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What are the Current Determinants that Influence the Total Amount of Greenhouse Gases Produced by Selected Asian Nations?

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Abstract: *Asian countries have been concentrating on providing sustainable economic growth since they have had to face the severe consequences of climate change. Thus, this study aims to fill a research gap by investigating whether waste sector emissions significantly contribute to greenhouse gas (GHG) emissions. In general, this study proposes three research hypotheses derived from a review of the literature on GHG emissions. The first and second hypotheses examine whether waste sector emissions, economic growth and other indicators significantly contributed to the total GHG emissions in 13 Asian countries between 2000 and 2016. The third hypothesis investigates whether countries individually and significantly determine waste sector emissions. Using pooled ordinary least squares and least squares dummy variable (LSDV) estimations, the study shows that that the emissions from the waste, agriculture, manufacturing, and construction sectors, as well as from land use and change, were positively associated with total GHG emissions. Second, economic growth and urban and rural population growth show the possibility of reducing GHGs in Asian countries. Subsequently, the LSDV estimation identified that India and Indonesia emitted 72 million tonnes and 148 million tonnes of carbon dioxide equivalent between 2000 and 2016 from the waste sector.*

Keywords: Waste sector emissions; Greenhouse gas emissions; Economic growth; Panel data analysis; Sector emissions
JEL Classification: Q5, Q20, Q53

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1. Introduction

Currently, the investigation of greenhouse gas (GHG) determinants is pertinent because atmospheric air quality has been deteriorating, especially in developing countries. GHG emissions are a phenomenon arising from anthropogenic human activities, namely, fossil fuel consumption (Vohra et al., 2021), industrial activities (Wu et al., 2021), transportation (Demircan Çakar et al., 2021), tourism (Jaz et al., 2023) and inappropriate sustainable growth (Ofreneo, 2015). Waste generation is caused by socioeconomic, demographic, household characteristics, settlement, population, economic development, recycling practices and facilities, and urbanisation (Beede & Bloom, 1995; Hanssen et al., 2016; Modak et al., 2017; Silvennoinen et al., 2014; Wilson et al., 2015). Waste mixtures, meanwhile, comprise food waste, electronic waste, industrial waste, product packaging, newspapers, and other materials (Kumar et al., 2017; Kusch & Hills, 2017). These waste products are categorised into municipal solid waste, industrial hazardous waste, waste oil, and biomedical waste, among others (Agamuthu & Tanaka, 2014; Agamuthu & Victor, 2011).

Nevertheless, both developing, and less-developed countries have been managing their waste sector problems ineffectively and utilise low-cost methods for the disposal of waste mixtures (Lino & Ismail, 2017). Therefore, the waste sector is responsible for emitting GHGs into the air (Adhikari et al., 2006). Waste mixtures at both operational and non-operational landfills are constantly releasing gases such as methane, carbon dioxide, nitrogen, oxygen, ammonia, and sulphur dioxide into the air (Adhikari et al., 2006). In the densely populated countries of China and India, waste sector emissions have increased dramatically and are forecast to only rise in the near future (Javed & Cudjoe, 2022). China's municipal solid waste emissions increased from 39.24 to 128.81 metric tonnes of carbon dioxide equivalent (CO_2e) between 2006 and 2019 (Y. Kang et al., 2022). Landfills in Australia have been shown to unintentionally leak GHGs (Reinelt et al., 2022). In South Korea, waste incineration is responsible for 3.5 times more ammonia being released than other GHG gases (S. Kang et al., 2022). India has been advised to regularly practice recycling, convert biodegradable waste into biogas, and upcycle non-biodegradable waste to prevent immense GHG emissions by 2035 (Sharma et al., 2022).

