The heterogenous role of energy policies in the energy transition of Asia-Pacific emerging economies

Peipei Chen[1], Yi Wu[1], Jing Meng[1], Pan He[2], Deyu Li[3], D'Maris Coffman[1], Xi Liang[1], Dabo Guan[1,4]
[1] The Bartlett School of Sustainable Construction, University College London, London WC1E 7HB, UK
[2] School of Earth and Environmental Sciences, Cardiff University, Cardiff, UK
[3] Cambridge Centre for Environment, Energy and Natural Resource Governance, Department of Land Economy, University of Cambridge, Cambridge CB3 9EP, UK
[4] Department of Earth System Sciences, Tsinghua University, Beijing 100080, China

Abstract: The achievement of sustainable energy systems requires well-designed energy policies, particularly targeted strategies to plan the direction of energy development, regulations monitored and executed through credible authorities, and laws enforced by the judicial system for the enhancement of actions and national targets. The Asia-Pacific region (APAC), responsible for more than half of global energy consumption, has enacted a large number of energy policies over the last two decades, but progress on the energy transition remains slow. This study focuses on the aggregate effect of energy policies on the progress towards sustainable targets in 42 emerging economies from 2000 to 2017. We find that energy policies have contributed to improving access to electricity (3.0%), access to clean cooking (3.8%), energy efficiency (1.4%) and renewable electricity capacity (6.9%), respectively. Among different types of energy policies (strategies, laws and regulations), strategies have greater impacts on advancing electrification, clean cooking and renewable electricity capacity than laws and regulations, whereas the laws are more effective for achieving energy efficiency.

Keywords: Energy transition; SDG7; Energy policy; Asia-Pacific region

Main

The transition from conventional energy consumption to clean and sustainable energy use is critical to sustainable development given that the energy sector contributes over 90% of CO_2 emissions worldwide[1]. Achievable energy transition has been repeatedly advocated as the fundamental solution to the climate crisis in the context of United Nations climate change conferences including the Paris Agreement[2]. The Asia-Pacific (APAC) region plays a crucial role in the global fight against climate change. It includes countries with diverse levels of economic development and geographical characteristics (ranging from continent countries to small islands). It is estimated that about half of all economic growth in the world will happen in the APAC region by 2050[3], leading to 45% growth in electricity demand[4]. However, the energy transition is lagging in the region. The proportion of renewable energy in overall energy use has fallen from 22.7% in 2000 to 16% in 2019 while greenhouse gas (GHG) emissions have doubled, accounting for half of the world's emissions. Many countries in the APAC region are heavily dependent on conventional energy sources with unpredictable levels of energy poverty and volatility in energy prices[5–7].

Against this complex backdrop, a systematic assessment of the measures introduced so far in the APAC region to facilitate the energy transition can provide critical information to support policymakers[8].To accelerate the energy transition, governments ensure that policies cover a broad set of industries, economic sectors and administrative units with various objectives[9–12]. Governments' commitment and effective implementation of policies are fundamental to make progress with the energy transition[13,14]. In particular, to achieve global pollution emissions reduction, energy transition and sustainable development, there is a strong need for integrated policy efforts[15–17]. However, previous studies have mostly focused on analysing the energy transition of countries in the Organization for Economic Cooperation and Development (OECD) or the developed economies rather than the Global South[2,18,19]. Studies have considered policy mixes to achieve energy transition as interactions between policy implementation and energy system operations[20,21]. The pros and cons of combinations of energy policies and their impacts have also been discussed[20,22,23]. Research has also analysed the institutional context of policy implementation to gain insights into the formulation of policy mixes for energy transition[24]. To support sustainable and inclusive development in the APAC region, understanding the impacts of energy policies on progress toward energy transition is critical to design effective policies.

Progress on energy transition is currently assessed primarily through Sustainable Development Goal 7 (SDG7) – ensuring access to affordable, reliable, sustainable and modern energy for all – that contains energy access and renewable energy use as an alternative indicator for energy transition[7,25]. So far, SDG7 targets have been used to assess the progress of energy transition under the Paris Agreement[26–28], and the performance of SDG7 in the APAC region is documented by United Nations[29]. In addition, energy policies in the APAC region have grown remarkably over the last two decades, particularly in relation to the promotion of electrification and renewable energy capacity[30]. However, there are substantial differences in the institutional, economic and resource endowments of countries in the APAC region, and there is considerable uncertainty in the development of their policy frameworks and regulatory environments, as well as notable disparities in the stages of energy transition across countries, especially in the case of emerging economies[15,31]. It is therefore challenging to measure the relationship between energy policy and energy transition from a regional perspective because of the lack of a quantitative research framework.

