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Economic development and environmental sustainability: evidence from Asia

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Abstract
We examine the relationship between economic development and environmental sustainability in Asia with a panel data of 34 Asian countries in 2000–2012. Along with the full sample of countries, we also examine three subsamples based on income level. We use six indicators of environmental sustainability—pesticide regulation, air pollution (PM2.5), PM2.5 exceedance, terrestrial protected areas (national biome weights), terrestrial protected areas (global biome weights), and child mortality. Our results indicate that Asian countries as a whole have managed well in pesticide regulation and child mortality, but poorly in air quality, as measured by PM2.5 exceedance. Apart from the poor management in air quality, we do not find any evidence of sustainability in protected areas. However, for the subsample of high-income countries, we find similar results to those of the entire sample but confirm evidence of sustainability in biodiversity and habitat. For the subsample of upper-middle-income countries, we find evidence of sustainability in pesticide regulation and child mortality, but air quality management has been poor and there is no evidence of sustainability in biodiversity and habitat. The subsample of low- and lower-middle-income countries, where air quality is at risk, appears to have achieved sustainability only in pesticide regulation.

Keywords Environmental sustainability · Economic development · Asia · GDP · Panel data analysis

JEL Classification Q56

1 Introduction

The negative correlation between economic development and environmental sustainability is more evident in Asia than other parts of the world (Iwami 2001; Hall 2002; Salze-Lozach et al 2015). Asia is the world's largest continent, covering about 30% of all land. Asia is also the most populous continent, home to 60% of global population.

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Population densities across Asia are up to 1.5 times higher than the global average, which places heavy pressure on natural ecosystems. In addition, Asia is the fastest growing region in the world and has the largest continental economy, with a total GDP of more than US$47 trillion in purchasing power parity (PPP) terms in 2014. Sustained rapid economic growth lifted general living standards and drastically reduced poverty in much of the region.

Rapid economic growth has clearly been a boon for Asia and Asians, but it came with a cost on the environment, placing enormous pressure on the ecological carrying capacity of the region. In order to grow, the economy uses up natural resources and emits waste that pollutes the air and threatens the fragile ecological environment. Therefore, in the long run, environmental degradation undermines the very foundation upon which economic growth is built. Future generations will suffer from inadequate environmental resources, and the key challenge is thus to achieve environmentally sustainable economic growth.

Sustainable development is widely interpreted as social and economic development that is environmentally sustainable. The concept of sustainable development has evolved from rather vague notions to more precise specifications that include the three pillars of sustainability, namely, social, economic, and environmental sustainability (Moldan et al. 2012). Both economic and social sustainability have their merits, but environmental sustainability is our main interest. We adopt the definition of environmental sustainability suggested by Moldan et al (2012) in which environmental sustainability is defined in terms of biogeophysical aspects. In this study, environmental sustainability means maintaining or improving the integrity of the Earth's life supporting systems.

The central objective of our study is to assess the extent to which economic development and environmental sustainability are mutually compatible, and can be simultaneously achieved. To this end, we empirically examine the connection between gross domestic product (GDP) and environmental sustainability in Asian countries. We focus on two high-priority environmental issues—protection of human health and protection of ecosystems. For this purpose, we use a number of indicators to assess the environmental sustainability of the region. We apply panel data techniques to a panel data of 34 Asian countries in 2000–2012. Since we find cross-sectional dependence in our data, we use methods that allow for cross-sectional dependence and are suitable for small-T panels. Specifically, we employed Pesaran (2007)'s unit root test and Banerjee and Carrion-i Silvestre (2017)'s cointegration test. Since we find cointegration in several cases, we estimate long-run parameters in the cointegration vectors using Pesaran's (2006) Common Correlated Effects Mean Group (CCEMG) estimator, and the Augmented Mean Group (AMG) estimator (Bond and Eberhardt 2009 and Eberhardt and Teal 2010).

Due to more and better environmental data, there have been more studies of the growth-environment nexus for advanced economies than for developing countries, including Asian countries (Sonnenfeld and Mol 2006). Besides the whole sample of Asian countries, we also analyse three subsamples of Asian countries based on income level. We find that Asian countries as a whole managed well in pesticide regulation and child mortality but relatively poorly in air quality as measured by PM2.5 exceedance. Nevertheless, we do not find any evidence of sustainability in protected areas. We find similar results for the subsample of high-income Asian countries, except there is evidence of sustainability in biodiversity and habitat. For the subsample of upper-middle-income Asian countries, we find evidence of sustainability in pesticide regulation and child mortality. However, air quality management, as measured by PM2.5 exceedance, has been poor. The subsample of low- and lower-middle-income countries, where air quality is at risk, has achieved sustainability only in pesticide regulation.

Overall, our results reveal that richer countries tend to manage better in environmental sustainability relative to poorer countries. This implies that countries with more financial resources can better implement policies that protect human health and the environment, and suggests developing countries would need supports from developed countries and the international community in terms of financial and technical resources to deal with environmental problems. The developed countries harmed the environment during their growth paths. They became richer at the cost of the environment. The common good nature of the environment makes the developing countries suffer from the harm that the developed countries inflicted on the environment. The developed countries are responsible for the harm they caused and liable to pay for it.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the empirical framework used in the study. In the section, we justify our choice of environmental sustainability indicators. Section 4 reports and discusses the main empirical results. Section 5 concludes the paper.

2 Literature review

Sustainable development has become the dominant development paradigm in both developed and developing countries. It is based on a triple bottom-line approach which integrates economic, environmental, and social factors (Hall 2011). Sustainable development emphasizes achieving economic growth in an environmentally-friendly manner, and acknowledges that past patterns of economic development inflicted serious damage on the environment. The aim of this study is to assess the extent to which Asia can pursue economic growth without compromising environmental sustainability. The term environmental sustainability was first coined by the World Bank, and the original term was environmentally responsible development (World Bank 1992, p. 8). Serageldin and Streeter (1993) modified the term to environmentally sustainable development, and Goodland (1995) developed the concept of environmental sustainability.

According to Goodland (1995), environmental sustainability "seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans". In this regard, the conceptualization of environmental sustainability fits into the resource-limited ecological economic framework of limits to growth. Holdren et al. (1995) pay attention to the biogeophysical aspects of environmental sustainability, which implies maintaining or improving the integrity of the Earth's life supporting systems. Simultaneously, mankind needs to maintain (a) biological diversity and (b) the biogeochemical integrity of the biosphere through conservation and proper use of critical natural resources such as air, water, and land.