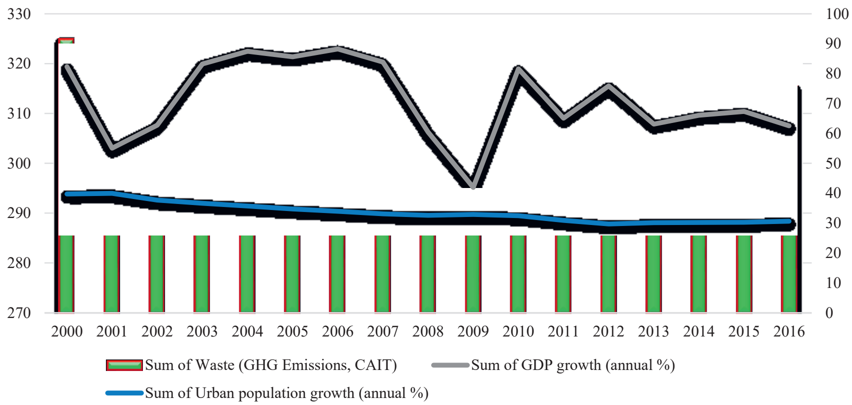
Specifically, cumulative GHGs in the atmosphere tend to reduce air quality (Magazzino, 2017; Mele & Magazzino, 2020), slowly deplete the ozone, and cause climate change (Singh et al., 2021). Scholars have identified that landfill emissions such as CH_4 and CO_2 will increase by 2023 across South Asian countries such as India and Sri Lanka (Johari et al., 2012; Shrestha et al., 2012; Yusoff et al., 2013). Overall, waste sector emissions cause ozone depletion, climate change, soil contamination, groundwater and surface water contamination, and air pollution (UNEP, 2016). Therefore, contaminated air quality could lead to ultraviolet rays directly entering the atmosphere, which can cause changes in the human respiratory system (Chen & Chen, 2021; Orach et al., 2021) as well as the extinction of some species of flora and fauna (Xu et al., 2021).

On this premise, our investigation examines the linear association between waste sector emissions and socioeconomic and environmental indicators for 13 sample countries in Asia—Bangladesh, Brunei Darussalam, Cambodia, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam. Prior studies have investigated the environmental Kuznets curve (EKC) theory, which applies non-linear methodology (Mazzanti & Zoboli, 2009) to determine waste sector emissions. According to Bogner et al. (2007), South and East Asian countries showed the highest rates of carbon storage in landfills between 1971 and 2002. Citing the United States Environmental Protection Agency (2006), the researchers forecasted that landfill emissions in these countries, particularly CH4, are expected to increase between 1990 and 2020. Waste sector emissions in 10 of the 13 countries in the present study showed high emission levels. The literature points to municipal solid waste being responsible for a lot of the GHG emissions (Clarke et al., 2019). In 2000, the Asian waste sector emitted 648.89 million tonnes of CO_2e, which subsequently climbed to 709.08 million tonnes in 2016 (Ritchie et al., 2020). The literature also explores the effect of economic growth on CO_2 emissions (Apergis et al., 2018). Magazzino et al. (2021) also recommend that future studies examine the relationship between wealth and waste emissions.

Considering this, this study attempts to fill a research gap by investigating wealth-waste emissions and revealing the influence and magnitude of waste sector emissions on total GHG emissions. In detail, the study includes potential sectors (e.g., agriculture and manufacturing) and socioeconomic factors (e.g., economic growth and population indicators).

Figure 1 illustrates the percentage of waste sector emissions in some Asian countries between 2000 and 2016. In Asia, the waste sector emits at least 290 to 324 tonnes of CO_2e, with highly populated countries such as India and Indonesia producing greater quantities of GHGs (Ritchie et al., 2020). The rest of the paper is organised as follows: Section 2 contains the literature review, Section 3 the methodology, Section 4 the results and discussion, and Section 5 concludes the paper.

Figure 1: Total GHG emissions (tonnes of CO_2e), Waste Sector Emissions (tonnes of CO_2e), GDP (annual %) and Urban Population (annual %)



Source: World Development Indicators (2021), World Bank Database, and Our World in Data (2021)

2. Literature Review: Economic Growth and Environmental Degradation

In the 1990s, Grossman and Krueger (1995) developed the EKC from the classic Kuznets curve that incorporated factors such as a country's economic growth and environmental pollution. The EKC theory, especially the inverted U-curve, holds that early-stage economic growth causes environmental deterioration, but that that degradation will be reduced in subsequent phases of growth (Beckerman, 1992). Researchers used EKC to model the waste Kuznets curve (WKC), which explains the correspondence between waste drivers and economic growth (Apergis et al., 2018; Bates et al., 1997; Highfill & McAsey, 2001). Unfortunately, the EKC theory and the new analytical WKC framework reveal very little information. Magazzino et al. (2021) examine the causal relationships among GHG emissions from the waste sector, income level, urbanisation, and municipal solid waste generation per capita in Denmark between 1994 and 2017 and reveal a significant negative monotonic relationship between waste sector GHG emissions and economic growth.

