What Drives Renewable Energy Consumption in Asia

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In more recent years Asia has had the highest level of investment in renewables and the highest level of electricity generation from renewable sources. This paper analyzes the determinants of renewable energy consumption in Asia and the Pacific from 1996 to 2018. It explores the major challenges this region has faced in moving towards a more environmentally friendly generation and use of energy. We find that the renewable electricity output, GDP per capita, merchandise trade, the value added of the manufacturing sector and the income share held by the poorest population boost renewable electricity consumption. On the other hand, energy use per capita, access to electricity, energy imports, broad FDI, population growth and the income share held by the richest population lower consumption of electricity from renewable sources. Trade openness and being an island do not seem to have a statistically significant impact in our sample over the observed period.

Keywords: renewable energy consumption, Asia

INTRODUCTION

Investment in renewable energy sources has been an increasingly important component of national policy agendas for many countries over the past decades. One of the reasons has been the growing need for energy to enhance industrial production as well as electricity consumption, especially in developing countries. Conventional sources of energy have been limited, and fast depleting, though. Energy security in most recent years has added another layer of urgency to the problem. That, combined with the ever-growing awareness of citizens of the negative impact of climate change, has generated an expanding need for a more diverse pool of energy sources, and most notably - for renewable sources of energy.

A longtime leader in those initiatives related to policies and investment in R&D in renewables has been the European Union. However, more recently it is actually Asia that has had the highest level of investment in renewables and also the highest level of electricity generation from renewable sources. Asia has reached over 1,700 GW of installed electricity capacity in renewable energy in 2022. At the same time, the population of Asia and the Pacific has reached 4.5 billion people in 2022, which emphasizes the crucial importance of renewable energy development in this region, given that demand for energy overall will keep rising. Asia is a vast continent, comprised of very different countries – large and populous developing countries like China, India, and Indonesia, which have invested increasing amounts of resources in renewables on one hand. On the other hand, we have less populous, but highly developed countries like Japan and South Korea, which have high standards of living and a high potential to develop and deploy renewables in the future.

Even by 2010 Asia had already surpassed Europe in installed capacity of renewable energy: Asia's installed renewables capacity was 32% of the global total vs. Europe's 26%. By 2018 Asia had become the world leader in installed capacity of renewable energy (over 1 million MW), comprising 44% of the global total, followed by Europe with 23%, and North America with 16% of the global total (IRENA, 2018). The top investor in Asia by far is China, followed at a distance by India, Japan, Vietnam and South Korea. In 2020 China is already an established leader in renewable capacity in Asia, with close to 900,000 MW renewable energy electricity capacity installed. For comparison, in 2020 Europe has close to 610,000 MW renewable energy electricity capacity installed overall, while North America has about 422,000 MW. If we look at the actual electricity produced from renewable sources, we observe a similar trend – starting in 2010 Asia has progressively expanded the share of electricity generated from renewable sources, and by 2019 it is a global leader with 2.9 million GWh generated, comprising 42% of the global total. It is followed by Europe with 19% of the global total, and North America with 18%. The top five performers in renewable electricity generation in Asia are again led by China far ahead, followed by India, Japan, Vietnam, and Indonesia (IRENA, 2021). In 2021, Asia is still the global leader in renewable electricity generation with over 3.4 million GWh, followed by Europe with less than half at about 1.5 million GWh and then North America at 1.4 million GWh (IRENA, 2023).

The Association of Southeast Asian Nations (ASEAN) is a fast-growing trade bloc of 10 member states: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. It has set a target of securing 23% of its primary energy from renewable sources by 2025. ASEAN is one of the most dynamic and fastest growing economic regions in the world: if ASEAN were a single country, it would be the world's fifth largest economy, after the United States, China, Japan, and Germany. The expected population increase in the ASEAN region to 715 million by 2025 is projected to result in 4% annual growth in energy demand until 2025, an increase of 50% over 2014 levels and doubling of electricity demand between 2014 and 2025, for example (ASEAN, 2015). Compared to 2014 levels, growth in the use of fossil fuels by 2025 will range from 31% for oil, 90% for coal, and 65% for natural gas. Most of the projected increase in electricity demand over this period will be supplied by coal (42% of total generation), natural gas (23%) or large hydroelectric installations (20%). The remaining 15% is expected to come from a mix of renewable sources, including geothermal (5%), bioenergy (4%), wind (3%), solar photovoltaic (2%) and small hydroelectric installations (1%) (IRENA and ACE, 2016a). However, excluding Brunei Darussalam and Indonesia, the region has limited oil and natural gas supplies to meet this rising demand: stagnating oil and natural gas reserves have reduced ASEAN production and some countries that have historically been exporters, such as Indonesia, Malaysia, and Vietnam, have begun to import fossil fuels. The region is thus expected to become a net gas importer between 2020 and 2030, and the large coal reserves in some ASEAN countries will be reduced by approximately 60% (IRENA and ACE, 2016b). Overall, most countries in Asia still rely heavily on traditional sources of energy for their fast-growing consumption and production needs.