The concept of environmental sustainability has gradually been adopted worldwide and has had a crucial impact on international agreements as well as national policies and strategies. For example, in a paper for the Commissioner for Environmental Sustainability of the Australian State of Victoria, environmental sustainability is defined as "the ability to maintain the qualities that are valued in the physical environment" (Sutton 2004). The question of whether economic growth and environmental sustainability are mutually inclusive or exclusive has received a lot of attention in the literature. Fiorino (2011) argues that several studies shed light on this key aspect of the sustainability concept during the last two decades.

Using specific measures of air and water pollution, many forms of pollution were found to increase in the early stages of growth but decline beyond some level of income. Furthermore, some forms of pollution eventually reduce in wealthy countries. The result is an inverted U-shaped curve—the environmental Kuznets curve, or EKC—rather than a linear relationship. Examples include Dasgupta et al. (2002), Cole et al. (1997), and Grossman and Krueger (1995). EKC implies the existence of a corrective mechanism that eventually brings pollution down to more acceptable levels. At first glance, this is puzzling. Economic growth almost inevitably involves more manufacturing, which implies the use of more fossil fuels, more vehicles, more urbanization, more water, more land and materials, and more pollution-intensive activity. As such, one might doubt whether environmental quality can improve as a country grows richer.

A variety of possible explanations have emerged. One argument, which reflects the post-materialism thesis of Inglehart (1995) and others, was that at a high income level, societies prefer a better and healthier quality of life. However, polluted air and water, hazardous waste sites, contaminated drinking water, exposure to harmful chemicals, and lost recreational opportunities are apparently inconsistent with this social preference. The other side of the picture is that increasing wealth augments a society's capacity to address environmental problems. Wealthier countries possess a stronger legal and administrative infrastructure, as well as more resources to invest in pollution control. In short, the general public of richer societies are more vocal in demanding a cleaner environment and their governments are better equipped to protect the environment (Dasgupta et al. 2006, p. 2; Dinda 2004).

One review of EKC studies concludes that "regulation is the dominant factor in explaining the decline in pollution as countries grow beyond middle-income status". (Dasgupta et al. 2005, p. 404). The explanation is not rooted in the fact that growth creates the conditions which enable government to intervene (Congleton 1992). Empirical findings for a variety of pollutants have been generally consistent (Dinda 2004; Levinson 2002). Specifically, the specific turning point and the precise shape of the curve may be different across cases. However, what is more important is the overall path of the relationship and what it means for policy design (Levinson 2002; Munasinghe 1999).

3 Empirical framework

In this section, we describe the model, data, and methodology we use for our empirical analysis.

3.1 Baseline model and data description

Following the literature, besides GDP, we incorporate three factors which are expected to influence the relationship between economic sustainability indicator (ESI) and economic output. These are governance quality, trade openness, and energy consumption (see, for example, Le et al. 2016; Esty 2011; Sorrell 2010; Dasgupta et al. 2005; Esty and Porter 2005; Dasgupta et al. 2002; Perrings and Ansuategi 2000). The baseline model of our study is follows.

$$\mathrm{ESI}_{it} = \alpha_{it} + \beta_{1i}\mathrm{GOV}_{it} + \beta_{2i}\mathrm{TO}_{it} + \beta_{3i}\mathrm{ENE}_{it} + \beta_{4i}Y_{it} + \beta_{5i}Y_{it}^2 + \varepsilon_{it} \tag{1}$$

where $i = 1, 2, 3, \ldots N$ for each country in the panel and $t = 1, 2, 3, \ldots T$ refers to the time period. ESI_{it} is the indicator of environmental sustainability, GOV_{it} is the indicator of environmental governance, TO_{it} is the indicator of trade openness, ENE_{it} is the energy consumption (kg of oil equivalent per capita), Y_{it} is per capita real GDP (constant 2005 US$), Y_{it}^2 is the square of per capita real GDP, and ε_{it} is the error term. All variables are converted into natural logarithms.

The coefficients $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ correspond to the elasticities of environmental sustainability indicator with respect to environmental governance, trade openness, energy consumption per capita, real GDP per capita, and squared real GDP per capita, respectively. The signs and statistical significances of β_4 and β_5 are the main interest of this study since effect of increased income on environmental sustainability is uncertain and ambiguous.

We choose the freedom from corruption (FFC) index as a proxy for the environmental governance. FFC is provided by the heritage foundation and available for 1995–2012, depending on the country. The FFC index ranges from 0 for totally corrupt to 100 for absolute freedom from corruption. FFC is highly correlated with Corruption Perceptions Index (CPI), but FFC is chosen because of its slightly better data availability. Unlike other corruption indices, FFC incorporates information from both private risk assessments and surveys, which make the index attractive for researchers (Serra 2006, p. 229). We use the ratio of total trade to GDP as our measure of trade openness since this is most widely used in the literature (Squalli and Wilson 2011). A large number of empirical studies used this indicator, including Deme (2002), Kim and Lin (2009), Squalli et al. (2010), Herrerias and Orts (2011), Kim (2011), Harris et al. (2011), Hye (2012), and Liargovas and Skandalis (2012).

A wide range of environmental sustainability indicators have been constructed and applied in different studies. Most of these indicators, however, are somewhat arbitrary and capture only partial dimensions of environmental performance (Olsthoorn et al. 2001). Recent studies use an aggregated measure of environmental sustainability. This often takes the form of an environmental performance index which provides a single summary number for analysts and decision makers who deal with energy and environmental related issues (Esty et al. 2006).

In this study, we analyse the relationship between income level and environmental sustainability using the Environmental Performance Index (EPI) (2016), constructed by Yale University. The EPI ranks countries according to two overarching environmental objectives: (1) reducing environmental stress to human health; (2) promoting ecosystem vitality and sound natural resource management. These two objectives are assessed using 25 performance indicators, which are then combined to create a final EPI score. By using the EPI, we hope to gain a fuller understanding of the income–environment nexus.

The data for per capita real GDP (constant 2005 US$) and energy consumption (kg of oil equivalent per capita) are extracted from world development indicators. All the data used in this study are pooled annual time series. The study covers 34 Asian countries in 2000–2012. Data availability was the main criterion for our choice of sample countries and sample period. The sample countries are at various stages of economic development. As such, we divide the 34 countries into three subsamples according to World Bank's income classification—(1) high-income countries, (2) upper-middle-income countries, and (3) lower-middle-income and low-income countries.[1] The whole panel and three subpanels are strongly balanced. Table 1 summarizes the list of countries.