Scholars have applied growth theory to examine economic growth and environmental degradation indicators such as CO_2 emissions (Chaabouni & Saidi, 2017). They discovered bidirectional causality between CO_2 emissions and economic growth for low-, lower middle- and upper middle-income countries between 1995 and 2013. Overall, the literature varies on the association between economic growth and CO_2 emissions, with some showing a positive relationship (Bilgili et al., 2016; Ren et al., 2014), and others showing a negative relationship (Hossain, 2011), unidirectional causality (Cowan et al., 2014), bidirectional causality (Apergis et al., 2020; Dabachi et al., 2020) and even an insignificant relationship (Mutafoglu, 2012; Tiwari, 2012). The present study highlights that environmental degradation, particularly GHG emissions, originates from numerous sources, such as waste and agricultural sector emissions, and that this occurrence in Asian countries has not been studied in detail.

3. Materials and Methods

3.1 Data specification and hypothesis

This study first collected the raw data from 2000 to 2016 from the Our World in Data database (Ritchie et al., 2020) and filtered out information on GHG emissions to gauge causal or determining factors. The data covers the 13 selected countries, namely Bangladesh, Brunei Darussalam, Cambodia, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam. Total GHG emissions represent total emissions in the sum of gases in the database and are measured in million tonnes of CO_2. In addition, this study examines the economic growth impact on air pollution that is measured in constant 2017 PPP \$. Furthermore, we introduced several potential GHG determinants, namely, waste sector emissions (measured in million tonnes of CO_2e), agriculture sector emissions (million tonnes of CO_2e), manufacturing or construction energy emissions (million tonnes of CO_2e), urban population (annual %) and rural population (annual %). Overall, this study attempts to fill another research gap through waste sector emissions data from 2000 to 2016. Table 1 defines the eight variables and their expected signs, while Table 2 presents the descriptive statistics.

Table 1: Description of Variables and Expected Signs

Variables	Description	Measurement	Sign
Dependent variable			
TGHG	Total greenhouse gas emissions	Million tonnes of CO_2e	
Independent variables			
WASTESE	Waste sector emissions	Million tonnes of CO_2e	+
AGRICSE	Agriculture sector emissions	Million tonnes of CO_2e	+
LANDSE	Land use and change emissions	Million tonnes of CO_2e	+
MANFCSE	Manufacturing or construction energy emissions	Million tonnes of CO_2e	+
GDP	GDP per person employed	Constant 2017 PPP $	+
URBPOP	Urban population growth	Annual %	+
RURPOP	Rural population growth	Annual %	-

Table 2: Descriptive Statistics

Variables	Observations	Mean	Std. dev.	Minimum	Maximum
TGHG	221	486.732	789.433	17.010	3256.170
WASTESE	221	23.685	40.629	0.090	192.800
AGRICSE	221	105.791	169.750	0.100	704.160
LANDSE	221	121.045	395.381	-167.130	1962.830
MANFCSE	221	45.799	94.842	0.100	533.800
GDP	221	5.487	2.907	-2.508	13.844
URBPOP	221	2.586	0.968	0.047	5.932
RURPOP	221	0.478	0.938	-1.822	2.351

The objective of the study is to determine whether a relationship or a significant association exists between waste sector emissions, economic growth and total GHG emissions. To achieve this aim, we formulated the following hypotheses from the literature review:

H1 *The waste sector positively and significantly contributes to total GHG emissions in the 13 Asian countries.*

H2 *GDP positively and significantly contributes to total GHG emissions in the 13 Asian countries.*

H3 *Each Asian country positively and significantly explains waste sector emissions.*

3.2 Estimation strategy

3.2.1 Panel data estimation

The present study applies panel data estimation and formulates equation (1) to examine the effects of economic growth and waste sector emissions from many different sources and angles as well as other explanatory variables on total GHG emissions. The study employs pooled ordinary least squares (OLS), as this method estimates a common constant for all countries, a fixed effects model (FEM) that allows for different constants for each country, and a random effects model (REM) because it handles the constants for each country not as fixed but as random parameters (Asteriou & Hall, 2015).

