., 2013; Baksi and Bose, 2016; Wang et al., 2019; Elgin and Oztunali, 2014). Subcontracting polluting activities to unregistered firms are possible in the presence of a large informal sector that helps to keep emissions unrecorded (Goel et al., 2013; Goel and Saunoris, 2020). This result is exactly similar to the findings of FMOLS and DOLS while the result of AMG (in Table S5) reveals its positive association with CO_2 emissions in insignificant Corruption Control scenario. The positive coefficient of corruption control on CO_2 emissions evident the findings of Goel et al. (2013) for Middle East and North American (MENA) countries. This result is also in line with that of Azam et al. (2021), and justifies the argument of Wang et al. (2019) and Ahmad et al. (2021b). For NO pollution, IE reports its positive role while CC contributes positively to emission reduction in the main model and FMOLS model. IE and CC are found to associate

negatively to EFs in PMG-OLS and AMG models although their results in FMOLS and DOLS model estimation indicate for emission swap by projecting positive sign for CC. The little contradiction in CC result may arise due to the broader purview of EFs that measures the demand for natural resources and provides an overall picture of resources depletion by human (Pata and Yilanci, 2020a, 2020b). EF captures both direct and indirect effects and tracks not only carbon demand on land by population but also the consumption of productive surface area that encompasses land, air and water (GFN, 2021). Sometimes informal sector activities are involved in waste picking and recycling activities that may also contribute behind this result. These results imply that strong institutions are capable to control corruption and ease implementation of strict environmental laws contributory to improve the overall environmental quality (Ahmad et al., 2021b).

In development process domestic institutional framework is important in controlling CO_2 emissions (Lau et al., 2014). However, CO_2 emissions worsens institutions (Acheampong et al., 2021) and in this study institutional activities against corruption are found to decrease environmental quality by increasing CO_2 emissions. This can be justified under the theoretical arguments of 'scale effect' and 'composition effect' (Baksi and Bose, 2016). Strict regulations reduce the production of harmful goods but also motivates the formal sector firms to produce less in-house and outsource more from informal sector firms ('scale effect and 'subcontracting effect'). This brings a compositional change in production ('composition effect') and increases the size of the informal sector that carries more harm due to the increased proportion of non-compliance firms. The counteracting effect of scale and composition can decrease the damage initially. Still, depending on the intensity and strictness of regulation and enforcement, harm can increase and crosses a turning point value that depends positively on enforcement intensity. This non-monotonic impact of regulations has adverse side effects on the production process that negatively affect social welfare (Baksi and Bose, 2016; Goel and Saunoris, 2020).

Consumption of RE is found to have a stimulating role to improve environmental quality which is similar to the result of Usman et al. (2021), Pata et al. (2021), Zafar et al. (2020), Zhang (2019), Sharif et al. (2020) while NRE contributes negatively to it that is evident in most of the empirical literature on environment (mentioned in literature review section). This result is established with strong statistical significance in all model estimation results of this study. Echoing to the opinion of Le and Sarkodie (2020) the empirical findings of this study supports in promotion of green energy to promote environmental quality in emerging economies.

6. Conclusions and policy implications

This paper explores the impacts of informal sector activities, corruption control, energy consumption and socio-economic conditions on environmental quality degradation of emerging economies. This study employs three degradation indicators: CO_2 emissions, ecological footprints (EFs), and NO emissions to obtain a reliable outcome. The period covered by the study is 2002–2019, and it includes 15 emerging countries. In empirical investigations, the study has checked for cross-country dependency at the beginning. Next, it has employed the first and second generation unit root tests and relevant cointegration tests. After confirming the level of integration, the study has applied the PMG-ARDL model for this dynamic panel and has proceeded to estimate the short-run and long-run dynamics of the variables for three models (3)–(5) employing CO_2, EFs, and NO, respectively. These long-run results have been cross-checked by estimating two widely accepted co-integration models FMOLS and DOLS. This study has also adopted AMG model to examine the validity of long-run results. The results of the PMG-ARDL models estimation are found to be consistent with FMOLS or DOLS or both for most of the variables. The long-run results have revealed that economic growth and renewable energy contributes negatively, and non-renewable energy contributes positively to environmental degradation for all three indicators. Informal sector activities contribute to reduce recorded CO_2 emissions and EFs but appear as a positively contributing factor for NO emissions. Corruption control increases CO_2 emissions but improves EFs and NO emissions by PMG-ARDL results although Corruption control increases EFs by the FMOLS and DOLS results. Improvement in the socioeconomic condition of people reduces air pollution. Since the elasticity of variables is higher in the CO_2 model and corruption control result points to the possible expansion of informal activities that ultimately swap pollution from formal to informal firms and hide those as unrecorded, strategies for CO_2 emissions reduction needs to pay a priority in the environmental management policy. Similarly, NO emissions also need attention for its reduction.

The empirical findings of this study infer that insightful institutional and economic policies are required to minimize CO_2 and NO emissions, and to keep EFs at lower level in emerging countries. Increase in economic growth is not enough to improve environmental quality (Almeida and das, 2017). Promotion of institutional quality across emerging countries is also crucial in order to attain the benefits of economic as well as environmental sustainability. The empirical findings unambiguously demonstrate the need to implement environmental management policies that encourage renewable energy consumption and reduce reliance on non-renewable energy. An increase in the investment and subsidy in renewable energy projects, facilitating the penetration of renewable energy technology in the total energy mix, and gradual phase-out of fossil fuel based energy would be the confirmed solution to environmental degradation. Carbon and environmental tax that are under consideration to many countries can be implemented for the selected countries since it has been getting popular in countries recently (Bento et al., 2018;). Besides all these, the behavior of informal activities needs to be monitored, and corruption control measures should be evaluated and assessed with their effectiveness. Policymakers should understand and evaluate the informality of the economies to avoid poorly informed policy decisions. Indirect tax policy can be implemented to regulate the informal activities. At the same time, corruption control measures should be targeted and well-orchestrated so that the emissions cannot go unrecorded and unregulated. Economies should prevent excessive competition and high price discrimination in the formal sector to avoid leakage favoring the informal sector. In addition to these, countries should ensure high level in socio-economic condition to reduce aerial emissions to some extent.

Environmental degradation negatively affects human well-being, and therefore it is important to create a coherent, consistent and effective environmental framework to prevent its degradation. The analysis of dynamic interrelations among informal activities, economic growth, energy consumption, institutional mechanism, and environmental degradation reveals the coexistence of some possible means towards sustainable development. Although it is acknowledged that data limitation prevents this study from finding more dynamic outcome and the nature of interaction between informal economic activities and corruption control is not exposed elaborately by this study, this study opens up new research opportunity by focusing pollution from an unobserved sector that remains hidden and unrecorded. More comprehensive studies on nature of informal activities and their role in development process of emerging countries can make more accurate inference on environmental pressure. Improvement in socioeconomic aspects of peoples' life is another area of advanced research that can be highlighted in future studies to find strategy of emission reduce. From the outcome of this study it can be concluded that for effective outcomes, environmental regulations should be directed to specific dimensions of pollution control. Control of CO_2 and NO emissions is suggested as the top priority to this end. An effective measure of reducing CO_2 and NO emissions will facilitate improving the other indicators of environmental degradation. Economic growth with proper environmental management will support the overall well-being and ensure long-term economic stability contributory to the green growth of the emerging countries.

Declarations

Author contribution statement

Nahid Sultana: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mohammad Mafizur Rahman: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Rasheda Khanam: Conceived and designed the experiments.

Zobaidul Kabir: Conceived and designed the experiments; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e09569.

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6.4 Links and Implications

The studies presented in this chapter provide evidence supporting the notion that promoting cleaner production in informal enterprises can serve as a viable pathway towards sustainable economic growth, i.e. green growth. In section 6.2 **Study 7** demonstrates a positive association between pollution and the economic efficiency of informal enterprises, but also highlights the potential for eco-efficiency and thereby cleaner production in these informal manufacturing enterprises through pollution reduction efforts. This study stresses the need for institutional support to achieve eco-efficiency and cleaner production given the resource and technological constraints faced by these enterprises. In Section 6.3, **Study 8** indicates that institutional actions can result in pollution, as polluting activities may shift from the formal to the informal sector in response to strict institutional regulations. This shift can occur to avoid detection and regulation by formal institutions, such as those designed to control corruption. Therefore, direct stringent regulations may not be effective in preventing pollution in the presence of a large informal sector. Instead, innovative and indirect approaches should be adopted to encourage informal enterprises operating in urban areas to adopt cleaner production practices and facilitate green growth.

In conclusion, this research suggest that addressing pollution requires new approaches that promote eco-efficiency and cleaner production in the informal manufacturing sector. By doing so, the promotion of green growth can be achieved, and the adverse impacts of pollution on the environment and human health can be minimized. The next chapter will focus on examining the potential for innovative and indirect approaches that encourage informal enterprises operating in urban area to adopt cleaner production practices facilitating sustainable economic growth.

CHAPTER 7: ENVIRONMENTAL AWARENESS

7.1 Introduction

The United Nations (UN) recommended green growth as a solution for achieving sustainable development (SD) in 2005. This approach is widely seen as a means of addressing the environmental crisis and promoting SD without compromising the environment or the well-being of people (Merino-Saum et al., 2020; Wang et al., 2020, Abid et al., 2022). The concept of green growth has garnered global attention, and several studies have been conducted to understand its implementation in different countries (Stoknes & Rockström, 2018; Wang & Shao, 2019).

This chapter focuses specially on the cognitive determinants of SD in the informal sector and its people, with a particular emphasis on green growth. The previous chapter established that institutional support is necessary to minimize pollution, but it is uncertain due to the informal nature of this sector. Institutional regulations, such as attempts to control corruption, imposition of taxes and environmental laws, often fail to prevent pollution and may even encourage the expansion of the informal sector. Therefore, this research concentrates on the indirect institutional approaches to prevent or minimize pollution in informal manufacturing enterprises, which are required to achieve eco-efficiency, as discussed in the previous chapter.

This chapter delves in to the impact of building awareness of environmental degradation and emission management at firm level as an indirect approach to pollution control. It also evaluates the impact of such awareness on firm-level decisions regarding the adoption of green technology. The

study investigates the cognitive level of enterprise owners or managers regarding the environment and their attitude towards environmental protection, which is reflected in an index known as the awareness index (AI). The AI is considered one of the most significant antecedents of SD. Environmental awareness assists in identifying market opportunities and potential benefits that enable a more open and supportive attitude towards green innovation, which facilitates green growth. The chapter provides a detailed explanation of index construction and an empirical investigation of the probable impact of awareness on the technology adoption decisions of firms in **Study 9** under section 7.2. This study suggests an opportunity for developing awareness in informal firms by considering their present awareness level and response towards technology adoption. The study reveals that the decision to adopt green technology or environmental technology, which encompasses both clean technology (pollution prevention) and treatment technology (pollution control) (See Abid et al., 2022), is positively influenced by an improved awareness level of enterprise stakeholders. Therefore, environmental awareness can promote green technology in informal enterprises, leading to environmental and social benefits that promote sustainable development by converting traditional economies into green economies through the achievement of green growth.

7.2 Study 9

Interconnections between environmental awareness and green technology adoption: An empirical evidence from informal business enterprises

Abstract

Environmental awareness is increasingly recognized as a prerequisite for environmentally friendly behavior because human activities remain the primary cause of global environmental concerns. Environmental regulations have proven to be ineffective in studies on developing countries due to incomplete enforcement mechanisms. Therefore, the present study focuses on the role of environmental awareness in promoting green technology among informal enterprises, with the aim of enhancing environmental and social benefits. An Environmental Awareness Index has been constructed for this, comprising owners' and/or managers' knowledge, concern, behavior, and attitude in pollution and its prevention, based on an enterprise-level survey of informal manufacturing. This index is used in qualitative response models (probit and logit) to investigate its relationship with the probability of green technology adoption leading to the achievement of sustainable development. The results imply that the more environmentally conscious business owners and managers are, the more likely they are to adopt pollution-prevention or pollution-reduction technology. Therefore, this study recommends implementing an effective and sustained educational and training program to create a cultural change within the firm, permeating activities and adoption by all employees. Given the high cost associated with implementing this improvement, support from both the public and private sectors is recommended.

Keywords: Informal sector business enterprises, environmental awareness, green technology, probit and logit model, developing country.