Table 2 provides the means of the variables in raw data. On average high-income countries perform better than upper-middle-income countries, and both groups perform better than lower-middle and low-income countries in terms of most indicators. Subject to data availability, we use a number of indicators for ESI, as shown in Table 3.

Table 4 shows the means of ESI indicators. On average, high-income countries manage better than upper-middle-income countries and lower-middle and low-income countries in terms of most indicators of environmental sustainability. The exceptions are pesticide regulation (ESI1), for which lower-middle and low-income countries manage the best; and exposure to PM2.5, for which upper-middle-income countries manage the best.

3.2 Methodology

In our study, a panel data model is used to investigate the relationships between environmental sustainability index (ESI) and environmental governance (GOV), trade openness (TO), energy consumption per capita (ENE), real GDP per capita (Y), and square of GDP per capita (Y^2) for 34 Asian countries in 2000–2012. This is because panel data have a number of advantages over cross-sectional or time series data. In particular, using panel data to deal with short time series allows for more observations by pooling the time series data across countries and leads to higher power for the Granger causality test (Pao and Tsaim 2010). Furthermore, in contrast to time

[1] According to World Bank classification, the groups are: low income, US$1035 or less; lower middle income, US$1036–US$4085; upper middle income, US$4086–US$12,615; and high income, US$12,616 or more.

Table 1 List of countries in the study sample (34 countries), 2000–2012. *Source*: World Bank

Group 1: High-income countries (11)
Bahrain
Hong Kong
Israel
Japan
South Korea
Kuwait
Oman
Qatar
Saudi Arabia
Singapore
United Arab Emirates
Group 2: Upper-middle-income countries (10)
China
Iran
Iraq
Jordan
Kazakhstan
Lebanon
Malaysia
Mongolia
Thailand
Turkmenistan
Group 3: Lower-middle and low-income countries (13)
Bangladesh
Cambodia
India
Indonesia
Kyrgyzstan
Nepal
Pakistan
Philippines
Sri Lanka
Syria
Tajikistan
Uzbekistan
Vietnam

series and cross-sectional data, panel data control for individual heterogeneity and thus allows for "more informative data, more variability, less collinearity among the variables, more degrees of freedom, and more efficiency" (Baltagi 2008).

Table 2 Mean of the variables in the study (time period: 2000–2012). *Source*: Authors' calculation

Variables	Data sources	All countries	High-income countries	Upper-middle-income countries	Lower-middle and low-income countries
In level					
Freedom from corruption	Heritage foundation	38.5	65.26	28.45	23.6
Trade openness (TRADE/GDP)	World development indicators	1.06	1.41	1.06	0.76
Energy use (kg of oil equivalent per capita)	World development indicators	3166.8	7221.66	2046.29	597.73
GDP per capita (constant 2005 US$)	World development indicators	10,100	27,394.25	3145.36	816.13
In growth rate					
Freedom from corruption	Heritage foundation	3.50	4.15	3.31	3.10
Trade openness (TRADE/GDP)	World development indicators	−0.14	0.07	−0.026	−0.39
Energy use (kg of oil equivalent per capita)	World development indicators	7.4	8.69	7.54	6.21
GDP per capita (constant 2005 US$)	World development indicators	8.13	10.12	7.94	6.57

Table 3 Summary of ESI indicators used in the study, 2000–2012. *Source*: 2014 EPI—Indicator Metadata. Environmental Performance Index (EPI) (2016), Yale University

Variables	Description	Rationale for inclusion	Interpretation of the indicator	Overarching objective
ESI1	Pesticide regulation (POPs)—regulation of the dirty-dozen persistent organic pollutants (POPs) under the Stockholm convention	Pesticides are a significant source of pollution in the environment, affecting both human and ecosystem health. Pesticides damage ecosystem health by killing beneficial insects, pollinators, and fauna they support. Human exposure to pesticides has been linked to increases in headaches, fatigue, insomnia, dizziness, hand tremors, and other neurological symptoms. The pesticides included in this indicator are persistent organic pollutants (POPs), which are endocrine disruptors, or carcinogens	Pesticide regulation assesses the status of countries' legislation regarding the use of chemicals listed under the Stockholm convention on POPs. Pesticide regulation also scores the degree to which these countries have followed through on limiting or outlawing these chemicals	Ecosystem vitality: agriculture
ESI2	Air pollution (PM2.5)	Suspended particulates contribute to acute lower respiratory infections and other diseases such as cancer. Fine particulates or PM2.5 (particulates with a diameter of 2.5 microns and smaller) lodge deep in lung tissue and are far more injurious to health than coarser particulates. Average annual concentrations of greater than 10 micrograms per cubic metre are known to be injurious to human health	A population-weighted measurement of exposure to PM2.5 in micrograms per cubic metre ($\mu g/m^3$).	Environmental health: air quality
ESI3	Air pollution (PM2.5EX)		The average percentage of the population exposed to PM2.5 levels at 10, 15, 25, and 35 micrograms per cubic metre ($\mu g/m^3$)—the World Health Organization thresholds	

Table 3 continued

Variables	Description	Rationale for inclusion	Interpretation of the indicator	Overarching objective
ESI4	Terrestrial protected areas—national biome weights (PACOVD)	This indicator measures the degree to which a country achieves the target of protecting 17% of each terrestrial biome within its borders, weighted by the domestic contribution of each terrestrial biome. The convention on biological diversity (CBD) established the 17% target at its 10th Conference of the Parties in Nagoya, Japan	Percentage of protected terrestrial biomes weighted by national biomes (%)	Ecosystem vitality: biodiversity and habitat
ESI5	Terrestrial protected areas—global biome weights (PACOVW)		Percentage of protected terrestrial biomes weighted by global biomes (%)	
ESI6	Child mortality (CHMORT)	Environmental factors like polluted air and water are major causes of death for children between the ages of one and five. This indicator is useful proxy for the effects of pollution and poor sanitation on human health	Probability of dying in children between the exact ages of 1 and 5	Environmental health: health impact

Table 4 Mean of the various indicators of ESI in the study (time period: 2000–2012). *Source*: 2014 EPI and Authors' calculation. The variables are in raw data

Variables	All countries	Low and lower-middle-income countries	Upper-middle-income countries	High-income countries
ESI1	14.96	16.02	14.08	14.52
ESI2	13.77	15.24	13.58	12.20
ESI3	0.25	0.30	0.22	0.23
ESI4	7.98	7.66	6.64	9.58
ESI5	7.90	8.15	6.35	9.00
ESI6	0.006	0.011	0.006	0.002

Depending on the presence of cointegration (i.e., a seeming long-run relationship), which imply there is a long-run relationship, we estimate the parameters in the cointegrating vector. We perform estimations on the four following samples. The first sample includes all the 34 Asian countries in our sample. The second sample includes only high-income countries, the third sample includes only upper-middle-income countries, and the fourth panel includes only lower-middle and low-income countries.