$$\begin{aligned} TGHGE_{it} = \alpha_i + \beta_{it} + \delta_1 WASTE_{it} + \delta_2 AGRIC_{it} + \delta_3 LANDUC_{it} \\ + \delta_4 MANUFAC/C_{it} + \delta_5 GDP_{it} + \delta_6 URPOP_{it} + \delta_7 RURPOP_{it} \\ + \varepsilon_{it} \end{aligned} \quad (1)$$

where, *TGHGE* is the dependent variable, α_i the intercept, δ_1, δ_2, δ_3, δ_4, δ_5, δ_6 and δ_7 the coefficients, ε_{it} the error term, α_i the possibility of country-specific fixed effects, *i* a single country in the linear panel regression model ($i = 1, 2, \ldots, N = 13$; $t = 1, 2, \ldots, T = 17$), while *t* shows the time period. The independent variables consist of the seven characteristics described in Table 1 that can take on different values. The Hausman test is used to measure the association between GHGs and explanatory variables. The generalised least squares (GLS) method was applied to correct the possibility of heteroskedasticity and autocorrelation in the panel linear regression model.

This study employs a theoretical framework to investigate the effects of economic growth on total GHG emissions in 13 Asian economies. Basically, this study refers to the prior theoretical framework in Figure 2 to develop the conceptual framework in Figure 3 to justify the association between economic growth and environmental degradation, especially between economic growth and air indicators such as CO_2 emissions (Asumadu-Sarkodie & Owusu, 2017; Chaabouni & Saidi, 2017). Using neoclassical growth theory, Gao et al. (2021) show that China's economic growth caused higher CO_2 emissions. Other studies have also developed the same model to examine the relationship between economic growth and emissions of CO_2, CH_4, N_2O and other pollutants (e.g., Asumadu-Sarkodie & Owusu, 2017). Accordingly, this study applies the same theoretical framework as Asumadu-Sarkodie and Owusu (2017) and Chaabouni and Saidi (2017) and then derives a conceptual framework to examine whether there is a positive relationship between environmental degradation indicators, such as waste sector emissions and manufacturing and construction industry emissions, and socioeconomic factors, such as economic growth and population growth, and total GHG emissions in the 13 selected Asian countries.

Figure 2: Theoretical Framework

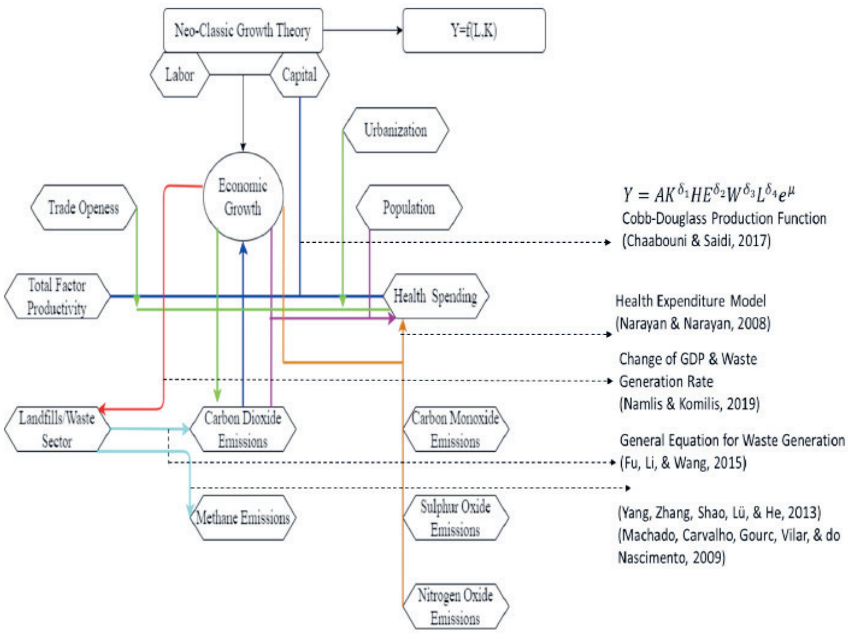
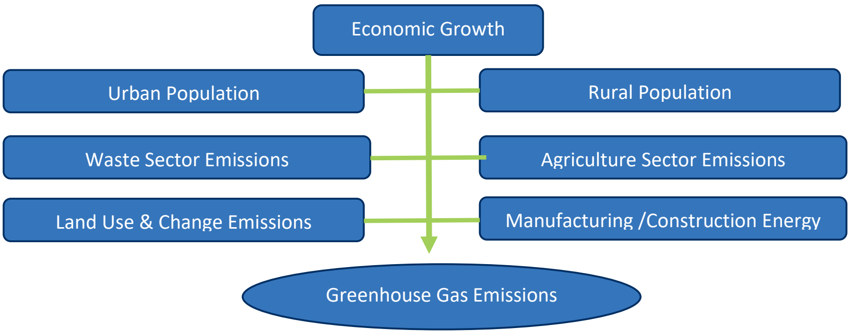