JEL Classifications: Q53, Q52, C21

1. Introduction

Environmental awareness (EA) is widely considered a prerequisite for environmentally friendly behavior (Fu et al., 2020; Khakimova et al., 2018; Saifullah et al., 2017). It is defined as the conception of environmental sensitivity through an individual's aware discernment of environmental problems, and by behaving and taking environmental safeguards accordingly (Coertjens et al., 2010; Saricam and Sahin, 2015). Additionally, it refers to an individual's capacity to take action in favor of the environment, beyond learning merely about the issues affecting the environment locally and

globally (Dunlop and Jones, 2002). Therefore, environmental awareness complements self-consciousness, which encompasses personal environmental philosophy (Saricam and Sahin, 2015). Studies have found that individuals who are more aware of or concerned about environmental issues are more likely to participate in activities that have a positive impact on the environment (Perron et al., 2006; Gadenne et al., 2009; Xu et al., 2020; Aruga, 2020). Consequently, an individual's environmental awareness is critical in preventing environmentally harmful economic activities, and increasing its levels can help to mitigate the adverse effects of human activities on the environment (Aruga, 2020).

The development of personal characteristics that promote environmental consciousness is crucial in addressing environmental challenges resulting from the production and consumption patterns entrenched since the industrial revolution and fueled by capitalism in the 20th century (Jabbour et al., 2013; Wittneben and Kiyar, 2009; Tonn, 2007; Kolk and Pinkse, 2005). In addition to possessing knowledge and adopting behaviors conducive to environmental protection, individuals must also have a caring attitude towards the environment and strive to minimize harm to it (Saricam and Sahin, 2015; Kencanasari et al., 2019; Saifullah et al., 2017). Adoption of green technology is an example of an environmentally conscious attitude. However, the decision to adopt green technology is often influenced by a conflict between social and private incentives since private agents usually lack sufficient incentives to develop, adopt, or innovate green technologies, even if they are beneficial from a societal point of view. Consequently, the adoption and dissemination of green technologies are often precluded despite their potential to reduce external costs, as these costs are not parallel to a reduction in the private costs of these technologies. Nevertheless, given the significant environmental pollution resulting from industrial production, widespread diffusion of pro-

environmental or green technologies is the ultimate solution in addressing environmental concerns (Dincbas et al., 2021, Manika, et al., 2021; Miller et al., 2022).

In developing countries, governments are under pressure to improve their production procedures and they typically respond to this by placing rigorous environmental regulations on formal sector production, even though both the formal and informal sector industries are responsible for pollution (Baksi and Bose, 2016; Franzen and Meyer, 2010; Gupta and Barman, 2015). These countries are characterized by the presence of a large informal sector, comprising mostly low-technology small and medium manufacturing enterprises (SMEs), that operate outside the purview of government regulation (Blackman et al., 2006; Blackman and Bannister, 1998a; Elbahnasawy et al., 2016). Many of these businesses directly expose themselves to emissions by failing to use pollution control equipment and proper waste disposal procedures. Environmental management in this sector is a challenging task (Blackman, 2000; Blackman et al., 2006; Yang et al., 2021a; Elgin and Oztunali, 2014). Informal sector enterprises often evade environmental regulations (Abid, 2015; Blackman and Bannister, 1998b), as command and control regulations that rely on peer monitoring are ineffective in this sector (Blackman, 2000; Biswas et al., 2012). The presence and dominance of the informal sector, along with weak and incomplete enforcement mechanisms in developing countries, prevent complete and effective enforcement of regulations addressing pollution, occupational health, and safety, leading to welfare loss (Baksi and Bose, 2016; Blackman, 2000). Thus, the "Porter hypothesis," which suggests that strict environmental legislation spurs innovations and advances in abatement technologies (Porter and Linde, 1995; Ling et al., 2020), appears inapplicable to developing countries.

Against this backdrop, innovative approaches should be adopted in the environmental management systems of the informal sector in developing countries (Blackman and Bannister, 1998a). Cognitive factors such as values, awareness, motivation, intention, and self-efficacy, which are linked to moral character and pro-environmental principles, can play a significant role in sustainable value creation (Cao et al., 2022; Munoz, 2017; Ploum et al., 2018). The current study has focused on these factors for informal businesses, with a particular emphasis on awareness, by constructing an environmental awareness (EA) index. Environmental awareness has been found to have a positive relationship with people's motivation and behavioural intention to engage in pro-environmental activities (Yang et al., 2021b).When the parties involved have awareness, they tend to behave in an environmentally responsible manner, as demonstrated by the behavioural change model (Akintunde, 2017). However, this has never been investigated for businesses in the informal sector. This study seeks to address this gap, specifically in the context of a developing country, Bangladesh, by constructing as environmental awareness (EA) index.

Bangladesh is considered a country with significant economic contributions from the informal sector, where 99% of industrial units are either micro, small, or medium-sized enterprises (SMEs), and a large number of them are operated informally (Ahmed, 2017). These informally operated manufacturing enterprises are mostly located in the surrounding areas of the capital city, Dhaka, and other major cities, and are liable for unplanned urbanizations and environmental crises (Rahman and Kashem, 2017). They are often accountable for uncontrolled disposal, which causes environmental degradation and health problems in urban areas of Bangladesh (Baul et al., 2021; Ferronato and Torretta, 2019). Although the individual impact of informal SMEs is low, their total environmental impact is high due to their dominance in the business arena of developing countries, including Bangladesh (Gadenne et al., 2009). Consequently, SME leadership in sustainable development is

thought to be crucial (Jansson et al., 2017). However, they are often considered laggards in terms of their commitment to sustainability (Jansson et al., 2017; Johnson, 2013). Therefore, the owners or managers of SMEs are under increasing pressure to develop their environmental management activities and practices (Gadenne et al., 2009).

The present study has contributed to mitigating concerns about environmental issues in informal enterprises by focusing on their awareness and exploring how this relates to their choice to use green technologies. This study adds to existing knowledge on this topic in several ways. Firstly, an index on environmental awareness (EA) was constructed based on related indicators: knowledge, concern, behavior and activities, as well as an index on the general perception of environmental conservation by informally-operated manufacturing enterprises. These perception and awareness assessments of informally operated firms on environmental issues will provide insight for future environmental policies and aid advanced research on environmental management. Secondly, by adopting qualitative response models, this study explicitly takes into account the firms' decision-making on environmental protection and reveals their responsiveness to the awareness level of the informal firms. Thirdly, the empirical findings of this study also explore the social business perspective of informally operated enterprises by focusing on their awareness-based pro-environmental technology adoption behavior, which is a new social business initiative (see Manika et al., 2021). This will ultimately contribute to assessing the role of firms' awareness in generating value for society through pollution reduction while meeting financial goals. Lastly, this study will provide policymakers with baseline information about the usefulness of indirect environmental regulations in environmental conservation of developing countries.

2. Literature review

According to Franzen and Meyer (2010), maintaining or even increasing environmental concern was crucial for ensuring environmental protection, while individuals' environmental concern was influenced by their level of education, knowledge about the environment, and the perceived environmental burden. In this study, a multilevel analysis of the International Social Survey Program for 1993 and 2000 demonstrated that individuals' concern for the environment varied between and within countries, but it varied more significantly within-countries. Constructing and measuring a cross-national Environmental Awareness Index (EAI), Harju-autti and Kokkinen (2014) revealed the highest EAI scores for European countries and weaker EAI for the countries near the Equator. This study found that the Environmental Awareness (EA) approach, which comprised motivation, knowledge, and skills, had significantly better correlations with other national-level indices compared to EA that only consider environmental issues. In a country level study on Omani citizens, Abdul-Wahab (2008) investigated their willingness to contribute to environmental protection by assessing the state of environmental awareness from three perspectives: environmental knowledge, environmental attitudes, and environmental behaviors, using a questionnaire-based survey. The results revealed a lack of basic environmental knowledge among the public in general although local and international environmental knowledge were found to be higher. Lin et al. (2011) also examined the EA of citizens in China and Japan through a questionnaire survey in urban and rural areas and revealed that Chinese people were more concerned about local severe problems, whereas Japanese people were satisfied with the existing environmental conditions. According to this study, most citizens in both countries felt the necessity of enhancing environmental education and publication by the government to improve citizens' environmental awareness and the level of their behavior. Regarding the nexus between EA and pro-environmental behavior, Fu et al. (2020) conducted a

study on Road Freight Transport (RFT) drivers in China and revealed that awareness of environmental issues did not always translate into pro-environmental behavior. However, this study found that knowledge, environmental concern, and attitude indirectly influenced pro-environmental behavior via behavioral intention and a high level of purported policy efficacy, which facilitated the transformation of awareness into behavior, bridging the awareness-behavior gap. The empirical findings of this study was similar to Schaper (2002) for 154 retail pharmacies in Western Australia.

The owner/managers of small firms often have greater freedom in decision-making than managers in a large firm, and their personal motivations and responsibilities are crucial in determining the strategic direction of the firm. This leads to greater engagement with social and environmental issues, as revealed by Williams and Schaefer (2013). They found that managers of environmentally proactive SMEs were engaged in a number of pro-environmental activities and were aware of and involved in the personal and business challenge of climate change, which is a crucial environmental issue. The findings suggested that public policy and business advice in this area should be more focused on personal values and motivation to contribute to environmental protection in their engagement with small businesses. Johnson (2013) examined the rates of awareness and implementation of sustainability management tools in SMEs and found a connection between them. The outcome confirmed managers' awareness of sustainability management tools as the major determinant for the implementation of these tools in SMEs. The organizational size and optimistic perception of a relative advantage from implementing sustainability management tools over previous management practices also played an important role in their application.

Environmental awareness, pro-environmental attitudes, and pro environmental behavior were identified as significant predictors of the purchase of environmentally friendly products among

middle school students, as revealed by a structural equation model in a study by Ari and Yilmaz (2017). Interestingly, environmental literacy was found to be insignificant in this relationship. In a study by Saifullah et al. (2017), knowledge about green technology was found to be non-influencing, while green products and government policies directly influenced environmental awareness. Their research emphasized the need for a more practical awareness campaign to promote the use of green technology in modern living and suggested creating more awareness of environmental issues among the urban population, particularly among younger people, through workshops, seminars, and educational campaigns. They also recommended a top-down approach to promote the adoption of green technologies and products. Gadenne et al. (2002) showed that legislation resulted in general environmental awareness among SMEs, making them willing to change their business processes and environmental strategies, despite their lack of awareness of the benefits arising from cost reductions of their environmentally-friendly practices. In an evaluation of the effectiveness of environmental management training investments among two electricity companies, Perron et al. (2006) found that training on environmental management did not sufficiently increase employees' environmental awareness. However, this study emphasized the need for the presence of an effective environmental education and awareness training initiative for employees as a necessary condition for a successful environmental management policy. This study also suggested the need for more research to uncover the links between training format and training success, as well as the utilization of other tools to promote environmental awareness and the adoption of an environmental culture within organizations.

After reviewing the literature, it is apparent that existing studies on environmental awareness and its relationship with green technology are inconclusive and inadequate to offer a solution. Although

most studies stress the importance on environmental awareness among business stakeholders, few studies empirically examine the link between awareness and the engagement of firms in pro-environmental activity. Additionally, environmental awareness is a neglected issue in the economic literature of business operating in unobserved sectors that cater to people living in socio-economic backwardness. This study contributes to filling this gap by assessing the awareness level of owners and/or managers of manufacturing enterprises in this sector, and empirically investigating its influence on the pro-environmental initiatives of these informal firms. The findings of this study will help policy makers formulate policies for raising environmental awareness that facilitate the adoption of environmentally friendly technology and conservation practices among firms that are not monitored, regulated, or controlled by authorities but are important from a social business perspective.

3. Theoretical background and hypothesis

Behavioral decisions result from a combination of an individual's perception, environmental factors, and expected outcomes (Ji et al., 2019; Dong et al., 2022). The present study attempts to capture this by combining the ideas of two well-known behavioral theories, namely, the theory of planned behavior (TPB) (Azjen, 1991) and the technology acceptance model (TAM) (Davies, 1989). Theory of Rational Behavior provides the foundational framework for this integration and serves as a source for both TPB and TAM. According to TPB, an individual's behavior is a directly influenced by his/her behavioral intentions and perceived behavioral control. The key components of TPB include an individual's attitude, behavior, subjective norms, perceived behavioral control, and intentions, while attitude towards a behavior, subjective norms, and perceived behavioral control combine to form a behavioral intention, which is the immediate determinant of actual behavior (Chen et al., 2011). Awareness is the main force that influencing behavior (Dong et al., 2022).