To bridge this research gap, in this study we apply statistical methods to evaluate the impact of energy policies on the progress towards energy transition in the APAC region. We present a framework for the quantitative assessment of the aggregate effect of energy policies on energy transition. Here, we first track progress towards the achievement of the SDG7 targets within the APAC region through the SDG7 indicators. Then we collect the energy policies by using the *Asia Pacific Energy Portal Policy* database, which covers 42 emerging economies and 2112 energy policies over the period 2000-2017 (Supplementary Table 1-2, Supplementary Figure 1). Finally, we estimate the relations between the adoption of energy policies and the realization of the energy transition using panel data regression models, and further quantify the contribution of each policy type. The results offer an overview of the energy policies in the APAC region and their impacts on energy transition.

Energy transition progress in the APAC region

The 42 APAC economies are classified into three groups based on economic fundamentals released by the United Nations[32], which are least developed countries (LDCs), developing countries and economies in transition. Economies in transition refer to the Commonwealth of the Independent States, most of which are vulnerable to uncertainty and external shocks[32]. In the APAC region, progress toward energy transition has not been uniform over the period 2000-2017 (Fig. 1). Access to electricity (indicator 7.1.1) is well achieved, with a median value of the progress of 0.977 in 2017. It is followed by the access to clean cooking (indicator 7.1.2), for which about half of the economies in the region met the targets and the median value in 2017 is 0.48. Regarding the energy intensity level of primary energy (indicator 7.3.1), most of the countries are halfway to achieving their targets, thus requiring substantial improvement. For renewable electricity capacity (indicator 7.b.1), only one-fifth of the countries or regions have reached their targets.

Fig 1 shows the specific characteristics of the various stages of the energy transition in the different groups of countries. Electrification, as a priority target, is achievable across all countries. Economies in transition are progressing more toward electrification, clean cooking, and renewable electricity capacity, but less toward energy efficiency. LDCs have made notable progress in electrification and energy intensity targets, but they need to strengthen access to clean cooking. Developing economies do not stand out in terms of progress toward energy intensity and renewable electricity capacity targets. On the one hand, progress depends heavily on geographical location, local resources and infrastructures. On the other hand, it is significantly correlated to the level of economic development. In LDCs the primary aim is eliminating energy poverty and improving energy access, whereas industrialized countries promote renewable energy and clean cooking for a higher living standard.

Specifically, the highest success in the region has been achieved in terms of access to electricity. In 2017, 95% of the total population in the APAC region have access to electricity, growing from 87% in 2010 when 14 out of 42 economies have 100% access. Economies in transition and developing countries show higher levels of electrification on the whole, while LDCs are characterized by faster growth of electrification. Notably, since the government in Afghanistan pushed renewable energy adoption and focused on rural electrification through off-grid deployment, electrification increased from 23% (only 8% in rural areas) in 2005 to 97.7% (97.1% in rural areas) in 2017. In contrast, access to clean cooking has not progressed well. Energy consumption for cooking in least developed countries is still in part dependent on fuelwood, charcoal and solid biofuels, e.g. crop residues and dung, such as in the case of Bhutan (whose solid biofuels account for about three-quarters of energy consumption). Furthermore, the shift away from conventional biofuel sources does not ensure the adoption of cleaner energy sources, but rather the use of fuels such as liquefied petroleum gas[4]. Such a pattern seems undesirable but it might be the only way towards the energy transition for the LDCs and some small islands, where clean cooking has grown slowly starting from a low level.