Cross-sectional dependence is an important issue in panel data econometrics, and ignoring cross-sectional dependence of errors might have serious consequences such as unit root tests that have substantial size distortions (O'Connell 1998). Sources of cross-correlated errors might arise from spatial effects, omitted common effects, or interactions within socioeconomic networks (Chudik and Pesaran 2013). This is relevant for our analysis because Asian countries share common environmental issues, cultural and economic similarities, and similar economic development paths. In addition, they are working on building a common environmental agenda. Therefore, it is highly likely that there is cross-sectional dependence in our data. As such, prior to estimating the panel models, we conduct the Lagrange multiplier CD_{LM} test by Pesaran (2004) to check for cross-sectional dependency since this test is more suitable when the number of observations, N is large and the number of time period, T is small ($T<N$), which is the case for our data. The results show that there is also evidence of cross-sectional dependence under a fixed effect (FE) specification.[2] The finding is robust to different measures of ESI.[3]

Phillips and Sul (2003) show that under cross-sectional dependence both the pooled ordinary least squares (OLS) and the feasible generalized least squares (GLS) estimators are biased. Other conventional panel data methods such as fixed effects (FE) or random effects (RE) under cross-sectional dependence of errors are likely create inconsistent estimators and give misleading information (Sarafidis and Robertson

[2] For all models in our study, we conducted the Hausman test (with pooled OLS is preferred under the null hypothesis, while under the alternative, fixed effects are at least consistent and thus preferred). The results suggested fixed effects are preferred for all the models, regardless of the different measures of governance and vulnerability. The Hausman test results are available upon request.

[3] To conserve spaces, the results of these three preliminary tests are not presented here, but they are available upon request.

2009). Moreover, if the source of cross-sectional dependence is correlated with regressors, conventional estimators might be inconsistent.

The Mean Group (MG) estimator developed by Pesaran and Smith (1995) allows intercepts, slopes, and error variances to differ across groups. It fits a separate model for each group and takes arithmetic average of the coefficients. If the T is long enough, the MG estimator produces consistent estimates. However, the estimator does not take cross-sectional dependence into account, and assumes it away or models unobservables with a linear trend (Eberhardt 2012).

We thus estimate long-run parameters in the cointegration vector based on the baseline model in Eq. (1) using Pesaran's (2006) Common Correlated Effects Mean Group (CCEMG) estimator, and the Augmented Mean Group (AMG) estimator (Bond and Eberhardt 2009 and Eberhardt and Teal 2010) in lieu of other standard panel data methods as described above.[4] Pesaran's (2006) CCEMG estimator consists of cross-sectional dependence and heterogeneous slope coefficients. The cross-sectional dependence is modelled using cross-sectional averages of the dependent and independent variables to take into account unobserved common factors, which may be nonlinear or non-stationary. The slope coefficients are averaged across panel members. A major advantage of the CCEMG estimators is that they are very robust to structural breaks, lack of cointegration, and certain serial correlation (Kapetanios et al. 2011). Even though CCEMG is more appropriate for macro-panels (with large N and large T), Westerlund et al. (2017) showed that the large-T requirement can be relaxed in several cases, particularly for the pooled version of CCEMG used in this study.

The AMG estimator is an alternative to the Pesaran (2006) CCEMG estimator. Like the CCEMG estimator, the AMG estimator is robust to parameter heterogeneity and cross-sectional dependence. The main difference between the CCEMG and AMG estimators is the approximation method of the unobserved common factors. While the set of unobservable common factors is treated as a nuisance in the CCEMG approach, under the AMG approach they are treated as a common dynamic process that may have useful interpretations. The CCEMG estimator uses linear combinations of the cross-sectional averages of the observed common effects as well as the dependent and explanatory variables (Kapetanios et al. 2011). Each individual coefficient is estimated by OLS. On the other hand, AMG estimator employs a two-step method to estimate the unobserved common dynamic effect and allows for cross-sectional dependence by including the common dynamic effect parameter. Bond and Eberhardt (2013) find that the AMG estimator is unbiased and efficient for different combinations of the number of observations, N, and the number of time periods, T, in their Monte Carlo simulations. As such, we primarily use the AMG by Bond and Eberhardt (2009) and Eberhardt and Teal (2010). We also use the CCEMG approach to check for robustness checks since the method is suitable for large N relative to T.

[4] We also relied on the models diagnostics in order to discriminate between the estimators by FE, MG, AMG, and CCEMG. Particularly, we also estimated our models using FE and MG and employed the Pesaran (2004) test to examine if the models residuals pass the cross-sectional independence test and are stationary—I(0). The diagnostic test results favour both the AMG and CCMG models as their respective residuals pass the CD test at the 5% level and are stationary in all cases implying non-spurious regression. Meanwhile, the MG and FE models fail the CD test in many cases and their residuals follow an I (1) process in several cases. We may thus conclude that the diagnostic tests provide strong support for the AMG and CCEMG models in this study.

4 Empirical results and discussions

This section reports and discusses the main findings which emerge from our empirical analysis.

4.1 Results

We first perform panel unit root tests that take into account cross-sectional dependence. Specifically, we employ the CIPS test—a cross-sectional augmented version of the IPS (Im et al 2003) test proposed by Pesaran (2007). The results reveal that the variables have a unit root in level but are stationary in first difference.[5] Having established that all variables are integrated of order one, we examine the cointegration relationship among our variables of interest ESI, GOV, TO, ENE, Y, and Y^2 using the panel cointegration tests developed by Banerjee and Carrion-i Silvestre (2017) since these tests allow for cross-sectional dependence and suits small-T panels. The results show that there is a cointegration relationship for ESI, GOV, TO, ENE, Y, and Y^2 for the majority of ESI indicators.