In the technology acceptance concepts, TAM is one of the most widely-used theories for evaluating technology acceptance (Davies, 1989), as it has a high level of predictive power regarding technology use. According to TAM, perceived ease of use (PEOU), which reflects the ease of use of a particular technology, and perceived usefulness (PU), which reflects the degree to which an individual believes the technology will enhance performance, are the most important factors in explaining technology use (Chen et al., 2011). PU and PEOU in TAM are components of entrepreneurs' awareness, which is the main force to influences their behavioral attitude (BA) and consequently, it has an impact on the attitudes of firms. These attitudes, in turn, work together to influence firms' intention to adopt technology. Therefore, taking insights from Dong et al. (2022) and Clubbs et al. (2021), who combined TPB and TAM to frame a theoretical base and bridge the gap between behavior and intention, awareness has been considered as a factor that influences behavior in both TPB and TAM. Factors related to TPB and TAM serve as a background for predicting individuals' behavioral intentions towards pollution control and environmental management, which serves as a proxy for actual behavior activity (Clubbs et al., 2021). Since behavioral intention through awareness is believed to lead to activity, this study examined awareness (constructs jointly by TPB and TAM) to predict activity, i.e., technology adoption. Therefore, the main hypothesis has been stated that awareness significantly affects firms' adoption intention, and the stronger the awareness level, the stronger firms' adoption intention.

4. Research Methodology

Survey and data collection

The present study involved the participation of enterprise owners and/or managers of informally operated firms, drawing on the studies of Burke and Gaughran (2007); Cassells and Lewis (2011);

Kearins et al. (2010); Williams and Schaefer, (2013), Jansson et al., (2017), where environmental values, attitudes, and knowledge of SME owners and managers were used as an explanatory variable for environmental sustainability practices. In the context of informal SMEs, organizational structures are less formalized, and ownership, control, and operations are often in the hands of a single individual or a small group of individuals (Jenkins, 2004; Parry, 2012; Sharma and Sharma, 2011; Jansson et al., 2017) who have the potential to significantly influence the strategies and culture of the enterprise (Williams and Schaefer, 2013). Therefore, the owners, who are often the managers (sometimes workers as well) of the informal enterprises, were found to be suitable informant for this study and were interviewed using a structured questionnaire. The questionnaire-based interviews were conducted with them between August-December 2021.

The authors designed the data collection instrument based on insights from Harju-autti and Kokkinen (2014) and Fu et al. (2020). The questionnaire was designed with consideration for the low socio-economic, educational, and cognitive backgrounds of the respondents. Owners from three types of manufacturing enterprises were selected for interviews due to the heterogeneous nature of informal manufacturing. Hemayetpur, Lalbagh (including Islambagh) and Keraniganj areas in Dhaka city of Bangladesh were selected for the interviewer-administered survey based on the cluster setup of the specific type of enterprise. Since the formal list or total number of informally operated enterprises was unavailable in official statistics, this study employed the snowball sampling method. Primary information was collected from the owners' association offices of the particular products as the study sought their recommendations for enterprise selection. Based on the provided information, Hemayetpur area was selected for interviewing firms in the leather and leather products industries, Lalbagh (including Islambagh) area for plastic and small machinery, and Keraniganj area for the

dyeing and clothing industries. Although the economic activities of the firms are different, they are homogeneous in terms of their scale of activity. The selection criteria was guided by the number of full time workers in the enterprises, their polluting nature (discharge of metallic pollutant), and the ILO (2018) instructions for identifying informal firms, which include unincorporated private firms with no permanent premises, registered at the local level (not at the national industrial authority), do not maintain accounts (no formal book-keeping) and pay no social security contribution or tax on wages.

A total of 90 questionnaires were distributed to the respondents, and out of them, 14 were incomplete as the respondents were unwilling to answer questions related to their waste disposal practices. The COVID-19 restrictions during the study period posed challenges to the smooth data collection process, and prevented from reaching out to further enterprises. Thus, the data set used in this study is cross-sectional, consisting of information from manufacturing enterprises operating under informal conditions. The observation method was also employed as a means of collecting information, guided by owners' behavior, their interaction with polluting activities, and the work conditions in the enterprises. Prior to the interview, the enumerators provided adequate information to the respondents on the aims and objectives of the study to ensure reliable responses. Consent was obtained from the respondents before conducting the interview. During the survey, researchers and enumerators adhere to all the guidelines and ethical norms directed by the Human Resource Ethics (HRE) office of the University of Southern Queensland, Australia (UniSQ HREC ID: H21REA014).

Methods

The understanding of Environmental Awareness (EA) is highly influenced by individual ideology, making it challenging to reach a consensus on its precise definition. EA is a multidimensional

construct consisting of concern (affective), knowledge (cognitive), and behavioral and activity factors (conative) (Fu et al., 2020). The information on these three categories is gathered from the responses of the respondents (owners/managers) to a questionnaire designed to study the basic knowledge about the environment, value judgments about environmental concerns, behavioral attitude towards pollution at the firm level, and skill to prevent pollution. This questionnaire is based on the studies by Harju-autti and Kokkinen (2014); Fu et al. (2020). The questionnaire begins with questions regarding the demographic information of the respondents and then uses an intuitive approach to understand the meanings of their responses. Since the education and cognitive level of the respondents may not be adequate, it makes sense to ask enterprise owners/managers for their opinions, ideas, and actions on these concrete elements. The information collected from the responses to the questions under the above mentioned sections was used to construct the environmental awareness index (EAI). The next section of the questionnaire consisted of questions aimed at assessing the general perception of the respondents about environmental conservation practices. The sample questions covered under the aforementioned categories are reported in Table1. The final section of the questionnaire included questions about technology adoption for pollution control at the firm level. The respondents were asked to select their desired responses on a 5-point Likert type scale for the concern, and behavior and activity sections. The knowledge about environmental pollution and perception of environmental conservation were assessed in an innovative way to avoid exaggerated answers and were later combined empirically to construct the EAI.

Table 1: Description of the questionnaire survey on items of environmental awareness and general perception on environmental practices.

Question grouping	Concept	Category	Covered area
knowledge about environmental pollution [1-5]	The respondent's familiarity with various types of pollution and their causes.	Knowledge (Cognitive)	1. Knowledge about types of pollutions. 2. Knowledge about polluted items. 3. Knowledge about source of pollution. 4. Knowledge about human action generating pollution.
Concern about environmental pollution [1-5]	How do respondents rank different types of pollution in terms of their negative impact?	Affective (non-cognitive)	Level of concern with the environmental problems as mentioned below: 1. Overall pollution 2. Air pollution 3. Water pollution 4.Soil quality degradation 5.Noise pollution
Behavior on conservation, and activity [1-5]	How do the firms contribute to environmental activities?	Conative (Skill and Behavioral aspects)	1. To what extent does the firm abide by environmental regulations 2. Practice of solid waste disposal 3. Practices of waste water disposal 4. information on using pollution minimizing technology 5. information on recycling practice
General perception on environmental conservation [1-5]	To what extent the respondents are familiar with environmental conservation and its importance.	Perception (Cognitive)	1. Perception about environmental regulation 2. Importance of clean environment 3. Perception about solid waste disposal 4. Perception about waste water disposal 5. perception about pollution hazards

An additive index was constructed for the binary variables, knowledge and general perception of environmental conservation. Each question was assigned a value of 1 for a desired perception and 0 for a wrong perception and then the values were added together to find the mean score. The mean score on the scale was also calculated for the other two sections of the questionnaire (Concern, and Behavior and activity) and then standardized to apply in the Principle Component Analysis (PCA). PCA was applied to combine and modify data from independent categories and to create a new set

of mutually independent categories in the data set, which is suitable for further use (see Roger et al., 2008). PCA was applied in this study to construct the Environmental Awareness Index (EAI) comprising knowledge, concern, and behavioral and activity aspects of the respondents, and its construction through PCA ensured that the different aspects of the respondents are equally weighted and non-redundant.

Due to the dichotomous nature of the enterprises' decision on technology adoption for pollution prevention, a qualitative response model is deemed appropriate to apply. Qualitative response models relate the probability of an occurrence to various independent variables and are often useful when assessing the characteristics of firms that are associated with technology adoption decisions (Khan, 2002; Uzunoz and Akcay, 2012). To provide a detailed analysis of the firm's decision and action on technology adoption, the study has applied discrete choice probit and logit models for binary choice (yes or no) responses to the questions about the use of emission reduction technology. The probit model is a statistical probability model with binary categories in the dependent variable (Liao, 1994; Uzunoz & Akcay, 2012), which is based on the cumulative normal probability distribution. In this study, the binary dependent variable, technology use, takes the value 1 if the response is 'yes' and 0 if the response is 'no' (Aldrich and Nelson, 1984; Uzunoz and Akcay, 2012).

This study uses the following regression model to test the effect of firm level environmental awareness on the firm level technology adoption.

$$TA_i = f(EA_i, PEP_i) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Here, TA represents firm's decision on technology adoption, which is the dependent variable. EA and PEP are the independent variables in the model that represent environmental awareness and perception of environmental conservation practice, respectively. In the next stage, demographic

variable age (AGE) of the respondents, and business related variable, engagement of firms in subcontracting, (SC as binary variable) have been incorporated into the model as moderating variables. The moderating variables can be treated as confounding factors that may limit the environmental behavior of firm owners. The subcontracting variable is incorporated to capture the impact of globalization on the model, as the informal economy is expected to grow in the context of a globalized world. It is expected that globalization of production and trade often leads to subcontracting and outsourcing activity, as per neo-Marxist viewpoint (Huang et al., 2020).

$$TA_i = f(EA_i, PEP_i, AGE_i, SC_i) \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

The probability p_i of choosing technology against not choosing it can be expressed as in (3) following Green (2011),

$$p_i = prob\,[Y_i = 1|X] = \int_{-\delta}^{X_i'\beta} (2\pi)^{-\frac{1}{2}} \exp(-\frac{z^2}{2}) dz$$

$$= \emptyset(x'\beta)$$

$\emptyset$ represents the probability density function. The association between a specific variable and the outcome of the probability can be understood by means of the marginal effect that accounts for the partial change in the probability. The marginal effect that is associated with explanatory variables Xs on the probability P(Yi = 1 | X) while holding the other variables constant provides insights into how the explanatory variables shift the probability of frequency of explained variable (Green, 2011).

In the next stage, Logit analysis is applied to predict the probability of occurring an event. This type of analysis is particularly useful for models involving decision-making (Boateng and Abaye, 2019).

The Logit transformation is based on the 'ratio of chances' within the logistic regression and is important to establish the dependence of magnitude y on the variable x. This transformation allows for the ultimate relationship between the dependent variable y and a vector of independent variables x, with calculated probability ranging from 0 or 1. (Klieštik et al., 2015). Since the dependent variable in this study is categorical and there is no requirement for the independent variables to be normally distributed or linearly related, or have equal variance in each group, logistic regression (LR) can be applied. Application of LR gives each predictor a coefficient that measures its independent contribution to the variation in the dependent variable.

$$p(y) = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_k x_k}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 X_2+\cdots+\beta_k x_k}}$$

$$= \frac{1}{1+e^{-(\beta_0+\beta_1 x_1+\beta_2 X_2+\cdots+\beta_k x_k)}}$$

Here, $p(y)$ is the probability of technology adoption, x_k is the kth explanatory variable that are estimated by using the method maximal likelihood and β_k are the coefficient of individual indicator. By applying Logistic analysis in regression model (1) and (2) this study attempts to identify the independent variables that affect the probability of adopting emission reduction technology in firms. This study has formulated to test the following hypothesis: the use of clean or pro-environmental technology for emission control is positively related to environmental awareness among firm owners. Therefore, the expected sign of the EA coefficient is positive.

5. Results

Table 2 presents the results estimated from the binary probit model projected in eq.1 and eq.2. The models have been estimated by maximum likelihood method. The models are significant at 1% level of significance.