Figure 3: Conceptual Framework



3.2.2 Least squares dummy variable estimation

In particular, the study attempts to estimate each country's individual influence on waste sector emissions. We considered the variance in terms of economic growth and demography between the countries, then measured those countries' total waste sector emissions separately. In this respect, least squares dummy variable (LSDV) was identified as the most suitable and appropriate methodology that allows for heterogeneity among the selected countries. This study also took the dummy trap into account and set Bangladesh as a benchmark country with the assumption of no influence from other regressors. As such, the following equation was formulated:

$$TGHGE_t = \gamma_1 + \gamma_2 DBrunei_{2t} + \gamma_3 DCambodia_{3t} + \gamma_4 DIndia_{4t} + \ldots \gamma_{13} DVietnam_{13t} + \varepsilon_{it} \quad (2)$$

Equation (2) measures waste sector emissions among the selected countries. The model applies dummy variables to measure qualitative influence by coding the different possible outcomes on each continuous dependent variable. The dummy variable dichotomised the possible outcomes and assigned values of 0 and 1. Thus, the countries are coded as D_{2t} = 1 for Brunei, 0 otherwise; D_3 = 1 for Cambodia, 0 otherwise; D_4 = 1 for India, 0 otherwise, and so on.

4. Results and Discussion

4.1 Preliminary analysis

Table 3 displays the results obtained in the panel data regression that captures the four block analyses in OLS, REM, FEM, and robust FEM which provided significant results. Based on the Hausman test, the final model was FEM, which encountered autocorrelation and heteroskedasticity effects because the *p* value was set at less than the 5% significance level. Consequently, we used the GLS method and assumed that the robust FEM would rectify autocorrelation and heteroskedasticity. We obtained similar results for pooled OLS and robust FEM, although we expected the GLS method to fix errors in autocorrelation and heteroskedasticity. Accordingly, the research proceeded to employ the robust FEM, which then correctly explained the relationship between various waste sector emissions and economic growth influences on total GHG emissions.

Table 3: Greenhouse Gas Determinants in 13 Selected Asian Countries

Dependent variable: Total GHG emissions				
Variables	**OLS**	**Fixed effect**	**Random effect**	**Robust fixed effect**
WASTESE	1.5107***	0.3971	1.0202***	1.5107***
	(0.1725)	(0.3106)	(0.1734)	(0.1693)
AGRICSE	1.5375***	1.7891***	1.7001***	1.5375***
	(0.0500)	(0.2261)	(0.0630)	(0.0491)
LANDSE	0.9635***	0.9468***	0.9933***	0.9635***
	(0.0150)	(0.0217)	(0.01401)	(0.01470)
MANFCSE	3.6409***	3.4554***	3.4061***	3.6409***
	(0.0793)	(0.0834)	(0.0605)	(0.0778)
GDP	-1.8767***	0.2773	0.06950	-1.8767***
	(0.8947)	(0.8486)	(0.8555)	(0.8784)
URBPOP	-7.9203***	-12.4436***	-10.3538***	-7.9203***
	(2.7421)	(3.3882)	(3.2713)	(2.6920)
RURPOP	-25.8587***	-2.8402	-12.5522***	-25.8587***
	(3.2204)	(5.6445)	(4.8231)	(3.1616)
Constant	48.0738**	47.2160**	38.8870***	48.07382***
	(9.2310)	(28.3225)	(13.5972)	(9.0624)
R-squared	0.9978	0.9928	0.9970	0.9928

Variables	OLS	Fixed effect	Random effect	Robust fixed effect
Adjusted R-squared	0.9977			
Multicollinearity	5.20			
Heteroscedasticity chi-squared	0.000			
Normality	0.0122			
Prob > F	0.000	0.000		
Prob > chi2			0.000	0.000
Hausman Test		0.0438		
Autocorrelation		0.000		
Heteroscedasticity chi-squared		0.000		
Endogeneity				
Durbin chi-squared				0.5317
Wu-Hausman				0.5386
N	221	221	221	221

Notes: Standard errors in parenthesis. *, **, and *** represent 10%, 5% and 1% significance levels, respectively.