The cointegrating relationships are observed across different income groups of countries. However, the results are slightly different among country groups. Specifically, for the full sample and high-income subsample, a cointegrating relationship is found for ESI1, ESI3, ESI4, and ESI6. For upper-middle-income countries, cointegration is found for ESI1, ESI2, ESI4, and ESI6. For low- and lower-middle-income countries, cointegration is found for ESI1, ESI2, ESI5, and ESI6.[6] We discuss such relationships later in the section. The economic interpretation of cointegration suggests there is a stable equilibrium long-run relationship between ESI, GOV, TO, ENE, Y, and Y^2 for both full sample and subsamples.

Next, we estimate the long-run parameters in the cointegrating vectors found in the previous section, using the AMG estimator that allows for heterogeneous slope coefficients across group members and accounts for cross-sectional dependence.[7] The results are presented in Tables 5, 6, 7, and 8 for the full sample, high-income subsample, upper-middle-income subsample, and low- and lower-middle-income subsample, respectively.

Before analysing the results, we conducted the models diagnostics to examine if the models residuals pass the cross-sectional independence test by Pesaran (2004). The diagnostic test results as also reported in Tables 5, 6, 7, and 8, confirming that all

[5] The unit root statistics (for the logged variables in level and first difference) are not presented to conserve space, but they are available upon request.

[6] The Banerjee and Carrion-i Silvestre (2017) cointegration tests are performed with different specifications for robustness checks: constants, constants and trends, constants and level shift, and constants and cointegration vector shifts. The cointegration results mentioned in the text are those found for a majority of specifications. The cointegration results are not reported here to conserve space but they are available upon request.

[7] Prior to the AMG estimator, the Di Iorio and Fachin (2007)'s test for breaks in cointegrated panels is performed in order to examine the stability of the relationship among the variables of interest. The results indicate that there is not enough evidence to reject the null hypothesis of no break. That is, the relationship among the investigated variables is stable and not subject to structural breaks during the investigation period.The results are not presented here to conserve space but they are available upon request.

Table 5 Heterogeneous parameter estimates using AMG and CCEMG estimators: all countries

	All countries							
	AMG (1) ESI1	CCEMG (2) ESI1	AMG (3) ESI3	CCEMG (4) ESI3	AMG (5) ESI4	CCEMG (6) ESI4	AMG (7) ESI6	CCEMG (8) ESI6
GOV	−0.05 (−0.60)	0.15* (1.28)	−1.22*** (−2.71)	−1.04** (−2.08)	0.04 (1.05)	0.23 (0.91)	0.02** (1.80)	0.01** (2.25)
ENE	0.14 (1.07)	0.22 (0.83)	2.77*** (2.69)	2.89*** (2.66)	−0.13 (−0.83)	−0.68 (−0.71)	−0.08 (−0.90)	−0.03 (−0.25)
TO	0.12** (1.66)	0.10 (0.94)	0.84*** (3.07)	1.56** (1.66)	0.15** (1.90)	0.29** (1.67)	−0.01 (−0.07)	0.01 (0.02)
Y	203.70*** (4.09)	264.36** (2.09)	372.26*** (3.04)	164.02*** (3.49)	−43.64 (−0.95)	151.27 (0.96)	−1.76** (−2.11)	−32.20** (−2.04)
Y^2	1294.02 (1.12)	1694.13 (1.06)	2294.51 (1.04)	1092.86 (0.52)	233.29 (0.93)	−837.87 (−0.93)	2.93 (0.03)	190.14 (1.40)
ESI_avg		1.17*** (2.57)		2.22* (1.84)		0.27 (0.22)		2.07 (1.43)
GOV_avg		−0.22 (−0.74)		−2.71 (−1.05)		1.62 (1.00)		0.21* (1.71)
ENE_avg		−1.27 (−1.31)		4.39 (0.87)		3.07 (1.10)		0.10 (0.21)
Y_avg		−4.70 (−0.26)		−66.86 (−0.87)		−75.53 (−0.88)		3.16 (0.66)

Table 5 continued

	All countries							
	AMG (1) ESI1	CCEMG (2) ESI1	AMG (3) ESI3	CCEMG (4) ESI3	AMG (5) ESI4	CCEMG (6) ESI4	AMG (7) ESI6	CCEMG (8) ESI6
TO_avg		0.25 (0.57)		0.36 (0.95)		0.15 (0.37)		− 0.02 (− 0.27)
Y^2_avg		31.17 (0.32)		387.81 (0.95)		405.65 (0.88)		− 19.61 (− 0.74)
c_d_p	1.12*** (3.23)		0.85* (1.69)		0.67* (1.82)		1.22*** (4.67)	
_cons	− 2045.62 (− 1.13)	− 2748.93 (− 1.14)	− 3530.65 (− 1.04)	− 2375.02 (− 0.75)	− 307.89 (− 0.90)	605.96 (0.60)	1.27 (0.01)	− 247.57 (− 1.16)
Diagnostics CD test	− 1.68 [0.12]	− 1.85* [0.07]	− 1.42 [0.23]	− 1.70 [0.11]	− 1.19 [0.40]	− 1.23 [0.34]	− 1.07* [0.48]	− 1.25 [0.33]
Stationarity test (res)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)
N	442	442	442	442	442	442	442	442

c_d_p is the common dynamic process. *z* statistics in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 significance levels, respectively. CD test is the cross-sectional dependence test base on Pesaran (2004) test for the Null of cross-sectional independent residuals. Numbers in square bracket are the *p* values for CD test. Stationarity test is the Pesaran (2007) unit root test performed on the residuals. This test used three lags and rejects I(1) means that in all lags the test of unit root rejects with and without trend

Table 6 Heterogeneous parameter estimates using AMG and CCEMG estimators: high-income countries