Table 2: Estimates of the binary probit model

Variables	Model-1				Model-2			
	Coefficient	Std. Error	Z-statistic	Marginal effects	Coefficient	Std. Error	Z-statistic	Marginal effects
Environmental Awareness (EA)	0.723*** (0.004)	0.252	2.86	0.285	0.767*** (0.005)	0.270	2.84	0.301
Perception on environmental conservation	2.163 (0.130)	1.429	1.51	0.852	2.145 (0.148)	1.481	1.45	0.842
Age					0.067* (0.067)	0.016	1.83	0.012
Subcontract					0.225 (0.481)	0.319	0.70	0.087
Constant	-1.817 (0.104)	1.118	-1.63		-3.293** (0.017)	1.374	-2.40	
Log-Likelihood	-45.270				-43.207			
LR Chi2(2)	14.61				18.73			
Prob>chi2	0.001				0.001			
Pseudo R2	0.139				0.178			
Predicted percentage correctly	61.84				60.53			

P-values are presented in the parenthesis.
*** statistically significant variable at 1% significance level.
* statistically significant variable at 10% significance level

The estimated coefficients and standard errors suggest that environmental awareness significantly affects the probability of adopting green technology in informal manufacturing firms. In the estimated models, the awareness variables exhibit positive signs and strong statistical significance (at 1% level). This implies that as business owners and managers become more aware of environmental issues, they are more likely to implement pollution-prevention or pollution-reduction technology. The marginal effect analysis indicates that for a firm with environmental awareness, the probability of using pollution-reducing technology is 28.5% in model 1 and 30.1% in model 2. This implies that the inclusion of demographic (age) and global factors (subcontract) in conjecture with awareness enhances the likelihood of technology use. Additionally, the study reveals that enterprise owners of a mature age are more likely to adopt emission-reducing technology, and the marginal

propensity of adopting pollution control technology increases by 1.2% with age. Interestingly, firm owners' general perceptions about environmental conservation practices do not significantly influence their decisions on technology use for pollution prevention. The correct prediction rates obtained from probit models are 62% and 60%, respectively. This implies that the probit models predicted 62% of the cases correctly for model 1 and 60% for model 2.

In the next step, a logit regression model has been fitted to the dataset to test the research hypothesis that environmental awareness increases the propensity of firms to adopt emission prevention technology and approves it.

Table 3: Estimates of dichotomous logit model

Variables	Model-1				Model-2			
	Coefficient	Std. Error	Z-statistic	Marginal effect	Coefficient	Std. Error	Z-statistic	Marginal effect
Environmental Awareness	1.241** (0.012)	0.492	2.52	0.304	1.278** (0.011)	0.500	2.55	0.312
Perception on environmental conservation	3.348 (0.142)	2.282	1.47	0.819	3.381 (0.161)	2.410	1.40	0.827
Age					0.049* (0.074)	0.027	1.79	0.012
Subcontract					0.357 (0.498)	0.526	0.68	0.087
Constant	-2.855 (0.111)	1.791	-1.59		-5.263** (0.021)	2.284	-2.30	
Log-Likelihood	-45.318				-40.215			
LR Chi2(2)	14.51				24.07			
Prob>chi2	0.001				0.000			
Pseudo R2	0.138				0.229			
Predicted percentage correctly	61.84							

P-values are presented in the parenthesis.
*** statistically significant variable at 1% significance level.
** statistically significant variable at 5% significance level

The results of logit regression presented in Table 3 indicate that environmental awareness significantly influence the likelihood of technology adoption by firms for emission control. The

Logit regression results are consistent with the probit outcomes and suggest that the more environmentally aware a firm is, the more likely it is to adopt pollution prevention technology. Additionally, the age of the business owner has a positive impact on the likelihood of technology adoption. The findings of this study are in line with those of Ari and Yilmaz (2017); Gadenne et al. (2009) but contradict to Schaper (2002).

6. Conclusion and policy suggestions

This study examines the role of environmental awareness in promoting the adoption of pro-environmental technologies in informal manufacturing and business units, with the aim of fostering a sustainable approach to informal manufacturing. An Environmental Awareness Index has been constructed for this, encompassing the cognitive, affective and conative aspects of entrepreneurs' perception of the environment, as well as their practices regarding waste management, firm-level pollution and its management. By incorporating this index into probit and logit regression models, the study empirically investigates the potential of environmental awareness to drive the adoption of green technology in informal enterprises, thereby enhancing environmental and social benefits and promoting green growth. The empirical findings of this study indicate that heightened environmental awareness among entrepreneurs corresponds to a higher likelihood of utilizing pollution-reducing technology. These findings contribute not only to the reduction of pollution but also to the improvement of waste management and recycling services, which is complementary to the principle of circular economy. Thus, building of environmental awareness in informal sector enterprises can uphold sustainability by shifting into the model of the circular economy, where, the economy, constructed from the societal production-consumption system, facilitate economic growth through the minimization of environmental impacts and externalities (see Tong et al., 2021). The findings of this study can provide valuable insights for development stakeholders and policymakers in designing

effective policies focused on awareness building to engage informal enterprises in waste management and emissions reduction through technology adoption. In light of alarming reports highlighting the consequences of human actions on the environment, such policies are essential for addressing the pressing environmental challenges we face (IPCC, 2021).

The informal sector is often praised for its ability to create employment and income, but also criticized for its negative impact on the environment. Adoption of new technology with pro-environmental behavior can facilitate social business initiatives in the informal sector since it can better connect economic activity with societal value. Improved awareness in informal enterprises can be suggested based on the spillover effect of social businesses, which prioritize saving society through survival mechanisms over profit maximization. This can help to implement environmental management approaches and initiatives, and install environmental values and culture within firm. Creating a cultural change requires an effective and sustained education system that generates awareness and provides access to information and institutional services that complement the implementation of an environmental management system. A training program with regular evaluations can be beneficial for this purpose, and firms must view training investments as important as other financial investments. Given the weak financial structure of informal enterprises, it is crucial for government and non-government organizations to step forward by providing tools to promote environmental awareness, education, and adoption of an environmental culture in these enterprises. Various tools are available to achieve this, including mass media, newspapers, school programs, outdoor educational programs, government and non-government training programs, leaflets, wall-writings, voluntary campaigns, and interaction with concerned bodies. These tools can be made easily accessible to informal enterprise stakeholders, which can play a crucial role in promoting

environmental behavior and improving environmental performance at the firm level. Consistent with Saifullah et al. (2017), this study also suggests including chapters on environmental issues in the education curriculum of primary and secondary schools.

Financial institutions also have a crucial role to play in encouraging enterprises to adopt green technology. One effective approach is to offer incentive packages that reward businesses for embracing sustainable practices. In addition, technical and financial support should be made available to help these enterprises in implementing innovative technologies that effectively reduce both local and global pollutants, especially within the production unit of the informal sector. By recognizing and understanding the relationship outlined in this study, regulators, environmental organizations, and firm-level stakeholder groups can work together to promote better environmental performances. Maintain effective communication and exchange information on environmental issues are crucial for these groups.

This study concludes that raising awareness about environmental issues among entrepreneurs is key to promoting sustainability practices in informal sector enterprises. Informal enterprises need to be committed to sustainability through an awareness-raising process that emphasizes their responsibility to the environment. By doing so, these enterprises can make a meaningful contribution to sustainable manufacturing. However, this study acknowledges several challenges behind this findings that arise from the lack of a universal definition of informal enterprises, the difficulty in identifying informally operated firms, and the challenge of engaging the owners and/or managers in the research project. Moreover, a lack of in-depth information, non-response bias, and social desirability bias, as well as a limited sample size due to the COVID-19 context, put a limit the to the

research. Despite all these challenges, this study attempts to minimize them by observing the behavioral aspects of respondents, i.e. entrepreneurs in person and applying robust empirical techniques. These findings are expected to advance understanding of the relationships discussed, and encourage further research to address more desirable prospects related to the topic. Future research can focus on implementing awareness-based environmental management policies in informal enterprises to contribute to the circular economy, as production in this sector often relies on secondary materials from the waste collection process or post-consumer waste. Since a material recycling facilities in the official treatment system are often absent or malfunctioning in developing countries (Tong et al., 2021), informal enterprises can contribute to this end, and further studies can explore its potential with an understanding of the central role of awareness in this process. Overall, this study holds significant implications for the field of environmental sustainability and sustainable business. The empirical findings provide valuable insights into opportunities and pathways for promoting a green economy including the establishment of green manufacturing and business hubs. By illuminating the role of environmental awareness in driving the adoption of pro-environmental technology and practices among entrepreneurs in informal businesses, this study can assist policymakers and other stakeholders in developing more effective strategies to promote sustainable development within informal manufacturing enterprises.

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CHAPTER 8: DISCUSSION AND CONCLUSION

This chapter provides an overview of the objective and findings of the thesis as well as discusses its contribution to addressing the issue of informality in the economy, particularly in the urban economy of a developing country, while considering the achievement of sustainable development goals (SDG). Additionally, this research provides recommendations for macroeconomic and policy tools that can stabilize and mainstream this vibrant sector in developing countries. This chapter also suggests the limitations of the research and its future scope.

8.1 Discussion and Policy Implications

The development process involves moving from a certain state to a desired state (Alenda-Demoties, 2022). The present research investigates this development path by engaging with the informal sector, which is officially unaccounted for. Specifically, this research examines the internal dynamics of the informal sector to determine its current trajectory, desired direction, and how it can contribute to sustainable development (SD) in developing and emerging countries. The urban context is emphasized in this research since the informal sector typically originates in urban conditions, and both urbanization and informal sector employment are listed as major challenges to global sustainable development in the 21st century by the United Nations Human Settlement Programme (UN-Habitat). This research focuses on Bangladesh as a case study to shed light on this issue.

The informal sector has been linked to many development challenges. While it can promote local economies and alleviate poverty and unemployment, it is also indicative of underdevelopment and unsustainability due to its potential threat to the economy, environment, and social life. The

dynamics and causes of the growth of the informal sector are linked to the process of urbanization in developing countries. Therefore, this research aims to investigate the economic, social, and environmental dimensions of the informal sector activities in developing and emerging countries and to evaluate their contribution to the transition towards green, inclusive, and resilient development outlined in the Sustainable Development Goals (SDGs). The overarching interest of the research is to critically evaluate the role of the informal sector in the green development agenda, which is based on the assumptions of sustainable development but has been criticized for disregarding and undervaluing the informal sector. Specifically, this research focuses on the socio-economic insecurity and inefficiency of urban informal enterprises, and on the emissions generated from the activities of small and medium manufacturing enterprises operating informally in urban areas. The research explores the prospects and pathways for informal (manufacturing) enterprises to achieve green growth, which is a component of sustainable or green development.

The expansion of the informal economy is a significant aspect of fast and unplanned urbanization in developing and emerging countries. However, this sector of the economy remains largely unobserved. Therefore, this research initially focuses on urbanization along with other economic and socio-economic indicators and investigates its contribution to environmental degradation, thus, sustainability. The negative impact of urbanization on the environment in South Asia and Bangladesh, as observed through regional and country-level studies, highlights the urgent need to address the economic, social, and environmental concerns associated with rapid and unplanned urban growth. The informal sector is integrated to urban growth, which also raises concerns in all these three areas, but remains underexplored. Thus, the informal sector, which is also an important thematic area within the SDGs, has been targeted in this research. This thesis seeks to generate

empirical evidence on the informal sector for policy measures by examining the burdens and prospects of this sector and providing guidelines towards sustainable development.

To accomplish the aim, nine empirical studies have been conducted and presents nine research papers as it is a Thesis by Publications. These studies evaluate and analyze informal sector activity in terms of the same basic themes of sustainable development, covering both the macro and micro aspects of the topic and utilizing a combined and component-wise approach that considers economic, socio-economic, and environmental factors in a chronological and cohesive manner. The outcomes of these studies are presented in a coherent manner to reach a reasonable conclusion on the topic of this thesis. For macro-level analysis, secondary sources of data are examined. Meanwhile, primary data was collected for micro-level study through an interviewer-administered survey conducted in Dhaka, Bangladesh, between August 2021 and March 2022, specifically for the purpose of this research. Both primary and secondary dataset are utilized in the empirical analysis to address the research objectives posed by the research questions.