4.2 Panel regression empiric and discussions

The findings in the study revealed that waste sector emissions contributed significantly to total greenhouse gas emissions. The results showed that whenever these 13 Asian countries' waste sector emissions increased by 10%, total greenhouse emissions also increased by approximately 10.51 units. The study has only employed carbon dioxide equivalent emissions from waste mixtures and empirically measured waste sector emission levels that contributed to total GHG emissions. This is in line with S. Kang et al. (2022) showing an increase in China's municipal solid waste emissions, Y. Kang et al., (2022) showing that incineration in South Korea caused significant ammonia emissions, as well as Asumadu-Sarkodie and Owusu (2017) establishing unidirectional causality from CO_2 emissions to enteric emissions of CH_4 and emissions of N_2O in the long run in Ghana.

The present study fills a gap in the research by emphasising waste sector CO_2 emissions from available pertinent data. Unlike prior literature that concentrated on a single country to identify sector emissions, this study looked at 13 countries' waste sector emissions cumulatively, ranging between 300 and 325 tonnes of CO_2. It was found that the waste sector in these countries engaged in several unsafe waste disposal methods, including landfilling, sanitary landfilling and incineration, which could still partially harm both humans and the environment. Specifically, this study only focuses on the sum of waste sector CO_2 emissions of total GHG emissions.

The findings also show that economic growth proxied by GDP per person employed resulted in reduced total GHG emissions. A 1% increase in economic growth decreases greenhouse gas emissions by approximately 1.9%. Initially, economic growth was expected to positively contribute to GHG emissions, but the empirical evidence provided an idea that Asian countries' economic growth could still improve air quality. This implies industry practices that adhere to environmental rules and regulations, which would help to reduce total GHG emissions. Past studies have shown that employment participation in economic activities can slightly decrease air pollution (Ozturk & Acaravci, 2013; Tiwari et al., 2013).

Other studies show that economic growth increased CO_2 emissions in India and China (Li et al., 2016; Pal & Mitra, 2017) and GHG emissions in highly populated countries such as Brazil, Indonesia and India (Alam et al., 2016). However, nonlinear EKC analysis always argues that economic growth at the threshold level reduces per capita carbon emissions (Ozturk & Acaravci, 2013) and CO_2 emissions (Tiwari et al., 2013).

This study fills another research gap by examining the influence of employment on total greenhouse emissions through GDP. Past studies frequently applied economic growth from different base years, different constant values and GDP per capita influence on air pollution indicators, especially CO_2 emissions. It is obvious that economic performance relied heavily on skilled, unskilled, and migrant labour participation in a given country (Bandara et al., 2007; Bodman & Le; Khan et al., 2021). First, companies that operate legally tend to comply with labour standards and environmental regulations. Second, there are companies that run their businesses without considering labour standards and environmental regulations. In the end, both types of companies contribute to economic growth, but they could still degrade environmental quality in the short and long term. Usually, economic activities or operations in both developing and less developed countries are neglected, which will lead to pollution and contamination of the natural ecosystem (Alam et al., 2016; Mujtaba et al., 2022; Pal & Mitra, 2017).

The results of this study also indicate that demography or the human population tends to reduce GHG emissions. This means that a 1% increase equally in both the urban population and rural populations will reduce GHG emissions by approximately 8% and approximately 26%, respectively. The results clearly demonstrate that the population factor does not significantly increase GHG emissions in the 13 Asian countries studies. This supports past studies that established a negative relationship between population and CO_2 emissions (Al-mulali et al., 2012; Alam et al., 2016; Li et al., 2016). Thus, this study has determined how both rural and urban populations can significantly determine the levels of total GHG emissions within their regions. Prior literature tends to concentrate on population and common air pollution indicators such as CO_2 emissions and particulate matter (PM) (Al-mulali et al., 2012; Chaabouni & Saidi, 2017; Li et al., 2016). Urban areas that are highly populated are often characterised by complex transportation systems, fossil fuel consumption, congested dwellings, and waste generation issues. Thus, it was expected that the urban population would cause air pollution, but the findings indicate that urban dwellers might apply sustainable practices to protect the natural environment. Unlike urban populations that are relatively restricted in terms of adopting environmentally friendly practices (Daramola & Ibem, 2010; Ren et al., 2023), rural populations have traditionally lived close to nature, contribute to protecting the ecosystem, and largely prevent severely harmful activities that would endanger environmental quality. To date, environmental legislation and enactments vary across Asian countries that fail to control human anthropogenic activities. Basically, this study reveals the population growth implications on total GHG emissions. We also recognise that each country has implemented its own specific environmental policies based on geopolitical concerns and other criteria.