Our paper analyzes the determinants of renewable energy consumption in 34 countries and islands in Asia and the Pacific over a period of 23 years: from 1996 to 2018, using data from the World Development Indicators by the World Bank and the International Renewable Energy Agency, performing a regression analysis. It explores the major challenges this region has faced in moving towards a more environmentally friendly generation and consumption of energy. Our research reveals that factors which positively affect renewable electricity consumption include variables such as renewable electricity output and GDP per capita, as well as more specific variables like the share of merchandise trade, the value added by the manufacturing sector, and the income share of the lowest 10% of the population. On the other hand, factors that negatively affect the renewable electricity consumption include energy use per capita, access to electricity, energy imports, and population growth, reflecting an overall increase in energy demand that is met by predominantly traditional sources of energy. Additionally, broad foreign direct investment (FDI), not specifically targeted at the renewable sector, and the income share of the highest 10% of the population contribute to reduced renewables consumption. Trade openness and being an island do not exhibit a statistically significant impact on renewable energy consumption during the observed period. We find that Asian countries and islands in the Pacific still consume energy predominantly generated from traditional

sources, yet the potential to develop the renewable sector in the future is substantial. Investing considerably, both privately and publicly, in the renewable sector would be our policy recommendation.

LITERATURE REVIEW

The research dedicated to both consumption and production of renewable energy in various Asian countries is ample and starts fairly early. Sovacool (2013) assesses the factors responsible for the success and failure of renewable energy access programs in Bangladesh, China, Laos, Mongolia, Nepal, Sri Lanka, India, Indonesia, Malaysia, and Papua New Guinea. Based on 441 research interviews over the course of four years, site visits to 90 renewable energy facilities, and focus groups with almost 800 community members in 10 countries, the study develops a series of qualitative determinants. It offers lessons for reaching renewable energy targets regarding appropriate technology, income generation, financing, political leadership, capacity building, programmatic flexibility, marketing and awareness, stakeholder engagement, community ownership, and technical standardization. Sharvini et al. (2018) presents a review of the energy demand in China, Japan, Malaysia and Indonesia and the growth of non-fossil energy in these countries. They find that fossil energy still constitutes the primary energy source in each country, where coal dominates in China (77%) and Indonesia (70%), oil in Japan (28%) and natural gas in Malaysia (61%). Their paper identifies the challenges for renewable energy development and highlights the necessity of enhanced multilevel governance processes and increased cooperation between the four countries to strengthen their renewable energy sectors and better compete in the global energy market. Usman et al. (2021) performs a panel data analysis covering the period from 1990 to 2014 for 20 Asian economies to explore the dynamic connections between financial development, economic growth, non-renewable and renewable energy utilization, trade openness and ecological footprint. They find that economic growth and non-renewable energy utilization significantly accelerate the environmental deficit, while renewable energy utilization reduces the total environmental damage in the long run.

Some papers take a more managerial approach to analyze renewable energy issues in Asia. Gabriel (2016) explores the problems faced by renewable energy entrepreneurs in developing countries. She conducts a literature review across two main bodies of literature – management (specifically, entrepreneurship) and renewable energy. Based on that review, she summarizes six key challenges: inadequate access to institutional finance; the price of renewable energy technologies; the lack of skilled labor; underdeveloped physical infrastructure and logistics; power/dominance of incumbents; and inadequate government or policy support. Qaiser (2022) uses SWOT methodology to identify that the poor financial situation of the distribution companies, because of power losses and tariffs, together with the lack of credit opportunities, due to high interest rates and inaccessibility of loans for the long-term, are the major impediments to the growth of the renewable energy sector in South Asia. He also finds a conflict of interest between the manufacturers of renewable energy equipment and the developers of renewable energy projects in terms of government policy concerning the imposition of import duties.

ASEAN countries are the focus of many research explorations regarding renewable energy. Erdiwansyah et al. (2019) observe that Southeast Asian countries stand at a crossroads concerning their shared energy future and heavily rely on fossil fuels for both electricity and transport. In Asia, China and India lead the world renewable energy generation, while undergoing a period of energy transition and economic transformation. They note that Southeast Asian countries have a huge potential for sustainable energy sources, but they are yet to perform globally in renewable energy deployment due to various challenges. The study examines their renewable energy growth and analyzes the government policies to scale up the deployment of renewables for power generation. It also offers policy recommendations to accelerate renewable energy exploitation sustainably across the region. They argue that to achieve the ambitious target of 23% renewables in the primary energy mix by 2025, ASEAN governments should take proactive measures like removal of subsidies of fossil fuels and regional markets integration. Khuong et al. (2019) describes ASEAN as a diverse region characterized by rapid economic growth, demographic changes, and urbanization. They recognize that the dominance of energy supply from non-renewable resources in the region means that the increasing energy demand has implications for energy security, as

well as adverse local and global environmental effects. They acknowledge the climate in the region as favorable for renewable energy resources, especially wind and solar technologies. Yet, they state that ASEAN countries differ strongly in terms of their national policy frameworks and progress in renewable energy development. They qualify the overall target of 23% renewables by 2025 as very ambitious under current policy frameworks. Their paper identifies a gap between these national policies and local governance, especially in urban areas, and advocates for urban areas to be the focus of renewable energy policy and governance in addition to rural areas. They see the tremendous impact economic growth creates as an impetus for renewable energy development. Nathaniel and Khan (2020) state that economic growth, accompanied by rising energy demand in ASEAN countries have been unprecedented, and embark to explore the influence of renewable and non-renewable energy consumption, economic growth, and urbanization on a more reliable environmental indicator (ecological footprint) from 1990 to 2016, while controlling for trade. Their findings reveal that economic growth, trade, and nonrenewable energy contribute significantly to environmental degradation in ASEAN countries, suggesting that the region is growing at the expense of its environment, while also indulging in emission intensive trade. Further, their findings show a one-way causality from urbanization to non-renewable energy consumption, and they try to come up with policy recommendations for sustainable development of the region. Vidinopoulos et al. (2020) acknowledges that fossil fuels currently dominate the energy systems of the ASEAN countries, a region rich in untapped renewable resources. Their paper illustrates an approach of how the ASEAN region may substantially increase its use of renewable energy. It provides an overview of the shortfalls in energy targets and investigates the technical potential of a selection of renewable energy technologies throughout the region.