As a background enquiry, this research seeks to determine the impact of urbanization on the environment. To satisfy this objective, the research investigates industrialization, urbanization, economic growth, and energy consumption in the South Asian region to identify their causal impact on the environment in **Study 1**. This study confirms the significant derogatory impact of urbanization, economic growth, and energy use on the environment, which sheds light on the impact of informal sector activities in urban areas, as migrants from rural areas primarily end up in this sector and contribute to socio-environmental crises. However, given that the qualitative nature of urbanization varies across countries, **Study 2** has been conducted on Bangladesh, a developing

country in the region. In this study, the environmental Kuznets hypothesis is explored for Bangladesh, which observes the long-term effects of urbanization and economic growth on the environment. The findings reveal a similar negative impact of urbanization on the environment, with confirmation of the environmental Kuznets relationship employing an indicator named Ecological Footprints (EF) that captures both direct and indirect impacts of production and consumption activities on the environment. Based on the causal relationships revealed in this study, the research comes to the understanding that economic growth and urbanization reinforce each other. This implies that the maintenance of a persistent level of economic growth with structural change can lead to improvements in environmental conditions in the country of study (Bangladesh). Economic growth should be pursued with targeted green growth arrangements in urban areas to uphold sustainable development, particularly in Bangladesh. Therefore, this research focuses on the urban area, considering its challenges and prospects for the overall growth and development of an economy. The study also justifies targeting the informal sector, which is a complex urban issue and a significant contributor to economic growth, as a suitable candidate to explore green urban development, an integral part of SD. The informal sector is examined from a sustainability perspective in a panel of developing and emerging countries, including Bangladesh, in **Studies 3, 5,** and **8**, to achieve the research objectives from a broader perspective. Additionally, this analyzes the economic activities involving the informal sector and systems in urban areas to strike a balance between inclusive growth and socio-environmental protection in **Studies 4, 6, 7** and **9**.

To be more precise, the empirical investigation in **Study 3** demonstrates that the informal sector does not promote sustainable development in developing countries. In this study, the impact of the informal sector (captured as a proxy of working poverty) has been explored in the context of SD in

developing countries by constructing a composite index of sustainability that comprises all three indexes (economic, social, and environmental). The effect of the informal sector is also explored in terms of each individual index of SD, where it poses a negative impact on the economic and environmental aspects of SD and ends up with an insignificant impact on SD in the social aspect. This outcome provides a rationale for a more detailed study of this sector by critically examining its prospects and problems in each of these three areas of SD.

In an attempt to explore the economic contribution of the informal sector to SD, this research faces the challenge of limited data availability on the informal sector. To overcome this constraint, this research generates time-series data on the economic contribution of the informal sector in Bangladesh, which reveals an increasing trend in its percentile contribution to the country's GDP. Using this dataset, **Study 4** examines both the symmetric and asymmetric impacts of the informal sector's contribution on the GDP growth of Bangladesh. The findings suggest that the size of the informal sector should be reduced to achieve higher economic growth while adhering to sustainability. However, in terms of employment, **Study 5** reveals the positive contribution of the informal sector to the economic growth of developing countries in the context of SD. Therefore, the research supports the ILO recommendations for decent work conditions, workplace safety, and productivity improvement, which can be achieved by gradually improving working conditions, increasing income, and gradual formalization of firms operating in the informal sector. Digging into the details of employment in the informal sector, this research has investigated the socio-economic conditions of informal sector workers in terms of food availability in **Study 6** and found that most of the workers who are under study are food insecure. The findings of this study project a significant

negative effect of food insecurity on the physical and mental health status of workers, which takes a toll on their productivity and prevents them from escaping the poverty cycle to which they belong.

At this point, this research delves into investigating the economic efficiency level of informal sector enterprises, which are often claimed to have lower productivity. Employing micro-level analysis techniques, this research reveals a lower level of economic efficiency for informal manufacturing firms in **Study 7.** In addition to this, a scientific investigation is conducted in this study on the metalloid pollution load in environmental compartments that are sourced from informal manufacturing enterprises. A composite pollution load index (PLI) is constructed and applied to efficiency analysis to investigate the cleaner production (CP) prospects of these informal enterprises. This study reveals a positive correlation between pollution and economic efficiency but also explores the prospect of CP in informal enterprises as an initiative for minimizing pollution load and achieving eco-efficiency. However, it requires technical, financial, and institutional supports that are hardly available for informal firms in developing countries. Thus, this research finds an opportunity for informal sector manufacturing enterprises to participate in the discourse of sustainable development by seeking or organizing support from government and non-government institutions, which can ensure eco-efficiency in their production. Further, delving into the environmental impacts of informal sector activities on SD, **Study 8** concludes that institutions also have incentives to work with informal enterprises, preferably through some indirect strategies. This study finds evidence that strict institutional measures can increase environmental degradation in the presence of the informal sector by shifting pollution from formal to informal enterprises since informal enterprises are less accountable for their pollution. Given that developing countries often lack the institutional

arrangements and resource capacity to provide support to informal enterprises, this research suggests the implementation of indirect policy measures that require less monitoring and financial support.

Under this backdrop, this research emphasizes increasing environmental awareness among stakeholders in informal enterprises, as an indirect strategy of pollution control, in **Study 9**. Constructing an awareness index based on the knowledge, concern, and behavioral activity of enterprise owners regarding the environment, its management, and pollution control, this study investigates the prospect of raising awareness for the resolution of firm-level environmental issues. This study finds an increasing probability of responses to green technology adoption with an increased level of awareness in informal enterprises. The findings reveal that environmentally aware individuals are more likely to show pro-environmental behavior and adopt a positive attitude towards environmentally friendly products and technology that facilitate green growth, in addition to effective measures for approaching formalization.

Through these nine empirical studies, this research evaluates the detailed impact of the informal sector on overall sustainability in developing countries, particularly in urban areas where green growth has to be pursued with the presumption that the informal sector will not disappear completely due to its primary goal of survival. Survival always legitimizes law-avoidance, as it is often justified by a lack of opportunities in this sector. The complete elimination of the informal sector is only possible if a trustworthy state reduces the regulatory burden and combines it with democratic citizen participation in upholding the rule of law (see Enste & Schneider, 2003; Gerxhani, 1999; Pardo, 1995), which is challenging for developing countries. In the context of the most rapidly urbanizing city, Dhaka, Bangladesh, where the dominance of the informal sector challenges economic growth

and informal sector activities and settlements pose a major threat to the health and well-being of urban life, the green growth phenomenon deserves attention from all socio-economic and environmental agents. Therefore, the informal sector has been targeted in pathways towards green growth in urban areas of the country to facilitate sustainability. The outcomes achieved for Bangladesh through this research, which can be applicable to other developing countries with similar contexts, provide a resolution to the socio-environmental costs of informal sector growth by encouraging decent work conditions, gradual formalization, institutional cooperation, technology adoption, and raising awareness. Thus, the outcome of this research will lead to strategic development in reducing the social, economic, and environmental costs associated with informal sector growth in Bangladesh and other developing countries.

The extreme diversity of economic units in the informal sector and their marginal nature preclude them from being subject to the same policies as the formal sector. Consequently, direct institutional regulation techniques are inapplicable for informal activities until they are incorporated into the formal sector. Therefore, this research contributes to the strategy of implementing indirect environmental regulations along with suggestions for the gradual formalization of informal firms to achieve the green development agenda of the SDG. Building awareness, encouraging innovative and clean technology, enhancing social responsibility, and implementing information-based policies with rigors environmental stewardship campaigns aimed at creating green cities, along with tax and financial reform, easing bureaucratic procedures, and enacting labor rights and decent work conditions are suggested as effective strategies by this research to promote sustainability. Attention to these strategies can be helpful for informal enterprises in implementing corporate social responsibility and a circular economy that targets sustainable development in terms of social welfare, environmental health, and the quality of socio-economic growth. Awareness building contributes to

changing mindsets that influence other strategies, including waste management, resource utilization, decent work and workplace safety, and the implementation of green technology in informal businesses and production units. Awareness enables people to appreciate the value of innovation, adoption, and engagement with clean practices that are most conducive to the implementation of economic, social, and environmental aspects of work practices guided by SD. Through awareness building, people can move beyond the notion that greater green legislation or technology would increase costs and place additional burdens on them. Instead, it can help building social responsibility, which is a new business strategy towards sustainability. Therefore, by increasing awareness among entrepreneurs and stakeholders, informal businesses can be encouraged to take part in SD practices. Such practices include adopting clean technology, enhancing social responsibility (e.g. indirect food support programs), and implementing information-based policies that promote environmental stewardship (e.g., educational programs that advertise information about pollution and pollution control, and encourage adopting innovative technology). These strategies, combined with gradual formalization policies, indirect taxation policies, financial and/or technological support policies, subcontracting to formal businesses, and more engagement with formal firms, can create a conducive environment for informal businesses to thrive sustainability and contribute positivity to the economy.

To be more precise, the findings of the studies undertaken in this research contribute to policies by suggesting a reduction in the size of the informal sector (in **Study 3** and **Study 4**), improvement in employment condition and decent job creation (in **Study 5**), and supply of food, health, and nutritional support to informal workers (in **Study 6**). Encouraging the formalization of micro, small, and medium-sized enterprises this research also contributes to policies by suggesting ways for

institutional support to informal manufacturing enterprises, that can ensure an implementation of CP strategies in informal businesses (in **Study 7** and **Study 8**). Additionally, this research proposes raising awareness about firm-level environmental management to encourage technology adoption for pollution minimization (**Study 9**), which is another valuable policy recommendation. Successful implementation of any one or more of the above-mentioned strategies will contribute to minimizing the socio-economic and environmental costs and bring the informal firms onto the path of green development that contributes to SD, as long as they are not absorbed into the formal sector and comply with the formal arrangements for SD. The policy suggestions of this research align with the recommendation of the ILO, essential for achieving inclusive development and realizing decent work for all as reflected in the 2030 Agenda for Sustainable Development, notably Sustainable Development Goal (SDG) 8 in Target 8.3. The policy recommendations of the studies are also helpful in implementing SDG 1, SDG 5, SDG 9, and SDG 11 either directly or indirectly.

8.2 Contributions of the thesis

The main contribution of this research is to analyze and comprehend the informal sector, or its designated segment, in the context of SD and its components and to identify the challenges posed by this sector to the sustainable development of urban areas by employing short-run, long-run, or cross-sectional analysis. Besides this, the studies conducted in this research provide insights and recommendations for policies and interventions that can facilitate the transition towards a more sustainable and inclusive development model. All findings have been derived through inductive reasoning, which means that the analytical examinations are based on data rather than theoretical assumptions. The research employs advanced statistical and econometric techniques to extract the outcomes. Thus, this thesis makes contributions to the existing literature by providing evidence on

the challenges and prospect of the informal sector in the context of sustainable development. Employing national and global datasets, this thesis offers empirical evidence to complement policy measures aimed at addressing the burning issues involving the informal sector in developing and emerging countries. The evidence-based suggestions generated from this research will be helpful in realizing the concept of the green economy, which has gained significant importance in response to multiple crises such as climate change, economic instability, food insecurity, health pandemics, and social issues ahead of achieving the SDGs. This alternative paradigm offers the promise of growth while protecting the earth's ecosystems and contributing to poverty alleviation opportunities. With a focus on the informal sector's involvement in the crisis towards green development, this research identifies a path that proactively addresses ways to minimize constraints hindering the achievement of the goals. These findings will help to improve the understanding of the potential employment opportunities in the informal sector, considering the different and vulnerable economic perspectives of developing countries. As a result, this thesis could contribute to the design of appropriate strategies and the provision of a quality environment and decent work conditions in informal sector enterprises. This is significant since the informal sector is a vibrant and growing phenomenon in urban areas and is limiting economic development and the achievement of sustainable development.

With an estimated 70% of the world's population predicted to live in urban areas by 2050, the micro-level studies of this research have significant potential to contribute to urban green development. This research will have direct benefits for developing nations, where urban growth is often correlated with the physical expansion of metropolises beyond formal administrative borders. Such urban growth is typically induced by the growth of the non-agricultural informal economy, and thus, the growth of the informal sector coincides with rapid urbanization. This provides opportunities for the

informal sector to be included in the inclusive economic growth of urban areas, leading to green growth. Exploring the potential and pathways to green growth through cleaner production and awareness, this research has immense potential to contribute to sustainability, particularly in urban sustainability, which ensures a balance between urban development and environmental protection along with social equity regarding aspects such as income, employment, and basic needs and services.

This research also contributes to satisfying the call of international agencies that have emphasized the dynamic ability of cities to create new green jobs and economic opportunities to promote cities' role in green development (Brown & McGranahan, 2016). Adopting the policy suggestions proposed in this research is expected to contribute to accessing green jobs and economic opportunities in urban Bangladesh, thereby promoting the role of cities in the green development of developing countries. Amidst the rising question of whether the inclusion of the informal economy in the green development process requires formalization through new or existing regulations, this research suggests that the green development agenda may engage constructively with the urban informal economy (see Brown & McGranahan, 2016), along with a concrete suggestion for its gradual formalization. Concentrating on the segments of the urban informal sector that are neither green nor environmentally just, this research aims to suggest strategies to transform their unsustainable and unjust behavior, making them safer, more inclusive, and ideally greener. By suggesting strategies to transform unsustainable practices, this research contributes to the creation of safer and more inclusive work environments while also aligning with the goals of green development. The policy suggestions put forwards by this research have the potential to foster green growth and the creation of new economic opportunities, particularly in urban areas, in a sustainable and inclusive manner.