Moreover, the results show that the agriculture sector is one of the prominent emitters across the countries studied. A 10% increase in agriculture sector activity increases total GHG emissions by approximately 15 units. Asian countries are essentially dependent on agricultural activities for soil cultivation and planting, aquaculture, floriculture, horticulture, breeding operations, and farming. As a result, agricultural soil, plant decomposition, agricultural residues as well as microbial activity all emit CO_2 (Bhatia et al., 2013; Dobbie et al., 1999; Schaufler et al., 2010). Prior studies show that agricultural land use increased N_2O emissions in 15 countries, including Brazil, Argentina, and Mexico (Haider et al., 2020). Rice fields also emit CH_4, while agricultural soil and agriculture activities discharge N_2O into the atmosphere in India (Bhatia et al., 2013). Since Asian countries have been enhancing their agricultural activities in recent years, it is important to seriously address this emission problem. At present, modern agricultural activities are focused on increasing yields of maize, rice, fruits and vegetables, and use chemical applications which cause the emission of GHGs, such as CO_2, CH_4, and N_2O (Gradish et al., 2011; Hu et al., 2023). In the end, these harmful components will be absorbed into the soil, water resources and atmosphere, which deteriorates environmental quality. Nevertheless, there have been many successful and new large-scale agricultural ventures using organic and natural fertilisers in place of chemical applications.

Various studies have also proven that the manufacturing and construction sectors only impose externalities on the environment. The positive relationship indicates that a 10% increase in manufacturing and construction increased GHG emissions by approximately 36%. Even though these sectors contribute vastly to economic growth, they are still responsible for large amounts of CO_2 emissions into the atmosphere. This is in line with past studies that identified construction and heavy manufacturing as causing CO_2 emissions in China (Tian et al., 2017) and an indirect relationship between construction and emissions (Chen et al., 2017). The construction and heavy manufacturing sectors are expected to only accelerate in Asian countries. The foreign investment in many Asian countries in centred on manufacturing and construction, with cheap labour costs serving as an attraction. Developed countries also transfer their skills and technologies to manufacturing industries in developing and less developed countries (Gachanja, 2023; Sanni et al., 2007). Sophisticated manufacturing industries tend to pollute the water, soil and atmosphere, while others state that an excessive amount of cement and concrete buildings will raise the Earth's temperature (Barcelo et al., 2014).

Land use and change, including forestry ecology, negatively impact air quality and increase GHG emissions by 0.96%. These factors include economic development, agriculture, and forest clearing, which contributed slightly to total emissions. In this study, panel estimation confirmed that land use activities are associated with GHG emissions. Similarly, Schaufler et al., (2010), using simple regression and Pearson correlation estimations, claim that land use types correlated with GHG emissions in European countries. The results of this study demonstrate that forestry and land have also systematically caused GHG emission increments. Other studies commonly measure forest and land size emissions, but this study specifically estimated the effect of land and forestry CO_2 emissions on overall air quality in the countries under study. Every building, road, and other land and sea constructions emit different kinds of pollutants with harmful gases. Similarly, forest areas are now cultivating seasonal crops, being logged illegally, and serve as the sites of other socioeconomic activities, all of which contaminate the air quality around the region (Xu et al., 2015; Zhang et al., 2015).

4.3 Waste sector emissions

Of the countries studied, Indonesia, India, and Bangladesh have the highest average waste sector emissions, suggesting that these countries can do more to efficiently manage and combat environmental degradation. Brunei, Cambodia, Nepal, Sri Lanka, Myanmar, Pakistan, the Philippines and Thailand exhibited only light average waste sector emissions (see Table 4). The findings for Malaysia were insignificant, perhaps due to the limited years of data. Each country positively significantly explains waste sector emissions. The figures for Indonesia and India were 148 (17.8 + 129.5) units and 72 (17.8 + 54) units, respectively. The results for the other countries ranged between 0.14 and 11.81 units, with Brunei at 0.14 (17.80 + -17.66), Cambodia at 0.45 (17.80 + -17.35), Nepal at 0.83 (17.80 + -16.97), Sri Lanka at 3.06 (17.80 + -14.74), Myanmar at 4.48 (17.80 + -13.32), Pakistan at 7.69 (17.80 + -10.11), the Philippines at 11.47 (17.80 + -6.33) and Thailand at 11.81 (17.80 + -5.99). The investigation only measured each country's waste sector emissions from the dummy representatives.