Progress in terms of energy intensity is also limited, with the indicator falling well short of the target value. There is a low correlation between the target and the level of economic development, and economies in transition have generally achieved limited progress in terms of energy intensity. This is because reducing energy intensity takes place relatively late in the energy transition[18], with access to electricity and clean cooking being the main targets of the current transition in APAC[33]. The policy framework for energy efficiency in emerging countries is currently weak, and only a few economies have relatively mature energy efficiency policies and regulatory environments[34]. In addition, renewable electricity capacity is the least developed overall, and energy sources vary by income levels in the APAC region. Low-income countries rely on solid biofuels mostly (accounting for 88%), while the contribution of solar and wind energy is gradually increasing in the better-off economies (Supplementary Figure 2). Recently, the installation costs of solar and wind have dropped substantially and have nearly achieved grid parity compared to fossil fuels[35]. The installations of solar and wind energy have grown from only 396 MW and 1482 MW in 2000, to about 216 GW and 217 GW in 2017, with their average annual growth rates being 45% and 34% respectively (Supplementary Figure 3).

The aggregate effect of energy policies on energy transition

We estimate progress toward energy transition in the APAC in absence of any energy policy (counterfactual progress) and compare it to observed progress, under existing energy policies (Table 1). We calculate the aggregate effect of energy policies on progress toward energy transition (Fig. 2). The shaded area between observed progress (solid line) and counterfactual progress (dashed line) represents the aggregate effect of energy policies. The figure shows that energy policies started to affect the energy transition from 2000. According to Fig. 2, energy policies contribute to progress toward energy transition by 3.0% in terms of access to electricity, 3.8% in terms of access to clean cooking, 1.4% in terms of energy intensity reduction and 6.9% in terms of renewable electricity capacity, on average over the study period.

In addition, we disaggregate the counterfactual progress of each target by individual country in each category (Fig. 3). We find that overall energy transition is progressing faster in developing economies than in the other two groups because these countries have more energy policies in place and are better positioned to promote, monitor and safeguard their implementation. For example, India and Vietnam have issued 232 and 200 policies, followed by the Philippines and Thailand with 193 and 101 policies respectively. The aforementioned countries are ranked top among the 42 economies in the Asia Pacific region and showed the fastest progress toward energy transition. For example, in South-East Asia, countries are set to achieve a 23% share of renewable energy in the primary energy supply by 2025. The governments have therefore adopted proactive measures, such as removal of fossil fuel subsidies, consolidation of regional markets and acceleration of existing projects[12,36,37]. Some countries have also set other targets. The Philippines aims to reduce its energy intensity by 40% by 2030, and to this end, it has developed many strategies including the use of energy efficiency codes, efficiency standards and equipment labelling[12,38]. To accelerate the adoption of renewables, Thailand has established an electric vehicle manufacturing industry by providing tax incentives through fiscal policy[12]. Our estimations include the impacts of all these policies.

Effect of policy type on energy transition

Policies may differ greatly in terms of their requirements, implementation and governance[39]. Energy policies adopted by APAC countries are of different types. We codify policy documents into categories such as laws (397 in total), regulations (221 in total), strategies (353 in total), and others (1159 in total). Here law means legal requirements established by legislation and enforced by the judicial system in line with national targets, while regulation refers to the promulgation of targeted rules by executive power which are accompanied by extra-legal mechanisms for monitoring, enforcement, and sanctioning of rule breakers[40]. And strategy provides overall energy development direction and strategic goals, including often a plan for the next few years.

We focus on the effect of the targeted policies in the form of law, regulation, and strategy on energy transition (Supplementary Table 8). Overall, law, regulation and strategy policies all have positive effects on the energy transition. Strategies play a relatively more important role than laws and regulations, which is consistent with previous studies[41]. In Vietnam, for example, long-term strategies are preferred to other policies and play an important role in facilitating energy transition. Over the past decades, Vietnam has introduced a number of mid- and long-term development strategies, including the development of fossil fuels, electricity and renewable energy[42]. Among them, the Renewable Energy Development Strategy to 2030 with outlook to 2050, aims to achieve an increase of power generation capacity of 12.5% by 2025 (excluding large hydro) and of 21% by 2030, in addition to developing pathways for various non-fossil fuel resources. At present, Vietnam's renewable energy capacity has already far exceeded the 2020 target stated in its strategic plan.

We also quantify the effects of different types of energy policies in each country (Fig. 4) by estimating the counterfactual effect of energy policies based on the regression results. Five economies representative of different economic development levels are selected: Myanmar (least developed country), Kazakhstan(transition country), and Vietnam, India and Fiji, which are developing countries located in different geographical areas in APAC.