Trade openness and trade policies are explored in many papers dedicated to this region. Ghazouani et al. (2020) applies a new bootstrap autoregressive distributed lag approach to examine the nexus between trade openness, renewable electricity consumption, and economic growth for seven countries in the Asia-Pacific region during 1980–2017 period. They do not find evidence of cointegration among real trade openness, electricity consumption, and real GDP per capita in most countries. They highlight one implication of their research: that any environmental policy aiming to reduce the use of non-renewable energy and carbon dioxide emissions will lead to greater renewable energy consumption, which in turn may enhance trade openness and ultimately accelerate economic growth. Murshed (2020) empirically analyzes the compatibility of national trade liberalization policies with promoting widespread use of renewable energy resources across 71 low, lower-middle and upper-middle income countries from South Asia, East Asia, Pacific, Central Asia, Latin America, Caribbean islands and Sub-Saharan Africa from 2000 to 2017. The results of the paper show long-run links between trade liberalization policies and renewable energy consumption. Overall, his results broadly indicate that greater trade openness is facilitating renewable energy transition only in the low-income economies, while prolonging the transition periods in the lower and upper-middle income countries. However, trade liberalization is found to add to greater efficiency of renewable energy use across all the three income groups. Thus, he argues, these findings have critically important policy implications for the respective governments. Murshed (2021) analyzes the impact of regional trade integration on the prospects of undergoing renewable energy transition in selected South Asian economies between 1992 and 2015. The results emphasize the importance of promoting intra-regional trade among the South Asian economies to boost both the renewable energy consumption shares and the renewable electricity output shares. He also finds that greater FDI inflows reduce the overall use of renewable energy, while higher levels of economic growth and CO_2 emissions increase renewable energy use in South Asia. Lei et al. (2022) looks at the importance of international relations for the promotion of renewable energy, preservation of natural resources and the environment in South-East Asia over the period 1990 to 2020. Their results show that the countries with strong international relations have a higher ability to adopt policies that may be helpful for the promotion of renewable energy. Therefore, their study concludes that international relations between the countries are essential to lower the burden on natural resources and enhance the transition from nonrenewable to renewable energy sources in Southeast-Asian countries. Their research also argues that strong international relations between the countries may act as a catalyst to control carbon emissions through the promotion of renewable energy.

Mohsin et al. (2021) analyzes the effects of economic growth and energy resources (renewable and nonrenewable) on the emissions of greenhouse gasses over the period 2000–2016 using panel data from 25 developing Asian countries. Their findings indicate the significant contribution of nonrenewable energy resources to greenhouse gas emissions and the positive impact of renewable resources on greenhouse gas emissions' control. Furthermore, their study highlights the potential of developing Asian economies to preserve the environment through more robust regional environmental policies and renewable energy resources. They urge policymakers in Asian economies to develop policies on renewable energy infrastructure to improve GDP and reduce greenhouse gas emissions. Fang et al. (2022) examines the effects of urbanization and education on renewable and non-renewable energy demand in the emerging economies of Brazil, India, China, and South Africa from 1990 to 2015, using panel data. They find that urbanization and economic globalization reduce renewable and non-renewable energy demand; yet income level and pattern of education (primary and secondary) levels induce it. They state that although industrialization is ineffective in improving the demand for renewable energy, it drives up total energy (and non-renewable energy) demand and argue for policies to tackle those energy inefficiencies and promote pro-environmental education.

Other studies add foreign direct investment as an explanatory variable and investigate in depth the relationship between FDI and energy generation and use. Nepal et al. (2021) looks at the role FDI and trade openness play in energy security, economic growth, and environmental sustainability in India. They find that a 1% increase in FDI results in a 0.013% reduction in energy use. Energy use is also found to be Granger caused by output, carbon emissions, FDI and trade openness in the long run. Although they do not analyze specifically the renewable energy use, they do advise that the Indian government should galvanize FDI inflow in the renewable energy sector to ensure sustainable economic development. Kiliçarslan (2019) looks at the relationship between foreign direct investment and renewable energy production in Brazil, Russia, India, China, South Africa (BRICS) countries and Turkey, using annual data from 1996 to 2015. They find that the increase in FDI actually reduces energy production from renewable energy sources, arguing that their result may be an indication that FDI inflows are not necessarily directed towards the renewable energy sector. Their recommendations for policy makers are for them to adopt appropriate policy incentives in order to attract FDI specifically in the renewable energy sector. Kutan et al. (2018) explore the role of FDI inflows and stock market development on the promotion of renewable energy consumption in Brazil, China, India, and South Africa with annual data from 1990 to 2012. Their findings confirm that both FDI inflows and stock market development play an important role in promoting renewable energy consumption. They also affirm that renewable energy consumption helps to mitigate the growth of CO_2 emissions and promotes economic development. Doytch and Narayan (2016) examine the effects of sectoral FDI inflows on renewable and non-renewable industrial energy resources by using a dynamic panel estimator in the period of 1985-2012 for 74 countries. Their panel of countries is global and includes all income levels. Their results suggest that FDI reduces non-renewable energy-based energy consumption and increases renewable energy-based energy consumption. On the other hand, Lin et al. (2016) investigates the factors influencing renewable electricity consumption in China using data from 1980 to 2011. They find that economic development and financial development promote renewable electricity consumption, while FDI, trade openness and the lobby of conventional energy sources undermine the share of renewables in total electricity consumption in China.