Landfills, both operational and non-operational, account for the emissions of ammonia, methane, nitrogen, and other gases (Adhikari et al., 2006). More recently, researchers have pointed to the dramatic increase in waste sector emissions in China and India, which are only predicted to rise in the near future (Javed & Cudjoe, 2022; S. Kang et al., 2022).

This study measures waste sector CO_2 emissions in each of the 13 Asian countries. Previous studies only gauged emission levels for a small set of countries or a single country, and the results for each country were either inconclusive or difficult to pinpoint (Bian et al., 2022; Dey & Thomson, 2023; Yulianto et al., 2023). Overall, Asian countries have been practicing low-cost waste disposal methods such as open dumpsites, open burning and landfills. In addition, most Asian countries neglect to segregate mixed liquid and organic kitchen waste from solid plastics, wood and metals. For instance, highly populous countries such as Indonesia and India generate tons of waste mixtures annually without proper waste segregation (Duan et al., 2008; Khajuria et al., 2010; Khan et al., 2016). Waste mixtures in open dumpsites and landfills are exposed to humidity and rainwater, resulting in GHG emissions and landfill leachate.

Table 4: Waste Sector Emissions in 13 Selected Asian Countries

Waste sector E	**Coefficient**	**Std. error**	***t*-value**	***p*-value**	**[95% confidence interval]**		**Sig**
Country: base Bangladesh	0	–	–	–	–	–	
Brunei	-17.660	2.514	-7.02	0.000	-22.616	-12.704	***
Cambodia	-17.351	2.514	-6.90	0.000	-22.307	-12.394	***
India	53.794	2.514	21.40	0.000	48.837	58.750	***
Indonesia	129.528	2.514	51.52	0.000	124.572	134.485	***
Malaysia	-2.078	2.514	-0.83	0.410	-7.034	2.879	
Myanmar	-13.319	2.514	-5.30	0.000	-18.276	-8.363	***
Nepal	-16.972	2.514	-6.75	0.000	-21.929	-12.016	***
Pakistan	-10.113	2.514	-4.02	0.000	-15.069	-5.157	***
Philippines	-6.333	2.514	-2.52	0.013	-11.289	-1.377	**
Sri Lanka	-14.738	2.514	-5.86	0.000	-19.694	-9.781	***
Thailand	-5.995	2.514	-2.38	0.018	-10.951	-1.038	**
Vietnam	-2.290	2.514	-0.91	0.363	-7.246	2.666	
Constant	17.802	1.778	10.01	0.000	14.298	21.307	***

Mean dependent variable	23.685	SD dependent variable	40.629
R-squared	0.969	Number of observations	221
F test	545.980	Prob > F	0.000
Akaike criterion (AIC)	1520.204	Bayesian criterion (BIC)	1564.380

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5. Concluding remarks

This study was motivated by past and current assertions that waste generation has reached alarming levels in Asia (Khajuria et al., 2010; Kumar et al., 2017; WB, 2018). The study analysed 13 Asian countries' environmental degradation indicators and socioeconomic factors from 2000 to 2016. It found that waste sector emissions are the third most significant contributor to total GHG emissions, causing harmful enteric CH_4 emissions. On the other hand, economic growth was found to reduce total greenhouse gas emissions only slightly, which supports the economic growth and environmental degradation associations in prior studies. Both urban and rural populations were found to have reduced total GHG emissions, with the latter showing greater potential for reducing air pollution. In contrast, the agricultural, manufacturing and construction sectors, as well as land use change and forest ecology have produced significant GHG emission levels in all 13 Asian countries. The LSDV analysis reveals that waste sector emissions have contributed significantly to total GHG emissions in Indonesia, India, Bangladesh, Brunei, Cambodia, Nepal, Sri Lanka, Myanmar, Pakistan, the Philippines, and Thailand.

The research indicates that manufacturing, construction, agriculture, and waste sectors contribute to GHG emissions in Asian countries. As such, significant changes in waste management methods are needed, including implementing policies like United Nations Sustainable Development Goal 11.6—to "reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management"—in Asian countries' economic planning, which directly targets air quality and waste management procedures. Old waste management and environmental policies need updating due to four weaknesses: facilities, infrastructure, economic incentives, and other issues (Agamuthu & Victor, 2011). The study recommends further research on the impact of waste disposal methods, emissions, and employment activities on air and soil quality, with an emphasis on the need for a green economy.

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