	High-income countries							
	AMG (9) ESI1	CCEMG (10) ESI1	AMG (11) ESI3	CCEMG (12) ESI3	AMG (13) ESI4	CCEMG (14) ESI4	AMG (15) ESI6	CCEMG (16) ESI6
GOV	0.20** (1.81)	− 1.43 (− 0.94)	− 1.05** (− 1.47)	0.35 (0.33)	0.07 (0.72)	0.17** (1.65)	− 0.11** (− 1.71)	− 1.00** (− 2.17)
ENE	− 0.21 (− 0.35)	2.80 (1.47)	0.37** (2.25)	0.66* (1.68)	− 0.27 (− 0.81)	0.10 (0.21)	− 0.04 (− 0.32)	0.12 (0.81)
TO	− 0.13 (− 0.68)	0.78 (0.69)	0.66* (1.87)	− 1.61 (− 1.15)	0.14 (1.12)	0.27* (1.48)	− 0.02 (− 0.21)	− 0.11 (− 0.57)
Y	63.16*** (3.73)	1358.50** (2.11)	786.85** (2.07)	659.45*** (3.32)	23.87** (2.19)	51.62** (2.10)	− 79.81*** (− 3.70)	− 37.67*** (− 3.18)
Y^2	− 382.68 (− 0.69)	− 8648.70** (− 1.70)	10,983.75 (1.07)	− 4197.06 (− 0.32)	150.05 (1.17)	323.48 (1.08)	479.48 (0.68)	282.91 (0.21)
ESI_avg		− 0.68 (− 0.35)		1.51** (2.01)		0.91* (1.30)		0.67* (1.58)
GOV_avg		2.07 (0.87)		− 0.37 (− 0.13)		0.07 (1.17)		0.62 (1.43)
ENE_avg		2.47 (1.03)		− 4.39 (− 0.56)		0.25 (0.40)		− 0.56 (− 2.35)
Y_avg		− 201.78 (− 1.23)		744.47 (1.17)		10.82 (0.29)		− 29.84 (− 1.07)

Table 6 continued

	High-income countries							
	AMG (9) ESI1	CCEMG (10) ESI1	AMG (11) ESI3	CCEMG (12) ESI3	AMG (13) ESI4	CCEMG (14) ESI4	AMG (15) ESI6	CCEMG (16) ESI6
TO_avg		− 3.31 (− 0.70)		5.02** (1.77)		− 0.21 (− 0.37)		− 0.38* (− 1.50)
Y^2_avg		1342.05 (1.20)		− 4791.68 (− 1.18)		− 70.03 (− 0.30)		202.34 (1.11)
c_d_p	0.59*** (3.14)		1.05*** (3.75)		0.82*** (3.30)		0.87*** (3.99)	
_cons	580.35 (0.65)	11,497.25 (1.50)	− 16,875.76 (− 1.06)	14,441.82 (0.62)	− 231.77 (− 1.14)	− 395.70 (− 0.67)	− 723.74 (− 0.66)	− 856.25 (− 0.38)
Diagnostics CD test	− 1.52 [0.15]	− 1.01 [0.45]	− 1.02 [0.53]	− 1.46 [0.20]	− 1.69 [0.11]	− 0.23 [0.54]	− 0.67 [0.30]	− 0.03 [1.81]
Stationarity test (res)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)
N	143	143	143	143	143	143	143	143

c_d_p is the common dynamic process. z statistics in parentheses. *, **, and *** indicate significance at the 10, 5, and 1% significance levels, respectively. CD test is the cross-sectional dependence test base on Pesaran (2004) test for the Null of cross-sectional independent residuals. Numbers in square bracket are the *p* values for CD test. Stationarity test is the Pesaran (2007) unit root test performed on the residuals. This test used three lags and rejects I(1) means that in all lags the test of unit root rejects with and without trend

Table 7 Heterogeneous parameter estimates using AMG and CCEMG estimators: upper-middle-income countries

	Upper-middle-income countries							
	AMG (17) ESI1	CCEMG (18) ESI1	AMG (19) ESI2	CCEMG (20) ESI2	AMG (21) ESI4	CCEMG (22) ESI4	AMG (23) ESI6	CCEMG (24) ESI6
GOV	0.03** (2.18)	0.04** (2.21)	− 0.06 (− 0.57)	− 0.47 (− 1.13)	− 0.02** (− 1.77)	− 0.01 (− 0.73)	− 0.01 (− 0.09)	0.02 (0.67)
ENE	− 0.10 (− 0.61)	0.03 (0.06)	0.25** (2.32)	0.18** (2.47)	− 0.01 (− 0.26)	− 0.01 (− 0.13)	0.03** (1.68)	0.04** (1.78)
TO	0.03 (0.50)	0.29 (1.06)	0.09 (0.72)	0.66 (0.76)	− 0.01*** (− 3.72)	− 0.03** (− 2.11)	0.03 (0.63)	0.07 (1.34)
Y	8.41*** (3.82)	38.35*** (3.95)	12.56** (2.15)	141.11*** (3.21)	− 0.50 (− 0.21)	− 0.89 (− 0.65)	− 10.28*** (− 3.36)	− 0.73** (− 2.10)
Y^2	49.51 (0.84)	229.14 (0.98)	76.80 (1.20)	828.82 (1.20)	2.77 (0.20)	5.33 (0.70)	58.93 (1.39)	2.99 (0.07)
ESI_avg		1.87* (1.32)		0.55*** (3.57)		1.01* (1.45)		0.85 (3.54)
GOV_avg		− 0.09 (− 0.44)		0.51* (1.49)		0.01 (1.24)		0.01 (0.05)
ENE_avg		− 1.93* (− 1.90)		3.02* (1.50)		− 0.04 (− 0.71)		− 0.06 (− 0.27)
Y_avg		27.17 (0.40)		25.77 (0.56)		− 0.86 (− 0.38)		0.87 (0.24)

Table 7 continued

	Upper-middle-income countries							
	AMG (17) ESI1	CCEMG (18) ESI1	AMG (19) ESI2	CCEMG (20) ESI2	AMG (21) ESI4	CCEMG (22) ESI4	AMG (23) ESI6	CCEMG (24) ESI6
TO_avg		0.15 (0.51)		− 0.69 (− 1.02)		0.05* (1.44)		− 0.03 (− 0.34)
Y^2_avg		− 145.27 (− 0.39)		− 156.27 (− 0.61)		4.80 (0.39)		− 5.43 (− 0.28)
c_d_p	1.18 (1.52)		0.86* (1.80)		0.87 (1.28)		1.07 (6.28)	
_cons	− 70.02 (− 0.82)	− 135.59 (− 0.49)	− 112.33 (− 1.21)	− 1002.86 (− 1.31)	− 2.36 (− 0.12)	− 14.20 (− 1.14)	− 89.62 (− 1.51)	5.68 (0.09)
Diagnostics CD test	− 0.68 [0.72]	− 0.85 [0.67]	− 0.62 [0.74]	− 0.91 [0.51]	− 1.19 [0.40]	− 1.25 [0.32]	− 0.86 [0.49]	− 1.81* [0.09]
Stationarity test (res)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)
N	130	130	130	130	130	130	130	130

c_d_p is the common dynamic process. z statistics in parentheses. *, **, and *** indicate significance at the 10, 5, and 1% significance levels, respectively. CD test is the cross-sectional dependence test base on Pesaran (2004) test for the Null of cross-sectional independent residuals. Numbers in square bracket are the *p* values for CD test. Stationarity test is the Pesaran (2007) unit root test performed on the residuals. This test used three lags and rejects I(1) means that in all lags the test of unit root rejects with and without trend