Several papers investigate the determinants of renewable energy consumption in the developing world. Omri and Nguyen (2014) look at the determinants of renewable energy consumption in a global panel of 64 countries over the period 1990-2011. Their main results are that the increases in CO_2 emissions and trade openness are the major drivers of renewable energy consumption. Shahbaz et al. (2014) explores the relationship between trade openness and energy consumption using data of 91 high-, middle- and low-income countries during the period of 1980–2010. They find that the relationship between trade openness and energy consumption is inverted U-shaped in high income countries but U-shaped in middle- and low-income countries.

Overall, there exists an interesting and abundant research on various aspects of renewable energy investment, production, and consumption in different Asian countries. Our research builds on previous

studies and findings by exploring different factors that could explain the renewable energy consumption in the region.

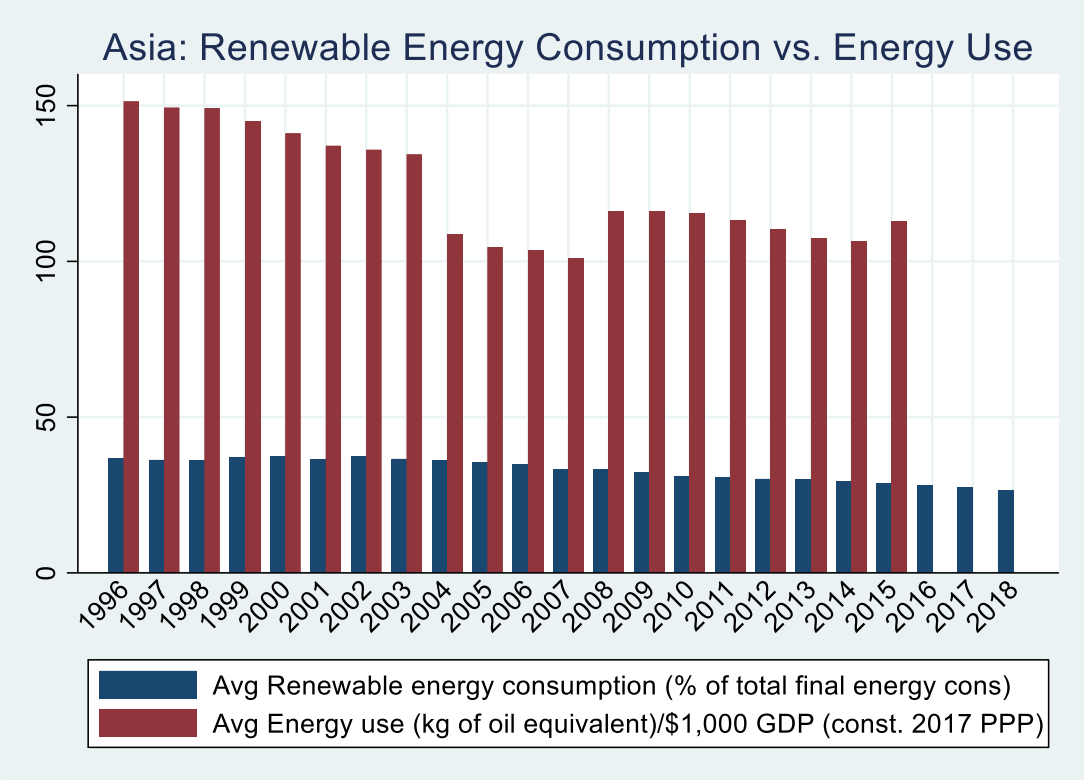
EMPIRICAL ANALYSIS

Renewable Energy Consumption Outlook in Asia and the Pacific

The data set we use comes from databases of the World Bank and the IMF, the World Development Indicators, and contains observations for 34 countries and islands (WDI, 2023). These countries are: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Fiji, Hong Kong SAR, India, Indonesia, Japan, Kiribati, Republic of Korea, Lao PDR, Malaysia, Maldives, Marshall Islands, Micronesia, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Tonga, Tuvalu, Vanuatu, and Vietnam. We have data on renewable energy consumption for 23 years: from 1996 to 2018.

Figure 1 below presents renewable energy consumption (as percentage of total final energy consumption) vs. the energy use (as kg of oil equivalent per $1,000 GDP units). It shows that renewable energy consumption has declined from 37% of total in 1996 to 26% in 2018. At the same time, the average energy use per unit of GDP produced, which is a measure of energy efficiency, has also decreased from 151 in 1996 to 113 kg of oil equivalent/$1,000 GDP in 2015. That means that although the energy efficiency has, on average, improved over the period we explore, clearly the energy needs for production in these various countries have been met by more traditional sources of energy, rather than by renewable ones.