Vietnam, as an emerging economy, shows a better energy transition performance than India, although the impacts of different types of policies are similar in both countries, with laws and strategies prominent and favouring especially access to electricity and clean cooking. In contrast, regulations play a role in India, while Vietnam relies more on laws and strategies. On the one hand, this is due to India's federal structure, which gives a more prominent role to regulations and supervision, although to a limited nature compared to countries like the US; on the other hand, the energy transition framework relies heavily on strategy and law in its early years and gradually developed to regulation. Fiji, an island nation in the Pacific, also relies heavily on laws and strategies to advance the energy transition. Laws are confirmed particularly positive to improve access to electricity and clean cooking, and strategies contribute significantly to enhancing energy efficiency. Myanmar is a country in South-East Asia and is one of the poorest countries in the world. Myanmar has been dominated by agricultural production and has made little progress in its energy transition, but results show that the implementating strategies has brought benefits, whereas the same is not true of laws and regulations, which is also in line with the previous research[43]. Regarding energy intensity reduction, laws are critical because early-stage promotion of energy efficiency needs especially strong and legislative support rather than a market push, particularly in the least developed areas. Kazakhstan is the largest country in Central Asia with an energy transition focused on the development of renewable energy and a related legal and regulatory framework that has developed over time[44]. In 2009, Kazakhstan adopted a law On Supporting the Use of Renewable Energy Sources, and the concept of transitioning to a green economy by 2050, a long-term strategy aimed at vigorous development of renewable energy sources, but early policy results have been less than impressive. Kazakhstan has since capitalised on the Belt and Road initiative to further promote clean energy projects, and its strategy has proved effective in terms of electrification, access to clean cooking and renewable electricity capacity. However, Kazakhstan has been slow to make progress in reducing its energy intensity, as much of the energy infrastructure was built during the former Soviet era and is badly aged and not very energy efficient, which is the focus of legislation and regulation in the next generation.

For the emerging economies in APAC region, the energy transition is not yet mature enough, therefore the energy market is not well-regulated and legal frameworks are not well-developed[34]. Strategy or planning usually starts with target settings and a clear target will help specify the time scale, deployment of technologies, and corrresponding political measures[45]. Especially the national strategies, within the APAC's political and governance environment, will usually be well supported by a high-efficient implementation system to ensure their effectiveness. Government will have to be more engaged with resource allocations, and adopt inclusive planning and innovative development. In terms of the other policies, strategies can play a key role in framing the policy mix and take advantage of them.

To sum up, different energy policies have had various effects on the energy transition of different countries. Countries need specific combinations of policies tailored to their specific needs to progress with the energy transition. In general, we can conclude that in order to support energy access and renewable electricity capacity, strategies should be prioritized. In the case of energy efficiency, countries in APAC can benefit more from legislative frameworks.

Discussion

Energy policies have significant effects on the energy transition in the APAC region, however, the region requires increased action in national policy commitments for energy transition targets. The transition of energy access needs a combination of improved on-grid electricity and promotion of clean cooking solutions. For example, lessons can be learned from rural electrification through off-grid in Afghanistan, and the deployment of liquefied petroleum gas for clean cooking in Indonesia. As a global manufacturing hub, energy efficiency improvements in the APAC region rely heavily on upgrading the industrial sector, while also requiring the enrichment and deepening of policy frameworks in areas such as buildings and transport, particularly through laws and strategies. In addition, the design of effective combinations of policies needs to be based on country-specific endowments and the stage of the energy transition they are at. For instance, institutional reforms in developing countries, such as structural reforms of the electricity system, the switch from fossil fuels to renewables, rebalancing of energy supply and demand, can provide policy inspiration for the energy transition in LDCs[46].

Progress of energy transition has also effects in terms of social welfare. By facilitating the energy transition, energy policies have ultimately improved the livelihoods of people across all APAC economies in terms of both access to electricity and clean cooking. For example, India has doubled energy consumption since 2000 and the IEA predicts that its future energy demand will grow to reach 25% of the world demand[47]. Making electricity available to all is the most pressing need in India, and with the implementation of energy policies, India has provided access to electricity, on average, to 121.2 million per year between 2000 and 2017, while 77.5 million people have had access to clean cooking. Vietnam is one of the fastest-growing emerging economies in Asia, but the rapid economic boom has been accompanied by changes in energy consumption[48]. Recent energy policies have provided access to electricity for the Vietnamese people, especially in rural areas that include 63% of the population, benefiting 9.6 million people. In addition, large segments of the APAC's population can particularly benefit from the energy transition. For instance, in Philippines, Thailand and Bangladesh, 10.2, 4.8 and 2.8 million people can benefit from improved access to electricity, and 6.6, 4.6 and 0.9 million people can take advantage of access to clean cooking respectively.