Table 8 Heterogeneous parameter estimates using AMG and CCEMG estimators: Low and lower-middle-income countries

	Low and lower-middle-income countries							
	AMG (25) ESI1	CCEMG (26) ESI1	AMG (27) ESI2	CCEMG (28) ESI2	AMG (29) ESI5	CCEMG (30) ESI5	AMG (30) ESI6	CCEMG (32) ESI6
GOV	0.06** (1.67)	0.02** (1.72)	− 0.01 (− 0.05)	− 0.05 (− 0.81)	0.01 (1.17)	− 0.01 (− 0.89)	0.38 (0.78)	− 0.03 (− 1.16)
ENE	− 0.20 (− 0.52)	− 0.06 (− 0.64)	0.09** (2.18)	0.21** (2.27)	0.10 (1.27)	0.02 (0.32)	0.25* (1.58)	0.30 (1.52)
TO	− 0.45 (− 1.37)	0.06 (1.06)	0.16** (2.03)	0.07* (1.68)	− 0.01** (− 2.15)	− 0.02** (− 1.95)	− 0.46 (− 1.01)	0.01 (0.18)
Y	12.52** (2.15)	14.21*** (3.62)	44.22** (2.16)	28.64*** (3.51)	35.77 (1.29)	54.64 (0.99)	− 117.73 (− 1.22)	− 5.06 (− 0.21)
Y^2	− 59.55 (− 0.14)	− 71.11 (− 0.60)	227.22 (1.83)	− 164.33 (− 0.55)	− 192.08 (− 1.28)	− 295.19 (− 0.99)	620.98 (0.74)	20.05 (0.16)
ESI_avg	1.25** (2.40)		1.22*** (5.02)		1.21 (1.19)		6.09* (1.44)	
GOV_avg	− 0.09 (− 0.30)		0.08 (0.61)		0.05 (1.06)		0.17* (1.37)	
ENE_avg	0.96 (0.80)		− 1.01 (− 1.06)		− 0.10 (− 0.67)		1.72 (1.10)	
Y_avg	19.82 (0.41)		35.15 (1.26)		− 4.68 (− 1.05)		− 44.51 (− 1.17)	

Table 8 continued

	Low and lower-middle-income countries							
	AMG (25) ESI1	CCEMG (26) ESI1	AMG (27) ESI2	CCEMG (28) ESI2	AMG (29) ESI5	CCEMG (30) ESI5	AMG (30) ESI6	CCEMG (32) ESI6
TO_avg	0.15 (0.88)		− 0.02 (− 0.08)		0.02** (1.70)		0.14 (0.48)	
Y^2_avg	− 108.50 (− 0.43)		− 172.54 (− 1.24)		24.04 (1.05)		232.17 (1.19)	
c_d_p		1.09** (2.81)		0.99*** (3.11)		1.07*** (1.23)		0.94*** (4.80)
_cons	211.91 (0.42)	91.25 (0.60)	− 74.38 (− 0.40)	237.91 (0.59)	226.66 (1.11)	400.36 (0.99)	− 110.76 (− 1.80)	− 20.40 (− 0.12)
Diagnostics CD test	− 0.88 [0.64]	− 1.27 [0.25]	− 1.43 [0.23]	− 1.52 [0.15]	− 1.17 [0.39]	− 1.23 [0.34]	− 0.51 [0.85]	− 1.09 [0.45]
Stationarity test (res)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)	Rejects I(1)
N	169	169	169	169	169	169	169	169

c_d_p is the common dynamic process. z statistics in parentheses. *, **, and *** indicate significance at the 10, 5, and 1% significance levels, respectively. CD test is the cross-sectional dependence test base on Pesaran (2004) test for the Null of cross-sectional independent residuals. Numbers in square bracket are the *p* values for CD test. Stationarity test is the Pesaran (2007) unit root test performed on the residuals. This test used three lags and rejects I(1) means that in all lags the test of unit root rejects with and without trend

the respective residuals of our AMG (and also CCEMG) models pass the CD test at the 5% significance level.

For the full sample, shown in Table 5, we find that increased economic output has a significant and positive effect on ESI1 and ESI3 and a negative effect on ESI6. This implies that Asian countries as a whole managed well in pesticide regulation and child mortality but poorly in air quality as measured by PM2.5 exceedance. We could not find a significant relationship between output level and ESI4, which suggests lack of sustainability in protected areas.

The empirical results for the high-income subsample are qualitatively similar to the full sample. The only exception is that we find a positive relationship between output level and ESI4, which implies sustainability in biodiversity and habitats.

For the upper-middle-income subsample, we find that the level of output has a significant and positive effect on ESI1 and ESI2 and a negative effect on ESI6. This implies sustainability in pesticide regulation and child mortality. However, management in air quality as measured by PM2.5 exceedance has been poor. The insignificant relationship between output level and ESI4 suggests lack of sustainability in protected areas.

For the low- and lower-middle-income subsample, economic output has a positive and significant effect on ESI1 and ESI2. This implies sustainability in pesticide regulation. On the other hand, air quality remains at risk.

Overall, our findings are consistent with the view of Mol et al. (2009) that increased income level does not necessarily improve all forms of environmental quality, although it may have a positive impact on some.

For robustness checks, we report the heterogeneous parameter estimates of the CCEMG specifications in Tables 5, 6, 7, and 8. The results are qualitatively similar to the AMG results. Furthermore, the CIPS tests indicate that the residuals from each specification are stationary, which satisfies a requirement of a good fitting model.[8]

4.2 Discussions and implications

Our analysis yields evidence of sustainability in pesticide regulatory management across different income groups of Asian countries. Since 1982, the United Nations Food and Agriculture Organization (FAO) has assisted Asian countries to establish pesticide legislation and manage pesticide in line with international conventions and treaties that foster regulatory harmonization (FAO 2013). Harmonized pesticide management would enable Asian countries to apply the same requirements and quality standards, and helps less developed countries to learn from their neighbours. All countries in the region now have legal arrangements for pesticide registration, and almost all countries have special legislation or regulations for highly toxic products (FAO 2013). Nevertheless, there is plenty of scope for further regulatory harmonization in the region.