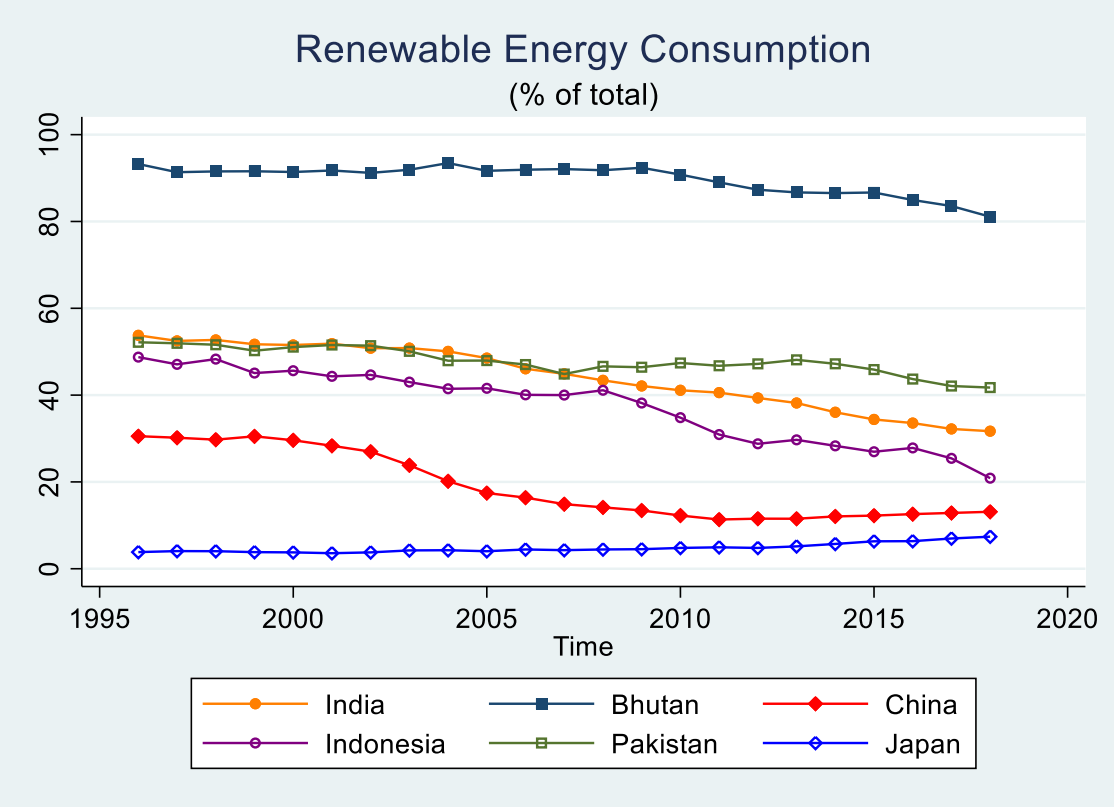
FIGURE 1
ASIA: RENEWABLE ENERGY CONSUMPTION (% OF TOTAL) VS. ENERGY USE



Source: The World Bank, WDI (2023).

Figure 2 shows the renewable energy consumption, as a percentage of total, in a variety of selected countries. As we can see, Bhutan has the highest share of renewable energy consumption starting at 93% in 1996, averaging about 90% since then, and declining only after 2010 to 81% in 2018. Pakistan and India follow a similar trend over the years: Pakistan starts at 52% in 1996 and has a share of 42% in 2018, while India starts at 54% in 1996 and ends at 32% in 2018. Indonesia has a similar beginning in 1996: 49% down to 21% in 2018. Given the noticeable economic growth of these developing countries over those 23 years, it is clear that their energy needs have been met by sources other than renewables during that period. China is a vivid example of that economic growth trend: it has 31% renewables share in 1996 and only 13% in 2018. Japan is an interesting illustration of the opposite trend: it is a highly developed country with a huge manufacturing sector, that has a 4% renewable energy consumption in 1996, which actually increases to 7% in 2018. To summarize our current observations so far: the more developed the country is over the period 1996 - 2018, the lower its share of renewable energy consumption. Also, the faster a country's economic growth over the same period, the quicker the decline in renewable energy consumption as a share of total energy consumption. Economic growth in Asia is therefore due to energy produced by more traditional, likely more polluting energy sources, which would negatively affect climate over time.