Furthermore, energy policy implementation can increase benefits, and effective implementation needs to be complemented by suitable policies and requires a stable political environment. Looking at the diversity within the region, across countries and levels of advance in energy transition, customized policy mixes are needed. For those countries at the early stage of the energy transition, such as those where electricity is not widely available, balanced and strategy-oriented policies are more effective to promote electrification levels and facilitate the energy transition. Regarding those countries undergoing energy transition, such as improving efficiency in the traditional energy sources and deploying installed renewable energy capacity, clear strategies and active subsidies, and timely revision of existing policies may help reduce the risk of policy overlap and ensure effective policy mixes[49]. Meanwhile, the political stability and administrative efficiency of the country can affect the realisation of the energy transition by improving the credibility of policies[50,51]. As shown in Table 1, the control variable, Political stability, is significant for all indicators, suggesting that in the APAC region, the more stable the political environment, the more favourable the energy transition, which is not quite the same as in developed countries that rely mainly on legislative activities[39].

Overall, to achieve the energy transition goals, economies in the APAC region need more effective energy policies. Effectiveness of policies is dependent on the types of policies, monitoring, and enforcement of measures. For example, the effectiveness of different types of policies also varies across jurisdictions, sectors, technologies and geographic contexts[52]. Besides, inadequate policy attention also undermines the effectiveness of policies because without strong policy interventions, sustainable energy progress cannot cover wider areas including the rural areas[53]. It's also worth emphasizing that policies are effective only when they are properly implemented and synergic with other types of interventions or with similar policies in use in different industries. And these emerging countries may seek collaborations with other countries to better exploit their resources, such as South-South cooperation, China's "One Belt And One Road" policy, etc. We expect future research to draw lessons about the needed institutional changes to realize energy transition in APAC or other regions in the world. Policymakers may benefit from the implications of such research and accept scientific information as the basis that sets the boundaries for policy-making[54], and thus improve the design of policies to build stronger connections between energy policies and the energy transition they are supposed to promote.

Our study has a few limitations. Institutional, economic and resource endowments vary greatly from country to country, and some emerging economies have issued very few policies, which may introduce bias into this study. Furthermore, future policy deployment and policy-type arrangements, energy technology development, and energy-economic-social impact mechanisms are still unclear but are essential to achieve the SDGs by 2030. In this sense, the mechanisms of transition from energy policy to energy sector and then to energy transition should be further explored in future work in order to guide policymakers in the design and evaluation of a more comprehensive policy scheme. Finally, our study assumes broad policy alignment towards achievement of SDGs. Some countries may occasionally elect politicians who eschew that consensus, which may lead to the promotion of discordant policies. An example of such a scenario might be Bolsonaro's election in Brazil, which is not included in our analysis, but could potentially confound a similar analysis made of Latin American countries.

Methods

The regression models

Our hypothesis is that a country's progress towards energy transition depends on political and socio-economic factors. Models are estimated using fixed-effect panel regression as follows:

$$y_{it,k} = \ln\left(SDG_{it,k}\right) = \alpha + \beta \ ST_{it} + \boldsymbol{\gamma}\mathbf{X}_{it} + u_i + e_i \cdot v_t + \varepsilon_{it} \tag{1}$$

where $SDG_{it,k}$ represents the SDG 7 target k of country i at year t (see detailed descriptions about targets used in the model in Supplementary Table 3). $y_{it,k}$, also defined as $\ln\left(SDG_{it,k}\right)$, is the energy transition indicator. ST_{it} indicates the size of policy stock. The model here also includes country fixed effects, u_i, and economic-specific characteristics interacting with time-period fixed effects[55], where e_i refers to the economic development stage of countries, i.e. least developed country, developing country, and transition country; v_t refers to the year fixed effects. The fixed-effect model includes a full set of country and year fixed effects, which control for the unobservable heterogeneity across economies in APAC. Here α represents the intercept of the model. β and $\boldsymbol{\gamma}$ are coefficients of policy stock and control variables. ε_{it} is the error term.