For air quality, measured by PM2.5 exceedance, we find the evidence that Asian countries of all income groups managed poorly. Air pollution indeed poses one of the biggest environmental risks, especially in Asia (Gupta 2015). Low- and middle-income

[8] The results are not presented here to conserve space but they are available upon request.

countries in South-East Asia and Western Pacific incurred the highest air pollution-related costs in 2012, with a total of 3.3 million deaths linked to indoor air pollution and 2.6 million deaths related to outdoor air pollution (World Health Organisation (WHO) 2014). Furthermore, about 97 per cent of 227 Asian cities do not meet World Health Organisation standards for air quality and the situation is getting worse (Gupta 2015).

The current situation underlines the need for effective governance that facilitates sound policy development and enforcement. Furthermore, effective governance strengthens stakeholder participation in all aspects of air quality management (Gupta 2015). In addition, proper planning in urban land use and transport is vital for tackling air pollution. Systematic urban planning can facilitate transport efficiency and environmental cleanliness. A good example is Singapore's seamless integration of rail and bus lines within a high-density urban environment.

Asian countries have generally shown growing interest in monitoring and improving air quality. In recent years, the Chinese government is actively taking steps to improve air quality in major cities. Furthermore, the pollution problem in China has been well documented by the Chinese media. Increased public awareness, along with improved governance, will enable Asia to improve air quality. New technologies such as remote sensing and mobile networks can also help (Gupta 2015).

In child mortality, the results reveal that high-income and upper-middle-income Asian countries in Asia have achieved sustainability. In contrast, low- and lower-middle-income countries still manage poorly. The significant decrease in under-five mortality rates in more developed countries is due to clean water, better hygiene, and higher quality of healthcare and childcare. On the other hand, many less developed countries still suffer from high infant mortality due to poor economic conditions, education, and healthcare.

While child mortality rate in Asia has dropped by nearly 50% between 1990 and 2011, it remains more than twice as high as Latin America (ADB 2013). As such, reducing child mortality is an urgently priority in Asia. Policy options include controlling fertility rates and further investments in primary healthcare and sanitation (CNN 2015).

Since Asia is the world's most populous region, its protected areas are important for safeguarding global biodiversity and natural capital, ensuring the delivery of ecosystem services, and minimizing the adverse global effects of climate change (UNEP 2016). However, protected areas cover 2.9 million square kilometres, or only around 13.9% of Asia's land mass. This implies that an additional 655 thousand square kilometres of protected areas, about the size of Myanmar, are needed to meet the 17% coverage of Aichi Biodiversity Target 11 (UNEP 2016).

A key challenge for Asia's protected areas is human–wildlife conflict (UNEP 2016). As human settlement encroaches upon protected areas, the chances of conflict increase. Illegal wildlife trade, deforestation, pollution, invasive species, energy production, and mining hinder the effectiveness of protected areas in conserving biodiversity (UNEP 2016). In certain areas of Nepal, the damage caused by elephants was as much as 27% of household income (UNEP 2016). Poor law enforcement associated with weak governance has further increased the vulnerability of wildlife. Large number of protected animals is killed as part of the wildlife trade. Energy production and mining is another problem. For example, the rapid expansion of Mongolia's mining industry poses the biggest threat to the country's protected areas (Asia Protected Planet Report 2014).

Overall, mankind must find a way to balance economic development and environmental sustainability. Developing alternative energy sources can contribute to a more sustainable environment-growth balance. Better management of population and economic growth is equally important. Specific measures include improving protected area management and strengthening law-enforcement protection in partnership with the private sector, and consumer education campaigns against use of illegal wildlife products (UNEP 2016). Reforms must strengthen relevant government agencies, and more effectively implement multilateral environmental agreements (Asia Protected Planet Report 2014).

Efforts to achieve a cleaner environment may adversely affect income and living standards in the short run. The delicate and difficult balancing act of growing the economy while safeguarding the environment requires a deeper understanding of the trade-off between short-term economic growth and long-term environmental sustainability (Higgins 2013). In the long-run, however, the trade-off weakens since growth is not possible without adequate environmental resources.

Furthermore, for the full sample and all three subsamples, we could not find evidence of an inverted U-shaped pattern between environmental performance and income per capita at 5% significance level. This observation is robust to different measures of environmental quality. Our results are consistent with Fiorino (2011), who finds that the inverted U is less applicable to pollutants such as carbon dioxide, which has effects that are not immediately apparent and may be shifted to other areas or future generations. Suri and Chapman (1998) contend that developed countries shift the production of pollution-intensive goods to developing countries to reduce their own emissions. Our findings are, however, contrast with those obtained by Apergis and Ozturk (2015), which found evidence of EKC for 14 Asian countries. The difference could be attributable to different dataset and different methodology.

Another reason why our evidence fails to support EKC is that even though there may exist an underlying relationship between pollution levels and income, observable indicators of environmental quality may continue to worsen due to stock effects. This is particularly relevant to upper-middle-income and low and lower-middle-income countries. As such, one must not put too much faith in the EKC, which may lead to misleading policy implications. Pollution may indeed decline over time due to technological advances and the general public's growing demand for a cleaner environment, but stock effects from irreversible emissions subject to hysteresis may delay the advent of the cleaner environment (Ranjan et al. 2007).

5 Conclusions

In this paper, we examine the relationship between GDP per capita and environmental sustainability in Asia using a panel data of 34 Asian countries in 2000–2012. Along with the full sample of countries, we look at three subsamples of countries based on income level. Our results indicate that Asian countries as a whole managed well in pesticide regulation and child mortality but poorly in air quality as measured by PM2.5 exceedance. In addition, we find no evidence of sustainability in protected areas. Our findings for the high-income subsample are similar, except for evidence of sustainability in biodiversity and habitat in the subsample. We find evidence of sustainability in pesticide regulation and child mortality in upper-middle-income countries, which managed poorly in air quality. Low- and lower-middle-income countries, where air quality is at risk, have achieved sustainability only in pesticide regulation.

Overall, our results show that richer countries tend to manage better in environmental sustainability relative to poorer countries. This tendency implies that countries with more financial resources can more effectively implement policies that protect human health and the environment. This is consistent with EPI (2014), which finds that both environmental health and ecosystem vitality objectives are positively associated with GDP per capita. The result suggests that environmental performance improves when countries grow richer. Nevertheless, our findings indicate that there is room for improvement in ecosystem and natural resource management in Asian countries of all income levels, including rich ones.

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