FIGURE 2
RENEWABLE ENERGY CONSUMPTION (% OF TOTAL): SELECTED COUNTRIES

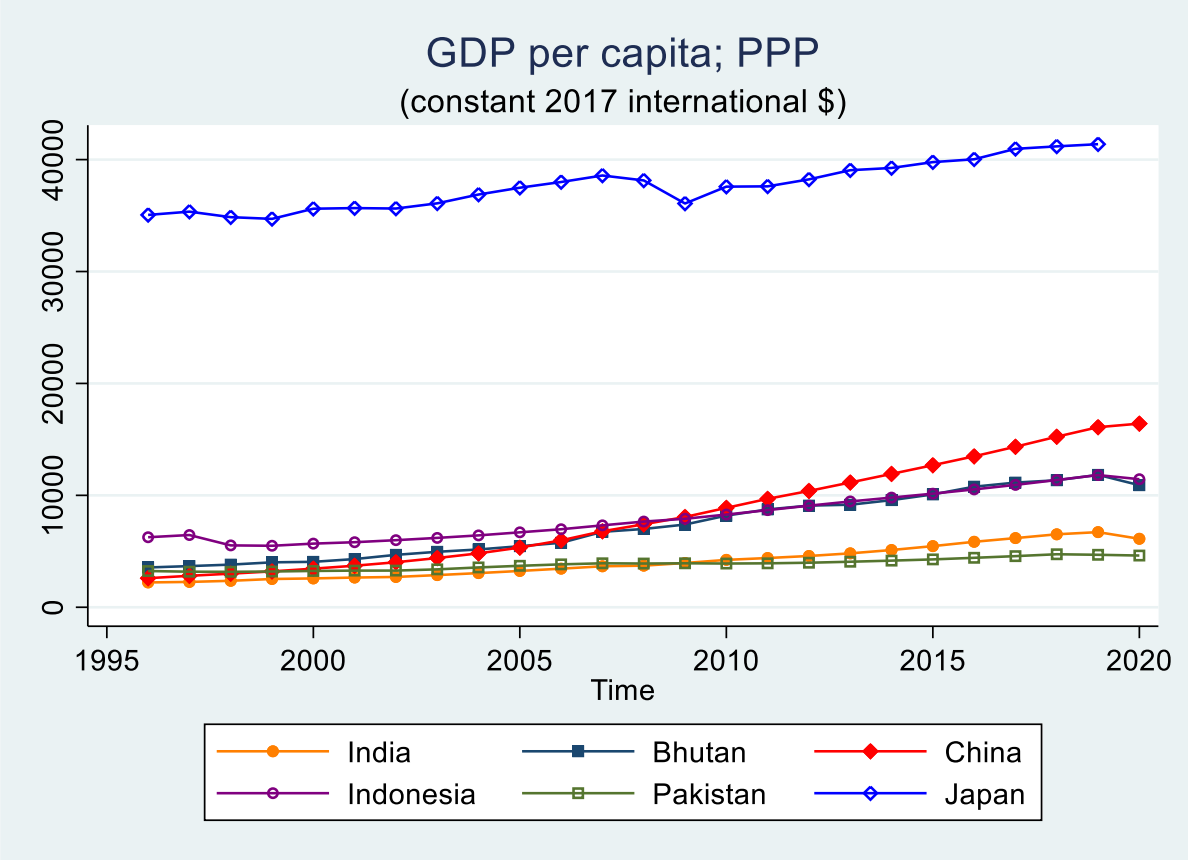


Source: The World Bank, WDI (2023).

Figure 3 below illustrates the GDP per capita in purchasing power parity over the period 1996 – 2020. Not surprisingly, Japan has the highest GDP/capita over the entire period covered. We select these countries for the graph mostly to show the contrast between Japan, and the rest of those Asian countries, the majority of which have much lower GDP/capita. However, China exhibits solid growth over the 25 years in our study. India and Pakistan, on the other hand, do not have an impressive record of GDP/capita increase in terms of purchasing power over time. GDP/capita reflects the level of development of a country, measured

by its production divided by its population, and compared by purchasing power across the board – all of which defines the energy needs of a given country. If its production, especially its manufacturing production, does not increase visibly, then its energy needs would not rise much either. It is also true that over the explored period of time the development and use of traditional sources of energy, such as coal and gas, would have been cheaper. Only recently have the costs of renewable energy dropped sufficiently for it to be a viable candidate to meet developing countries' growing demand for energy.

FIGURE 3
GDP PER CAPITA, PPP: SELECTED COUNTRIES



Source: The World Bank, WDI (2023).

Models and Estimation

The main model estimated in this paper analyzes the determinants of renewable energy consumption in different countries in Asia plus islands in the Pacific. Therefore, our dependent variable is $(Renewable\ Energy\ Consumption)_{ij}$, i.e. renewable energy consumption is the share of renewables energy in total final energy consumption in country *i* and year *j*. The detailed description of all the variables used as well as their summary statistics are presented in Tables A1 and A2 in the Appendix. We include the following country-specific indicators:

$$(Renewable\ Energy\ Consumption)_{ij} = \beta_0 + \beta_1*(Energy\ Needs)_{ij} + \beta_2*(FDI)_{ij} + \beta_3*(Country\ Performance\ Indicators)_{ij} + \beta_4*(Trade)_{ij} + \beta_5*(Manufacturing\ Production)_{ij} + \beta_6*(Income\ Inequality\ Indicators)_{ij} + \beta_7*(Island)_{ij} + \varepsilon_{ij}, \quad (1)$$

where:

- ***Energy Needs*** combines several dimensions. First, it reflects the energy use per capita. The energy production of a country could be realized in three main ways: (1) from traditional sources, i.e. fossil-fuel based ones; (2) from renewable energy sources; (3) from a combination of both. The hypothesis we test here is whether higher energy use per capita creates incentives for more energy consumption from renewable sources as well. In that sense, traditional sources and renewable ones could be both substitutes and complements, and therefore the expected coefficient signs could be ambiguous. Electricity generation from traditional sources includes all the alternative possible sources of electricity production in each country, which have been historically used even before the existence of renewables. Electricity generation from coal, gas, nuclear and oil sources is expected to have a negative impact on production from renewable ones. Part of the explanation is that they are substitutes in production. Another, more interesting part of the explanation is that traditional sources of energy production have developed over time the ability to influence the energy sector through political and economic means. The energy mix between traditional and new sources is considered a proxy for the competition between all these energy technologies and renewables as well as the lobby power of the traditional sources. Based on the insights gathered during our research, we have also concluded that the higher the share of electricity generated from traditional sources, the less likely a country would be to pursue meaningful environmental policies. Therefore, the less proactive a country would be in deployment of renewable sources and in renewable energy consumption.
  Second, we include what percentage of the population has access to electricity at all. Third, we add net energy imports (as a percentage of energy use) as a measure of a country's dependency on other countries for their own energy needs. Finally, we explicitly have renewable electricity output (as a percentage of total) which must be directly related to renewable energy consumption. All of these variables could also be perceived as development indicators, meaning that higher energy needs per capita indicate a move towards industrialization and more advanced stages of a country's economic development.
- ***FDI (Foreign Direct Investment)*** measures potential transfers of capital that could affect the renewable energy sector. FDI in general can mean more resources for the development of any sector within the economy, though, so the question we are trying to answer here is what part of that inflow is directed towards renewable energy production, if any. More investment in renewable energy production would result naturally in more renewable energy consumption.
- ***Country Performance Indicators (GDP per Capita & Population Growth).*** We expect a clear positive impact of higher GDP per capita, indicating a higher level of income and thus ability to invest in and promote renewable energy. Higher population growth would definitely mean more energy consumption overall, though not necessarily from renewable sources.
- ***Trade*** in our analysis is included as both total trade (as a percentage of GDP) and merchandise trade (as a percentage of GDP), so that we could assess which type of trade would have more impact on renewable energy consumption. Merchandise trade is more specific, though, and could be more relevant for countries in Asia.
- ***Manufacturing,*** included as valued added by the manufacturing sector (and percentage of GDP) attempts to estimate to what degree that sector is a driver behind renewable energy consumption in a given country. We expect that a more developed manufacturing sector would lead to an increase in energy consumption overall, but we assume that at least part of that increase would come from renewable sources.
- ***Income Inequality Indicators*** are added in order to explore to what extent income distribution within a country is a factor in its consumption of renewable energy. We have two specific variables here: income share held by the highest 10% and by the lowest 10% of the population. Depending on the cost and the ease of a renewable energy source installation (a solar panel for household use, for example), the interesting question here is whether richer, or poorer households are better able to benefit from these new energy options for consumption.