The notation $\mathbf{X}_{it}$ denotes a set of control variables listed in Supplementary Table 4. The first type of control variables are economic and social variables. Here we have selected urbanization rate, GDP per capita, export share, import share, and service share. Urbanization rate and GDP controls for the economic growth. Export, import and service share control for the structural changes in the economy that may affect the energy transition. The second type of control variable is the energy mix variable, which here is the proportion of energy imports. The third one is government implementation effectiveness. We choose voice and accountability, political stability, government effectiveness, regulatory quality, control of corruption and rule of law[56], ranging from 0 (lowest) to 100 (highest) after normalization. For the descriptive summary and explanation of variables see Supplementary Table 5.

We rewrite Equation (1) to incorporate three types of policies:

$$\ln\left(SDG_{it,k}\right) = \alpha + \eta_p * TYP_{it,k,p} + \boldsymbol{\gamma}\mathbf{X}_{it} + u_i + e_i \cdot v_t + \varepsilon_{it} \tag{2}$$

where $TYP_{it,k,p}$ indicates the number of specific type energy policies p for specific target k, i.e. law ($TYP_{p=Law}$), regulation ($TYP_{p=Regulation}$), and strategy ($TYP_{p=Strategy}$), the policy category is shown in Supplementary Table 6. η_p indicates the coefficients of each type of energy policy.

The counterfactual impact of energy policies

Following the approach adopted in previous research (ref.[39,57]), we construct a counterfactual scenario of energy transition to quantify the overall impact of energy policies. Starting with Equation (1), we denote the estimated value of the SDG7 indicators as $\hat{y}_{it,k}$. By assuming the absence of energy policies, we have a counterfactual value $\tilde{y}_{it,k}$. We can obtain the aggregate effect of energy policies by subtracting the estimated value and counterfactual values:

$$\hat{y}_{it,k} - \tilde{y}_{it,k} = \ln\left(\widehat{SDG}_{it,k}\right) - \ln\left(\widetilde{SDG}_{it,k}\right) = \ln\left(\widehat{SDG}_{it,k}/\widetilde{SDG}_{it,k}\right) = \hat{\beta}_1 ST_{it} \tag{3}$$

where variable except ST_{it} is excluded from the equation. Rewriting Equation (3) by inverting the sign of the left-hand side of Equation (4), we obtain:

$$\widetilde{SDG}_{it,k} = \widehat{SDG}_{it,k} \times \exp\left(-\hat{\beta}_1 ST_{it}\right) \approx SDG_{it,k} \times \exp(-\hat{\beta}_1 ST_{it}) \tag{4}$$

where we make another assumption about the replacement of observed SDG7 with the estimated SDG7 from Equation (1). Therefore, we use Equation (4) to estimate the counterfactual scenario of energy transition without energy policies.

Similarly, in the analysis of the counterfactual effects of sub-policy types, we treat all variables other than the type under discussion as control variables. By assuming that there is no energy policy of this type, we obtain a hypothetical value without energy policies as $\tilde{y}_{it,k,p}$. Based on Equation (3) and (4), we obtain counterfactual effects for different policy types, shown in Equation (5) and (6).

$$\hat{y}_{it,k,p} - \tilde{y}_{it,k,p} = \ln\left(\widehat{SDG}_{it,k,p}\right) - \ln\left(\widetilde{SDG}_{it,k,p}\right) = \ln\left(\widehat{SDG}_{it,k,p}/\widetilde{SDG}_{it,k,p}\right) = \hat{\eta}_p * TYP_{it,k,p} \quad (5)$$

$$\widetilde{SDG}_{it,k,p} = \widehat{SDG}_{it,k,p} \times \exp\left(-\hat{\eta}_p * TYP_{it,k,p}\right) \approx SDG_{it,k,p} \times \exp\left(-\hat{\eta}_p * TYP_{it,k,p}\right) \quad (6)$$

Data availability

We employ three sets of data for the Asia-Pacific region over the period 2000-2017 in this study: socio-economic data, energy policy data and SDG7 indicators data. The socio-economic data are collected from the World Development Indicators database[58] and World Economic Situation and Prospects 2018[32], including the level of income, country's income and geographic classifications, urbanization rate, GDP per capita, export and import shares, service shares, and energy import shares.