Since working with informal enterprises poses a continuous challenge for educators, planners, policymakers, and environmentalists due to the internal dynamics of these firms (see Sasidharan & Raj, 2014), this research has contributed to capturing the contextual factors and dynamics of the informal economy and firms operating in this sector and analyzed them from an SD perspective. This research can be considered a collection of novel analyses of the informal sector on the pathway to achieving SD. One of the novel contributions of this research is the construction of a composite index of sustainability for developing countries and the revelation of the impact of the informal sector on it (**Study 3**). Another novel contribution is the generation of time series data on the informal sector of the studied country and its use in advanced empirical analysis to find a reasonable conclusion on the effect of informal sector activities on the economic growth of that country (**Study 4**). Additionally, the social challenges of the informal sector, highlighted by the negative association between food insecurity and the physical and mental health status of informal workers, are a topic that has not been explored in existing literature (**Study 5**). By exposing this social crisis underlying informal enterprises and suggesting policies accordingly, this research contributes to overcoming the crisis that hinders the prospects for socioeconomic sustainability. In COVID-19 pandemic circumstances, the outcome of this study has immense potential to contribute to an immediate response in socio-economic recovery, which cannot separate health from economic issues.

The most significant contribution of this research is its scientific investigation of the level of pollution in the surrounding areas of informal enterprises and the construction of pollution load indexes (PLIs) for metallic contamination in environmental compartments. The use of these indexes in analyzing the cleaner production (CP) prospects of small manufacturing firms through eco-efficiency assessment is another novel contribution of this research that has explored the possibility

of green growth in urban Bangladesh (**Study 7**). The pathways suggested by this study will contribute to the practice of CP, which is one of the best types of corporate culture enabling enterprises to improve their existing capabilities through resource optimization and exploration of new opportunities with institutional feedback. Providing evidence in favor of CP as an affecting strategy for informal manufacturing enterprises and promoting environmental awareness as a programme of implementing green management (see Cao et al., 2022), this research contributes to policy measures for green growth. Providing evidence-based suggestions for cultural change and behavioral aspects of unregulated informal enterprises as a desired sustainability practice is an important contribution of this research that policymakers can work on (**Study 9**). Implementation of these policies is expected to bring about a change in management, putting forwards two recent thrusts of sustainable development: social business and the circular economy. Through behavioral and cultural change, awareness-building can implement corporate social responsibility (CSR) in informal businesses and convert them into social businesses, which will put a duty on themselves to adopt desired policies beneficial for society and to act reasonably in handling the shifting dynamic between business and society. Such cultural and behavioral change in informal sector activities can bring sustainability closer to reach. This will also aid in implementing a circular economy in developing countries involving the informal sector since the material recycling facility in the official treatment system is mostly absent or malfunctioning in these countries (see Tong et al., 2021). The role of the informal sector in this regard has already been highlighted in developing countries, and raising awareness can help move this forward by bringing a behavioral change to the production and waste disposal practices in informal firms that mostly rely on secondary materials from the waste collection process or post-consumer waste.

Given that, different segments of the informal sector have different impacts on the economy, society, and environment, the compartmentalized analysis presented in this research will aid urban, economic and environmental policymakers, as well as civil society practitioners, in making informed decisions and developing resilience concerning informal sector activities. This research has provided important feedback by offering topic-wise policy suggestions based on the segment-wise studies presented in this thesis. The findings of the macro and micro-level studies on the informal sector and its enterprises provide important evidence-based policy suggestions for Bangladesh and other developing countries facing similar challenges. These suggestions are expected to contribute towards addressing issues associated with the informal sector (SDG 8) and sustainable cities (SDG11). The suggestions also expects to contribute to address a number of other SDGs relevant to social justice issues including free from Poverty (SDG1), reducing gender inequality (SDG5), promoting inclusive and sustainable industrialization (small-scale industries) (SDG 9). Moreover, as the informal sector is one of the most severely affected sectors due to the global pandemic and lockdown restrictions, this research is expected to add a significant contribution to the growing body of literature on post-pandemic economic restoration in the relevant areas of structural change.

8.3 Limitations and further research directions

This research has experienced limitations in terms of data availability at both local and international levels, as it is conducted on an officially unobserved and unrecognized sector. This research faces acute difficulties in the accessing and obtaining data at the country level due to the reason of its unobserved nature and consequently a lack of locally compiled data sets in a systematic manner. The COVID-19 pandemic situation has also added constraints, as primary data collection was required.

Furthermore, the lack of sufficient funding has restricted this research. Therefore, future studies should focus on generating more extensive datasets to address new dimensions of the informal sector and employing more updated econometric tools. Extensive dataset will facilitate further research to develop indices that evaluate an individual's awareness level more intensely, which can provide better policy support.

One of the main causes of the low level of productivity in the informal economy is the workforce with a low level of education and training. The gender dimension is also an important point of interest in the informal sector that this research fails to capture due to data limitations. Thus, human capital and its various dimensions, which are among the major causes of the productivity gap, deserve further study. Future research could also explore the desired form of linkage between the informal sector and the formal sector. Subcontracting, which is the globalized form of the informal sector activities, could be further examined to provide better policy suggestions. It deserves attention as it is sometimes viewed as growth strategy for small and marginal firms (see Sahu, 2010) by ensuring market for their products and offering benefits including technological upgrading and training for employees (Ranis and Stewart 1999), and sometimes is blamed for catalyzing the growth of informal firms.

This study doesn't capture the informal service sector considering it relatively clean. However, future research should include this sector given its magnitude and economic participation. Additionally, the development of advanced empirical methods in behavioral economics would be another area for future improvement, which can help better anticipate the behavioral aspects of

informal sector enterprises and identify the barriers to changing behavior in ways that benefit sustainability.

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APPENDIX A

Measurement of the Informal sector in Bangladesh: A Currency Demand Approach

For an empirical investigation of the informal sector at the country level, this study focuses on Bangladesh as a representative of developing countries. Bangladesh is one of the NEXT-11 countries of the world and is currently on track to graduate from the UN's category of lower-income to middle-income country list in 2026 (WB, 2021). It possesses the highest share of employment in the informal sector comparing to other South Asian countries where informal employments are also dominating in their employment statistics (Chaudhuri & Mukhopadhyay, 2010; ILO, 2013). The informal sector in Bangladesh combines both opportunities and challenges by its wide range of coverage in terms of the production of goods and services and percentage share of the total workforce (more than 80 percent) on the one hand and by the incidence of low productivity, economic inefficiency and inequality on the other hand (Raihan, 2010). Consequently, the evaluation of the trend of the informal sector as contributor to the final gross domestic product (GDP) is crucial for understanding the internal dynamics of economic development (Tanaka & Keola, 2017).

To explore the trend of the informal sector, the important first step is to measure the size of the informal sector which is inherently difficult (Tanaka & Keola, 2017). Among a few comprehensive studies to take account of the informal economy in Bangladesh, most have applied monetary approach. Among the three monetary approaches, namely, the simple currency ratio method, the transaction method, and the currency demand method, this study will apply Cogan's (1958) idea of currency demand for empirical analysis that was later developed and popularized by Tanzi (1983) (Duygun Fethi et al., 2006a). In an earlier work on Bangladesh the currency demand approach (CDA)

was applied for measuring the size of the underground economy by Haque, (2013) for the period 1973-2008. The present research has also applied CDA for measuring the size of the informal economy. The details of the theoretical perceptions of the models and their application are presented below.

Currency Demand Approach: data and method

For the first time Phillip Cogan (1958) correlated the ratio of currency to broad money that was later developed by Tanzi (1983) with an econometric approach and empirical investigation. Demand for currency can be augmented by the expansion of informal economy and therefore, it is estimated using econometric tools intending to have an idea of informal transaction in the economy (Schneider & Enste, 2000). However, this technique has applied mostly for the economies that belong to the high income groups (See Alm & Embaye, 2013). Since the contributing factors of informal economy of a developing country seem to be different from that of a developed country (Goel & Nelson 2016), this study has followed the basic idea of Tanzi (1983), Schneider & Enste (2000), Schneider et al., (2010) and others with a little modification in its application based on the context and data availability. The time series properties of the model are addressed by finding a long run co-integrating relationship and applying co-integrated regression model. Following Tanzi (1983), Duygun Fethi et al, (2006a), Haque (2013), Minhaj-ud-din et al. (2017) the empirical model of currency demand approach (CDA) is specified as follows:

$$CM_{2t} = \alpha_0 + \alpha_1 TB_t + \alpha_2 FD_t + \alpha_3 INTR_t + \alpha_4 INFR_t + \varepsilon_t \quad \text{.....(1)}$$

Where, CM_2 is the real currency in circulation to M_1money supply ratio, TB is the amount of total (direct) tax collection, expressed as a percentage of GDP, FD is the proxy for financial development, which is the ratio of total money demand and time liabilities to Nominal GDP, INTR stands for the real interest rate, which is the inflation adjusted lending interest rate and measured by GDP deflator,

INFR is the growth rate of consumer price index and ε_t is the white noise error term. Data against the variables are used in their level forms following Minhaj-ud-Din et al. (2017). The expected signs for the coefficients of the variables TB, FD, INTR and INFR are positive, negative, negative and positive, respectively. Following Arby et al. (2010) this study has resolved the disaggregation problem by splitting the result into illegal and legal money and has estimated the informal economy to find the trend based on the assumption applied by Haque (2013) that velocity of illegal money is equal to the velocity of legal money.

For empirical estimation of the model annual data covering the period 1982 to 2018 has been collected for Bangladesh economy. Variables are selected in accordance with the models estimated in this study grounded on earlier literatures. Data on nominal GDP were collected from yearly publications of Bangladesh Economic Review (1982-2019) and WDI (2020) data source. Money supply and tax collection data were collected from the publications of Bangladesh economic survey and Bangladesh economic review, data for real interest rate and inflation rate from the WDI (2020). To avoid the spurious result in empirical analysis, the time series properties of the data were checked by employing Augmented Dickey Fuller (ADF) (Dickey & Fuller, 1979) and Phillips Perron (PP) (Phillips & Perron, 1988) unit root tests. All the variables were found to be stationary at their first difference in both intercept and trend model. The results for the unit root test is presented in Table 1.

Table-1: The results of unit-root test

Variables	Models	ADF		PP	
		Level	1st Difference	Level	1st Difference
CM_2	Intercept	-3.48***	-5.00***	-3.47***	-4.97***
	Trend and Intercept	-3.14	-5.27***	-3.17	-5.28***
TB	Intercept	0.83	-8.58***	0.32	-8.70***
	Trend and Intercept	2.78	-5.85***	-2.78	-8.90***
FD	Intercept	-0.27	-4.29***	-0.29	-4.26***

	Trend and Intercept	2.28	-4.23***	-1.55	-4.16***
INTR	Intercept	-3.87***	-8.71***	-3.84***	-12.63***
	Trend and Intercept	-3.63**	-8.65***	-3.71**	-17.71***
INFR	Intercept	-2.08	-8.17***	-3.66***	-15.95***
	Trend and Intercept	-1.96	-8.11***	-3.72**	-17.06***

Note: *** indicates significance at 1% level.

After confirming the order of integration, the long-run relationship among the variables was investigated by applying the conventional Johansen co-integration (Johansen 1988, 1991) test using the 'trace' and 'maximum Eigen value' statistics. Both the test statistics 'Trace' and 'maximum Eigen value' indicate a rejection of the null hypothesis of no co-integration vector against the alternative hypothesis of at least one co-integration and it is rejected at a 5 percent level of significance. Therefore, the Johansen co-integration test result confirms a long-run relationship among the variables. The test result is presented in Table 2.