- ***Island*** is a dummy variable for being an island. Islands by definition have limited area to install new renewable sources of energy, but at the same time, given their location, they could benefit from solar and wind energy at the very least. We are trying to discover here whether these factors matter in renewable energy consumption.

Estimation Results

The results are presented in Table 1 below. The energy use per capita coefficient is significant, albeit slightly negative and small. Access to electricity overall also seems to negatively affect consumption of renewable energy specifically, as the coefficient is negative and statistically significant. Energy imports as well negatively affect the dependent variable and are statistically significant in two of the regression model specifications. Predictably, though, the renewable electricity output directly impacts the consumption of renewable energy and is strongly statistically significant. The above results affirm our previous discussion that the general energy needs of a given country could be fulfilled by utilizing both traditional, and renewable, sources of energy production. As a country develops, industrializes and its energy needs increase, these needs could be met by a variety of sources, and thus the consumption of renewable energy specifically may not necessarily increase as a percentage of total energy consumption. In Asia, it is the traditional ones that still dominate, apparently.

Regarding the foreign direct investment funds, the question we are trying to answer is what part of that inflow from abroad is directed towards renewable energy production and therefore could enhance consumption of it. Our results suggest that none - the estimates of the FDI coefficients are actually negative and statistically significant, suggesting that general foreign direct investment in a country may not have any particular impact on the renewable energy sector, unless it is directed concretely there and may, in fact, decrease consumption of renewable energy per se.

The GDP per capita coefficient estimate is small, but positive and significant in most specifications, suggesting that overall, the more developed and the wealthier a country is, the more prone and able it is to invest in renewables, and therefore to have a higher proportion of its electricity produced and consumed from such sources. Population growth – another driver of higher energy needs, and therefore a factor promoting higher energy consumption from all possible souces, including renewables, is negative, and significant in most specifications, suggesting yet again that increased energy needs in a growing Asian country are most likely met first by traditional sources of energy, rather than by renewable ones. That, however, also shows the huge potential of the renewable energy sector in those mostly developing countries, so that eventually they could procure their consumption of energy predominantly from renewables.

Overall trade did not seem to have any impact on the renewable energy consumption, so we include a more specific measure: merchandise trade as a percentage of GDP. Merchandise trade proved to have a small, positive and slightly statistically significant impact on our dependent variable in two of the models. Manufacturing value added (as a percentage of GDP) also indicates a positive and strongly statitically significant importance in renewable energy consumption in all model specifications. Therefore, the more specific variables included in the model, such as trade in goods and manufacturing production, exhibit a more strongly pronounced impact on the renewable energy consumption in these Asian countries and islands.

The inicators of income inequality in our models produce interesting results. Income share held by the highest 10% of the population seems to have a negative and statistically significant effect on renewable energy consumption. At the same time, income share held by the lowest 10% of the population has a high, positive and statistically significant impact on renewable energy consumption. The tentative conclusion here is that the poorer cohorts of the population may benefit more from the deployment of renewable energy sources, especially given that the cost of electricity production from renewables has been decreasing over the years, and may channel their consumption of electricity more from renewable sources, compared to wealthier cohorts, which may not be that sensitive towards the cost of electricity.

The island dummy variable is not statistically significant in three of the four models. It shows a positive and significant effect only in the last regression model, which also includes income share held by the lowest 10% - suggesting that the poorer parts of the population on the island could gain more from investment in

renewables, especially from the less expensive individual solar panels installation to supply an individual household, for example.

TABLE 1
DEPENDENT VARIABLE: RENEWABLE ELECTRICITY CONSUMPTION
(AS % OF TOTAL FINAL ENERGY CONSUMPTION)

	(1)	(2)	(3)	(4)
Energy use (per capita)	-0.00591*** (0.000713)	-0.00584*** (0.000715)	-0.0157*** (0.00209)	-0.00765*** (0.00180)
Access to Electricity (% of population)	-0.704*** (0.0325)	-0.706*** (0.0325)	-0.553*** (0.0891)	-0.425*** (0.0780)
Energy Imports, net (% of energy use)	-0.0203*** (0.00438)	-0.0203*** (0.00424)	-0.0184 (0.0168)	-0.0146 (0.0145)
Renewable Electricity Output (% of total)	0.482*** (0.0232)	0.483*** (0.0232)	0.585*** (0.0509)	0.577*** (0.0433)
FDI Net Inflow (% of GDP)	-0.348** (0.113)	-0.373** (0.114)	-0.471* (0.197)	-0.381* (0.170)
GDP per capita, PPP (current international $)	0.000258** (0.0000785)	0.000254** (0.0000772)	0.00106*** (0.000283)	0.000410 (0.000246)
Population Growth	-2.131** (0.766)	-2.012** (0.743)	-2.521 (1.640)	-5.104*** (1.414)
Trade (% of GDP)	0.0172 (0.0112)			
Merchandise Trade (% of GDP)		0.0240† (0.0129)	0.0193 (0.0248)	0.0426† (0.0217)
Manufacturing, VA (% of GDP)	0.512*** (0.0905)	0.520*** (0.0901)	0.797*** (0.168)	0.564*** (0.134)
Income Share Held by Highest 10%			-1.921*** (0.302)	