Table-2: The results of Johansen Co-integration test

Unrestricted Co-integration Rank Test (Trace)				
Trend assumption: Linear deterministic trend				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.594	81.541	69.818	0.004
At most one*	0.510	49.991	47.856	0.031
At most 2	0.439	25.022	29.797	0.161

The results of Currency Demand Approach (CDA)

To estimate the co-integrating relationship directly by traditional OLS, it needs to be modified with corrections that are capable of taking into account of endogeneity and autocorrelation problem. A Fully modified (FM) ordinary least square (FMOLS) estimator is used to determine and accommodate the importance of these effects in empirical investigations. It is opined that the FM estimator performs comparatively well comparing to other methods while estimating the co-integrating relationship (Phillips, 1993; Hansen & Phillips, 1990). Therefore the fully modified ordinary least square (FMOLS) regression which was designed by Phillips & Hansen (1990) is

applied in this study to get optimal estimates of co-integrating regression and the result is presented in Table 3. The result has shown that financial development and real interest rate are highly statistically significant and tax burden is weakly significant with expected signs. Theoretically, development of the financial sector should reduce the currency in circulation since people prefer to transact through banks and other financial institutions rather than keeping money in their possession that forgoes the interest rate. The negative and significant coefficient of financial sector development and real interest rate supports the fact. The model satisfies the relevant diagnostic tests that are presented in Table 3.

Table-3: The results of Fully Modified OLS (FMOLS)

Dependent Variable: CM_2			
Method: Fully Modified Least Squares (FMOLS)			
Variable	Coefficient	t-statistic	
TB	0.005*	1.84	
FD	-0.001***	-4.08	
INTR	-0.001***	-2.86	
INFR	0.001	1.56	
C	0.152	11.9	
Diagnostics:			
R-squared	0.625	Mean dependent var	0.136
Adjusted R-squared	0.577	S.D. dependent var	0.016
Jarque-Bera Probability	0.101		
F-statistic	19.081***		
Chi-square	76.326***		

Note: *** indicates significance at 1% level, * indicates significance at 5% level

Using the coefficients, the currency broad money ratio with tax ($CM_{2_{TB}}$) and without tax burden ($CM_{2_{WTB}}$) are estimated to have an idea of excess proportion of currency that may be used for operating economic activities in informal sector aiming to escape the tax net of the regulatory authority. This makes it justified to mention that the illegal money reflects the magnitude of tax

evasion. Taking insight from Minhaj-ud-Din et al. (2017), Ashok et al. (2017), Haque (2013) the study has used the following model to get the illegal money supply in informal economy.

Illegal Money $(IM) = [(CM_{2_{TB}} - CM_{2_{WTB}})] \times M_2$.....(5)

Following Tanzi (1983) the legal money is calculated by subtracting the illegal money from the total money supply which is the sum of currency and demand deposit (M_1).

Legal Money $(LM) = M_1 - IM$.....(6)

Following Haque (2013) and Tanzi (1983) this study assumes that the income velocity of illegal money is same as that for the legal money in Bangladesh. The income velocity of money is estimated by using the following equation,

$IV = NGDP/LM$ ..... (7)

The estimate of the underground economy has been obtained by multiplying the illegal money with income velocity.

Informal economy= $IM \times IV$..... (8)

The estimate is expressed as a percentage of total GDP and the result is presented in table 5. The graphical presentation of the estimated size of the informal economy in Figure-1 reveals that is increasing over the years in Bangladesh.

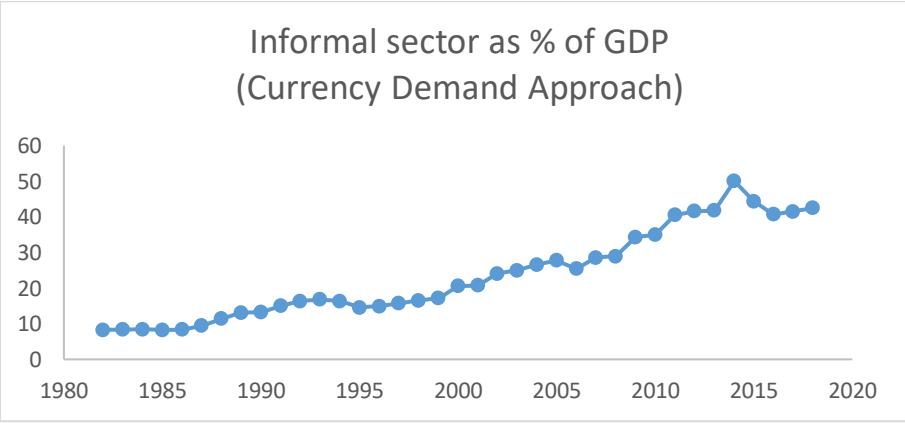

Fig-1: The trend of informal sector (as percentage of GDP) in Bangladesh estimated by Currency Demand Approach.

Table-6: The size of informal sector as a percentage of GDP in Bangladesh

Year	Size of the Informal sector (% of GDP)	Year	Size of the Informal sector (% of GDP)
1982	8.29758	2001	20.78822
1983	8.347852	2002	24.05636
1984	8.499569	2003	24.98879
1985	8.235898	2004	26.58025
1986	8.380871	2005	27.76139
1987	9.433378	2006	25.43219
1988	11.45755	2007	28.61992
1989	13.16946	2008	28.93961
1990	13.2498	2009	34.36658
1991	15.05814	2010	35.01498
1992	16.40296	2011	40.52737
1993	16.84948	2012	41.64194
1994	16.38835	2013	41.7944
1995	14.53318	2014	50.0665
1996	14.97603	2015	44.44856
1997	15.75529	2016	40.72155
1998	16.57807	2017	41.56027
1999	17.22407	2018	42.49722
2000	20.62828		

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APPENDIX B

Firm Serial No:	Date:
No of participants: Worker	

Questionnaire Survey on Socio-economic and Environmental issues of informal firms

(Section 1: Socio-economic information)

A. Work condition and socio-economic life of workers:

Age:…….. Gender: …… Marital status:…… Family size:……..

Work place condition (infrastructure and facilities)

Work place condition (infrastructure)

1. 1 **(a)**

Type of land /building occupied by the firm	a. Owned by the firm	=1 ( )
	b. Leased/rented by firm	=0 ( )

(b) What is the main building material? (The surveyor should make observation and confirm it with the interviewee - tick only one)
( ) Brick =1 ( ) Other =0
(specify)……

(c) Type of roof: ( ) concrete=1 ( ) other=0

(d) Type of floor: ( ) concrete =1 ( ) other=0

(e) How many rooms are there in the factory? ( ) more than 5=1 ( ) Less than 5=0

Work place condition (facilities)

2.1 Where do you get drinking water at your work place?

i. ( ) own municipality supply ii. ( ) Own tube-well
iii. ( ) Share with other firm iv. ( ) Share tube-well with other firm
v. ( ) Nearby water body

2.2 What type of toilet facility do you have at your work place?

i. ( ) Interior water supply (WS) with toilet flush tank ii. ( ) Exterior WS with toilet flush tank iii. ( ) Interior toilet without flush tank iv. ( ) Exterior toilet without flush tank v. ( ) Other…….

2.3 Do you have any owner organized accommodation? ( ) Yes=1 ( ) No=0

If 'Yes', what type of accommodation……..

2.4 What type of fuel is mainly used for production? (Tick one)

( ) Electricity =1 ( ) Other =0, Please mention ……

2.5 Do you get electricity supply for 24 hours? ( ) Yes=1 ( ) No=0

Education and Skill

3.1 Education level of the respondent:
i. ( ) Technical/Vocational ii ( ) Higher secondary
iii. ( ) secondary
iv.. ( ) Primary v. ( ) others vi. ( ) No education

3.2 (a) Why do you do this work?

i. ( ) skill ii. ( ) knowledge iii. ( ) kinship with owner
iv. ( ) unemployment v. ( ) other……
(b) For skilled worker) How long did you take to be skilled?……..

3.3 Did you do the same work before? ( ) Yes=1 ( ) No=0

If 'Yes", for how many years?.....Years/month

3.4 How long have you been working in this firm? i. ( ) more than 1 year ii. one year

iii. more than 6 months iv. Less than 6 months v. Less than 3 months

3.5 How many hours do you work per day? ( ) 8 hours =1 ( ) more than 8 hours=0

Income

4.1. (a) What is your average weekly income ? BDT……..

(b) Are you happy with your salary? ( ) Yes=1 …… ( ) No=0……

If No, why…….

4.2. Do you have any other income sources/wealth? ( ) Yes=1 ( ) No=0

If Yes mention…….

4.3. What is your average weekly expenditure? BDT……..

4.4 Can you save any money from your salary? ( ) Yes=1 ( ) No=0

4.5 Do you have loans? ( ) Yes=1 ( ) No=0

4.6 Do you have any work contract with the employer? ( ) Yes =1 ( ) No=0

Food and Nutritional status

5. Do you usually eat a diet in a day that has at least vegetables, pulses, protein and carbohydrate?
( ) Yes=1 (2100 kcl, aprox) ( ) No=0 (<2100 kcl)

Food Security Assessment

Order	Questions	Answers	
		Yes	No
6.1	During the last 12 months, was there a time when, because of lack of money or other resources, you were worried you would not have enough food to eat?		
6.2	During the last 12 months, was there a time when, because of lack of money or other resources, you could not eat healthy and nutritious food? (For example: meat, fish, fruits, or vegetables)		
6.3	During the last 12 months, was there a time when, because of lack of money or other resources, you had to eat only a few kinds of foods?		
6.4	During the last 12 months, was there a time when, because of lack of money or other resources, you had to reduce the number of meals per day because you did not have enough food? (For example, skip breakfast, lunch, or dinner?)		
6.5	During the last 12 months, was there a time when, because of lack of money or other resources, you had to eat less than you thought you should eat?		
6.6	During the last 12 months, was there a time when, because of lack of money or other resources, your food ran out in your household?		
6.7	During the last 12 months, was there a time when, because of lack of money or other resources, you went to sleep hungry because there was not enough food?		
6.8	During the last 12 months, was there a time when, because of lack of money or other resources, you went without eating for a whole day?		

Perception about work

1. Will you like to continue the same work? ( ) Yes=1 ( ) No=0

   Please mention reason in favour of your answer……

2. Do you want your son to do the same work? ( ) Yes =1 ( ) No=0

   Please mention reason in favour of your answer……

(Section 2: Health)

1. Health Status

1.1 In general, would you say your health is:

(i) Excellent (ii) Very Good (iii) Good (iv) Fair (v) Poor

The following questions are about your activities you might do during a typical day. *Does your health now limit you* in these activities? If so, how much?

1.2 Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing

(i) Yes, limited a lot (ii) Yes, limited a little (iii) No, not limited at all

1.3 Climbing several flights of stairs

(i) Yes, limited a lot (ii) Yes, limited a little (iii) No, not limited at all

During the *past 4 weeks*, how much of the time have you had any of the following problems with your work or other regular daily activities *as a result of your physical health*?

1.4 Accomplished less than you would like

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.5 Were limited in the kind of work or other activities

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

During the *past 4 weeks*, how much of the time have you had any of the following problems with your work or other regular daily activities *as a result of any emotional problems (such as depressed or anxious)?*

1.6 Accomplished less than you would like

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.7 Did work or activities less carefully than usual

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.8 During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

(i) Not at all (ii) A little bit (iii) Moderately (iv) Quite a bit (v) Extremely

These questions are about how you feel and how things have been with you during the *past 4 weeks*. For each question, please give the one answer that comes to the way you have been feeling. How much of the time during the *past 4 weeks*…

1.9 Have you felt calm and peaceful

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.10 Did you have a lot of energy

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.11 Have you felt downhearted and depressed

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

1.12 During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)

(i) All of the time (ii) Most of the time (iii) Some of the time (iv) A little of the time (v) None of the time

2. How do you feel at your workplace? ( ) happy ( ) moderately happy ( ) not happy

3. Did you face a health problem which required treatment within the last 12 months?

( ) Yes=1 (please explain)……( ) No =0

4.1 Do you have any accident while working? ( ) Yes=1 ( ) No=0

If 'Yes', how much severe was it? Were you satisfied with the immediate management by the firm owner:……

i.( ) highly satisfied ii. ( ) moderately satisfied iii. ( ) somewhat satisfied
iv. ( ) Not satisfied v. ( ) don't know

4.2 Do you face any health problem while working at your industry? ( ) Yes=1 ( ) No=0

If 'Yes' mention what problem you face? ……..

4.3 Do you take health safety measure while working? ( ) Yes=1 ( ) No=0

4.4 Do you have any health security insurance from the firm? ( ) Yes=1 ( ) No=0

4.5 Is your treatment cost borne by your owner? ( ) Yes=1 ( ) No=0

If 'Yes' mention……full or partial

Q5: Do you get sick/injury leave? ( ) Yes=1 ( ) No=0

If 'Yes', please mention, ( ) with payment =1 ( ) without payment=0

Q6: Overall health condition of workers:

Do you have any of the following permanent/chronic disease/health problem? (Answer can be multiple)

(i) Hypertension **(ii)** heart disease (including coronary heart disease and other heart condition)
(iii) stroke **(iv)** hyperlipidemia **(v)** liver disease **(vi)** diabetes mellitus and other endocrine disease **(vii)** respiratory disease **(vii)** urinary and reproductive disease
(ix) musculoskeletal disease **(x)** gastrointestinal disease
(xi) dermal diseases **(xii)** dental caries or other dental diseases

7.1. Were you COVID positive? ( ) Yes=1 ( ) No=0

If 'Yes' How many days you suffered ……days.