	(1)	(2)	(3)	(4)
Income Share Held by Lowest 10 %				13.98*** (1.565)
Island	-1.215	-1.363	3.018	6.329*
	(1.720)	(1.721)	(2.883)	(2.568)
Constant	79.17***	78.70***	120.2***	11.62
	(2.957)	(2.950)	(9.999)	(9.629)
N	313	313	85	85
R^2	0.916	0.916	0.916	0.937

Standard errors in parentheses; † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

CONCLUSION

This paper explores the major challenges Asia and the Pacific have faced in moving towards a more environmentally friendly generation and consumption of energy. We look at the determinants of renewable energy consumption in 34 countries and islands over a period of 23 years: from 1996 to 2018, using data from the World Development Indicators by the World Bank and the International Renewable Energy Agency. We find that the factors which tend to boost renewable electricity consumption include some general ones, like the renewable electricity output and the GDP per capita, but also some specific ones, such as the share of merchandise trade, the value added of the manufacturing sector and the income share held by the lowest 10% of the population. At the same time, the factors which seem to lower consumption of renewable electricity encompass the energy use per capita, access to electricity, energy imports and population growth – all related to the increase in demand for energy overall, which has to be met by more than renewable sources, together with broad FDI (i.e. not targeted to the renewable sector specifically), and the income share held by the highest 10 % of the population. Trade openness in general and being an island do not seem to have a statistically significant impact on renewable energy consumption in our sample over the observed period.

In summary: the demand for energy in Asia and the Pacific is growing substantially, both because of population growth and production growth - but renewables are not nearly enough to match that demand for energy. In addition, income inequality affects the consumption of renewable energy, with the income share held by the poorest boosting renewable energy consumption, while the income share held by the richest population lowering it. Asian countries still consume energy predominantly generated from traditional sources, but the potential to move to renewables in the future is substantial.

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APPENDIX

TABLE A1
VARIABLES DEFINITIONS

Variable	***Definition***
Renewable Energy Consumption	Renewable energy consumption is the share of renewable energy in total final energy consumption.
Energy use, per capita	Energy use (kg of oil equivalent) per capita
Access to Electricity (% of population)	Access to electricity is the percentage of the population with access to electricity. Electrification data are collected from industry, national surveys and international sources.
Energy imports, net (% of energy use)	Net energy imports are estimated as energy use less production, both measured in oil equivalents. A negative value indicates that the country is a net exporter.
Renewable electricity output (% of total)	Renewable electricity is the share of electricity generated by renewable power plants in total electricity generated by all types of plants.
FDI, net inflow (% of GDP)	Foreign direct investment, net inflows (% of GDP)
GDP per capita, PPP (current international $)	This indicator provides per capita values for gross domestic product (GDP) expressed in current international dollars converted by purchasing power parity (PPP) conversion factor.
Population Growth	Population growth (annual %)
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.
Merchandise Trade (% of GDP)	Merchandise trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP, all in current U.S. dollars.
Manufacturing, VA (% of GDP)	Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs.
Income Share Held by Highest 10%	Percentage share of income is the share that accrues to subgroups of population indicated by deciles or quintiles.
Income Share Held by Lowest 10%	Percentage share of income is the share that accrues to subgroups of population indicated by deciles or quintiles.
Island (dummy)	=1 if country is an island; 0 otherwise

Source: The World Bank, World Development Indicators and International Renewable Energy Agency (2023).

TABLE A2
DESCRIPTIVE STATISTICS

Variable	***N***	***Mean***	***Std. Dev.***	***Min***	***Max***
Renewable Energy Consumption	778	33.06125	28.19726	0	93.4565
Energy use per capita	402	1667.422	2013.371	58.0459	9837.473
Access to Electricity (% of population)	728	76.79288	25.75451	2.158483	100
Energy Imports, net (% of energy use)	362	-13.03196	156.9387	-849.5552	99.69292
Renewable Electricity Output (% of total)	684	23.97846	31.08394	0	100
FDI Net Inflow (% of GDP)	769	4.210147	6.870882	-37.15476	58.51875
GDP per capita, PPP (current international $)	835	11854.89	18231.82	642.566	102573.4
Population Growth	850	1.369029	.9179123	-1.474533	5.321517
Trade (% of GDP)	738	103.1267	78.312	.1674176	442.62
Merchandise Trade (% of GDP)	830	78.29724	63.42164	15.724	419.9623
Manufacturing, VA (% of GDP)	759	13.28564	8.612896	.356588	32.45233
Income Share Held by Highest 10 %	157	29.51911	3.265518	22.9	38.4
Income Share Held by Lowest 10 %	157	2.958599	.6019248	1.7	4.4
Island	850	.4705882	.4994281	0	1

Source: The World Bank, World Development Indicators and International Renewable Energy Agency (2023)