7.2 Did you receive any payment/Financial aid/food assistance during COVID? ( ) Yes=1 ( ) No=0

If 'Yes' mention……full or partial

If there is anything you would like to tell us about your life in this work, please mention that. We are very interested to know that_____

_____

The undersigned certifies he/she/it has exercised with due diligence, made all appropriate inquiries in completing this questionnaire and that the foregoing information is true and correct to the best of his/her/its knowledge. The undersigned acknowledges that this questionnaire is for research purpose of a Ph.D. student only.
Interviewer comment (if any):

Signature……

Name:……..

----------Thank You for the time----------

Firm Serial No:	Date:
No of participants: Entrepreneur	

Questionnaire Survey on Socio-economic and Environmental issues of informal firms

Name of the respondent:……**Age:**……
Gender: i. ( ) Male ii. ( ) Female **Marital status:** i. ( ) Married ii. ( ) single

(Section 1: Business Information)

1. Do you have trade license? ( ) Yes=1 ( ) No=0

If Yes, Please show the trade license? ……

2. What does your industry produce?
i. ( ) Leather and leather items ii. ( ) Plastic & Small machinery iii. ( ) Dyeing &Clothing
3. Is your industry located in an industrial area? ( ) Yes=1 ( ) No=0

Name of the area:…….

Information about output

4. (a) What is the volume of product (annually) before COVID……unit.

(b) What is the market price of your product (on average) before COVID? ……BDT.(per unit)

(c) What is the average volume of production in COVID years? …….unit

(d) What is the market price of your product (on average) in COVID years? ……BDT.(per unit)

(e) What was the status of sale of your products before COVID years?.....BDT.

(f) What was the status of sale of your products in COVID years?.....BDT
i. ( ) increased ….. ii. ( ) remain same…… iii. ( ) decreased……..

Information about input

5. (a) How many labors were working here before COVID?
Full time…… Part time……
(b) How many labors are working here in COVID?
Full time…… Part time……

(c) How much did you pay for workers (monthly per labor)? .....BDT.

(d) Did you reduce wage of the workers working in the firm? ( )Yes=1…… ( ) No=0……..

If Yes, Please mention the percentage……

(e)Are you aware of the income poverty level of your workers?
i. ( ) Fully ii. ( ) satisfactorily iii. ( ) Moderately iv. ( ) Fairly v. ( ) Not at all
(f) Are you aware of the occupational safety and health act? i. ( ) Fully ii.( ) satisfactorily
iii. ( ) Moderately iv. ( ) Fairly v. ( ) Not at all

6. (a) What are the main materials used for production? (annually/monthly)
i. …… …….... Q….. …… ii.…….Q…….
iii. ……Q……. iv.…… Q…….. .. v.……Q……...
(b) Have the quantity of this establishment's main input/materials increased, remained the same, or decreased in COVID year?
i. ( ) increased ii. ( ) remain same iii. ( ) decreased

please mention the name of material and percentage change ……

(c) How much you have to pay to buy each material for production (annually/monthly) before COVID? (annually/monthly)
i. Tk……...ii.Tk……
iii.Tk……..iv.Tk…….v. Tk…….

(d) Have prices of this establishment's main materials increased, remained the same, or decreased in COVID year?
i. ( ) increased ii. ( ) remain same iii. ( ) decreased

Please mention the name of material and percentage change……

Other information related to production

1. (a) How much were the yearly net profit from your firm (approx.) before COVID? ……BDT

(b) At what percentage the profit reduced in COVID years? …….

2. Do you subcontract from other big (formal) industries? ( ) Yes=1 … ( ) No=0……..

(a) If 'Yes' what is the nature of the contractual arrangement?

i. ( ) material support ii. ( ) production supply iii. ( ) financial support

iv. ( ) technology support v. ( ) Market provision arrangements

(b) If 'No' what are the reasons for not engaging in sub-contracting arrangement?

i. ( ) No need/not required ii. ( ) lack of reliability of supply iii. ( ) difficult to ensure quality

iv. ( ) unable to enforce contracts v. ( ) late payments

3. Where do you sell your product? i. ( ) Local ii. ( ) International/ supply to exporter

4. (a) Do you use any machinery? ( )Yes=1…… ( ) No=0……..

If Yes, What type of technology/machinery is used in your industry?

i. ( ) self-made ii. Locally made iii. ( ) second hand iv. ( ) imported v. ( ) other

5. How do you get information about marketing/ product / new technology?

i. ( ) Other firm ii. ( ) Equipment/ machinery supplier iii. ( ) Consultations with other business/ industry association vi. ( ) Govt. institutions v. ( ) Newspaper or other bulletins

a. Most important source _____ b. Second most important source _____

c. Third most important source _____

6. Do you have any loan for your business? [Please mention due to COVID/since before COVID]
( ) Yes=1 ( ) No=0

If 'Yes' mention the source (i) friend and family members (ii) non-government organization (iii) Govt. organization (iv) Commercial Bank (v) Other

…… End of Part 1……...

(Section 2: Environmental pollution and Awareness)

1. **Knowledge/General perception on environment and pollution:**

1.1 Can you tell Carbon dioxide, Nitrus Oxide, Methane, Water vapor are the examples of what?

i. component of soil ii. green house gas iii. Major atmospheric component.

[For interviewer ONLY: knowledge about environment and its components? ( ) Yes=1 ( ) No=0]

1.2 Choose one which is not harmful: i. black smoke ii. filtered air iii. Dark flowing water

[For interviewer ONLY: Idea about pollution created by the manufacturing enterprises? ( ) Yes=1 ( ) No=0]

1.3 Choose one about how the water get polluted?: i. if we filter water ii. if we preserve water iii. If we drain chemical waste to water bodies.
[For interviewer ONLY: knowledge about water pollution ( ) Yes=1 ( ) No=0]

1.4 Choose one about how sound pollution can be created: i. if we read loudly
ii. if we create loud sound iii. If we talk normally with each other
[For interviewer ONLY: Knowledge about sound pollution. ( )Yes=1 ( ) No=0]

1.5 Choose one about our contribute to air pollution: i. when we eat ii. when we talk iii. When industries emit smoke
[For interviewer ONLY: Knowledge about air pollution. ( )Yes=1 ( ) No=0]

If 'Yes' mention how it can be prevented…….

4. Motivation about pollution:

Please state your concern with the environmental problems as mentioned below:

	Extremely concerned[5]	Concerned [4]	Neutral [3]	Unconcerned [2]	Extremely unconcerned[1]
Overall pollution					
Air pollution					
Water pollution					
Soil quality degradation					
Noise pollution					

5. Knowledge on emissions at firm level

5.1 Do you think this industry is polluting the environment? ( ) Yes=1 ( ) No=0
If 'Yes', what are you polluting?.....

5.2 Where do you dump waste? Choose one: i. in public waste bin ii. in dumping land iii. around public waste bin or dumping land iv. elsewhere, sometimes in bin v. elsewhere, sometimes in dumping land vi. elsewhere at convenience

[For interviewer ONLY: How far does this enterprise follow the solid waste dumping procedure?
i. ( ) strictly [5] ii. ( ) moderately [4] iii. ( ) fairly [3] iv. Occasionally [2]
v. ( ) seasonally [1]

( ) not at all [0]]

5.3 Where do you discharge waste water from your factory?
i. ( ) Common sewerage system [5] ii. ( ) Septic tank disposed regularly by municipality [4]
iii. ( ) Discharged directly to a river / land [3] iv. ( ) Other (please specify)……..[2]
v. ( ) I do not know [1]

5.4 How are the solid wastes disposed of?
i. ( ) From where municipality collects regularly [5] ii. ( ) Disposed to a predefined landfill [4] iii. ( ) Disposed irregularly [3] iv. ( ) Disposed to the river/lake [2]
v. ( ) Other [1]

5.5 Choose from below: you can choose more than one.
i. Toxic substances control act ii. Clean water act iii. Clean air act iv. Solid waste dumping act
v. Noise pollution control act vi. None of the above

[For interviewer ONLY: To what extent does this firm abide by the environmental regulations?
i. ( ) strictly [5] ii. ( ) moderately [4] iii. ( ) fairly [3] iv. Occasionally [2]
v. ( ) seasonally [1]

( ) not at all [0]]

6. Skill or experience in pollution control

5.1 How frequently you buy and install environment friendly technology?

i. ( ) Very likely [5] ii. ( ) Likely [4] iii. ( ) Neutral [3]

iv. ( ) Unlikely [2] v. ( ) Very Unlikely [1]

6.2 How often do you recycle the solid waste/waste water from your industry?
i. ( ) Always [5] ii. ( ) Most of the time [4] iii. ( ) Sometimes [3]
iv. ( ) Once in a while [2] v. ( ) Very rarely [1]

( ) Never [0]

6.3 To what extent does the firm abide by environmental regulations in production technology?
i. ( ) strictly [5] ii. ( ) moderately [4] iii. ( ) fairly [3] iv. Occasionally [2]
v. ( ) seasonally [1]

( ) no idea [0]

6.4 Does this firm install any emission reducing equipment? ( ) Yes=1 ( ) No=0
If 'Yes',
From where did the enterprise collects the emission reduction equipment?
i. ( ) used own technology ii. ( ) bought from local market iii. ( ) donated by government or other source iv. ( ) managed from other firms v. ( ) imported the technology.

6.5 What is the education level of workers about pollution control?
i. ( ) satisfactory=1 ii. ( ) Not satisfactory=0

7. General perception/knowledge on environmental pollution control

7.1 Environmental laws: Have you heard about the EIA Guideline for industry/ Environmental Pollution Control Ordinance, 1977? ( ) Yes=1 ( ) No=0
[For interviewer ONLY:

7.2 Importance of clean environment: ( ) Yes=1 ( ) No=0

Choose one: i. Pollution free environment ⟶ healthy life

ii. Pollution free environment ⟶ loss of income

7.3 Perception about garbage dumping procedure: ( ) Yes=1 ( ) No=0
Choose one: i. We should through waste elsewhere ii. we should dump waster in municipal bins

7.4 Perception about the problems related to sound pollution: ( ) Yes=1 ( ) No=0
Choose one: i. Loud sound ⟶ more production ii. minimum sound ⟶ healthy environment

7.5 Perception about the problems related to air pollution: ( )Yes=1 ( ) No=0
Choose one: i. polluted air brings more diseases ii. polluted air brings more money

8. Pollution prevention at firm level

8.1 Do you follow any emission reduction technology? ( )Yes=1 ( ) No=0
8.2 Do you follow environmental laws for pollution control? ( )Yes=1 ( ) No=0
8.3Are you willing to adopt new technology for pollution control? ( ) Yes=1 ( ) No=0
8.4 Are you thinking to design new technology for pollution control? ( ) Yes=1 ( ) No=0
8.5 Does the firm find abatement process expensive? ( ) Yes=1 ( ) No=0

7. How much money do you like to spend for emission control purpose?
   Tk……
8. Do you think your industry requires any financial support to install emission control equipment?
   i. ( ) Yes ii. ( ) No ,if Yes, how much? ……

9. What is the most influential source to create awareness about environmental pollution in your view?

Code	Sources	Response
1	T.V., Radio	
2	Government program and strong monitoring	
3	From seniors, friend or relatives	
4	From book/ magazines/newspapers	
5	Do not know	

Point 5 for the best preferred option and 1 for the least preferred.

If there is anything you would like to tell us about your business, please mention that. We are very interested to know that_____

_____

Do you have any comment or concern regarding pollution by this enterprise and its prevention?

_____

_____

Please mention in brief what kind of support you deserve from the government to run your business smoothly and to control pollution from your industry?

The undersigned certifies he/she/it has exercised with due diligence, made all appropriate inquiries in completing this questionnaire and that the foregoing information is true and correct to the best of his/her/its knowledge. The undersigned acknowledges that this questionnaire is for research purpose of a Ph.D. student only.

Interviewer comment (if any):

Signature……

Name:……..

----------Thank You for the time----------