Energy policy data are collected from the *Asia Pacific Energy Portal Policy* database. The database consists of 2112 energy policies from 42 emerging economies in APAC over the period 2000-2017. After collection, we collated and calculated the number of existing policies for different countries and sorted out all policies into three policy types according to the type of documents (Supplementary Table 7), which are laws (Law or Act in original policy document category), regulations (Rule or Regulation), and strategies (Strategy or Plan). If a policy includes more than one type of document, all such types will be considered in the respective stock calculations. In Fig. 4, the effect of "other" is the total policy effect minus the sum of the effects of the three types of policy, which includes Standard, Agreement, Government Report documents that are not prominent in energy policy stocks.

Data about the SDG7 indicators in APAC are obtained from the Global SDG Indicators Database[29]. The renewable energy capacity data are collected from the International Renewable Energy Agency[59]. We control the differences in policy implementation using a number of indicators including voice and accountability, political stability, government effectiveness, regulatory quality, control of corruption and rule of law[56], which are exported from the Worldwide Governance Indicators[60].

Code availability

Code is available on Github (https://github.com/Peipei-Chen/Energy-policy-in-APAC/).

Acknowledgements

We acknowledge supports from National Natural Science Foundation of China (41921005 to D.G. and 72140001 to D.G.) and the UK Natural Environment Research Council (NE/V002414/1 to J.M. and 2021GRIP02COP-AQ to J.M.), the Royal Society (IEC\NSFC\191520 to J.M.).

Author Contributions Statement

P.C., Y.W. and J. M designed the research. P.C. and Y.W. collected the data. P.C. and J.M. led the study and draft the manuscript with efforts from all authors (P. H., D. L., D.C, X.L. and D.G.). P.C., P.H. and D.L. constructed the statistics model.

Competing Interests Statement

The authors declare no competing interests.

Table

Table 1. Effect of energy policies on energy transition.

VARIABLES	**Access to electricity (Indicator 7.1.1)**	**Access to clean cooking (Indicator 7.1.2)**	**Energy intensity (Indicator 7.3.1)**	**Renewable electricity capacity (Indicator 7.b.1)**
Policy stock	0.001***	0.002*	-0.001**	0.003**
	(0.000)	(0.001)	(0.000)	(0.001)
Urbanization rate	-0.008*	0.023***	0.005	0.019***
	(0.004)	(0.006)	(0.003)	(0.005)
GDP per capita	-0.037	0.672***	0.264**	0.551**
	(0.041)	(0.192)	(0.118)	(0.192)
Export share	0.000	-0.003**	0.003***	0.001
	(0.000)	(0.001)	(0.001)	(0.003)
Import share	-0.000	0.005***	0.001	0.002
	(0.000)	(0.002)	(0.001)	(0.002)
Service share	0.002	0.004	0.015***	0.007*
	(0.002)	(0.004)	(0.002)	(0.003)
Energy import share	0.000	-0.000	0.001***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Voice and accountability	-0.204**	0.654***	-0.094	-0.889***
	(0.074)	(0.124)	(0.128)	(0.200)
Government effectiveness	0.017	-0.126	-0.161	0.508**
	(0.043)	(0.105)	(0.103)	(0.225)
Political stability	0.218***	0.593***	-0.361***	0.391**
	(0.049)	(0.108)	(0.074)	(0.149)
Regulatory quality	0.016	0.380***	0.109	0.340
	(0.060)	(0.070)	(0.075)	(0.279)
Control of corruption	-0.139	-0.035	-0.064	-0.721**
	(0.090)	(0.181)	(0.061)	(0.287)
Rule of law	0.039	0.043	0.192	0.120
	(0.091)	(0.284)	(0.120)	(0.311)
Constant	4.658***	1.574**	0.724***	2.504***
	(0.183)	(0.575)	(0.165)	(0.435)
Observations	295	313	313	313
R^2 (within)	0.872	0.704	0.766	0.531
Country FE	YES	YES	YES	YES
Year*economic status FE	YES	YES	YES	YES

Note: (1) Standard errors in parentheses, (2) Statistical significance levels: *** p<0.01 (1% level), ** p<0.05 (5% level), * p<0.1 (10% level), (3) Independent variables in the models are lagged by one period, (4) Dependent variables are in logarithm form.

Figure Legends/Captions

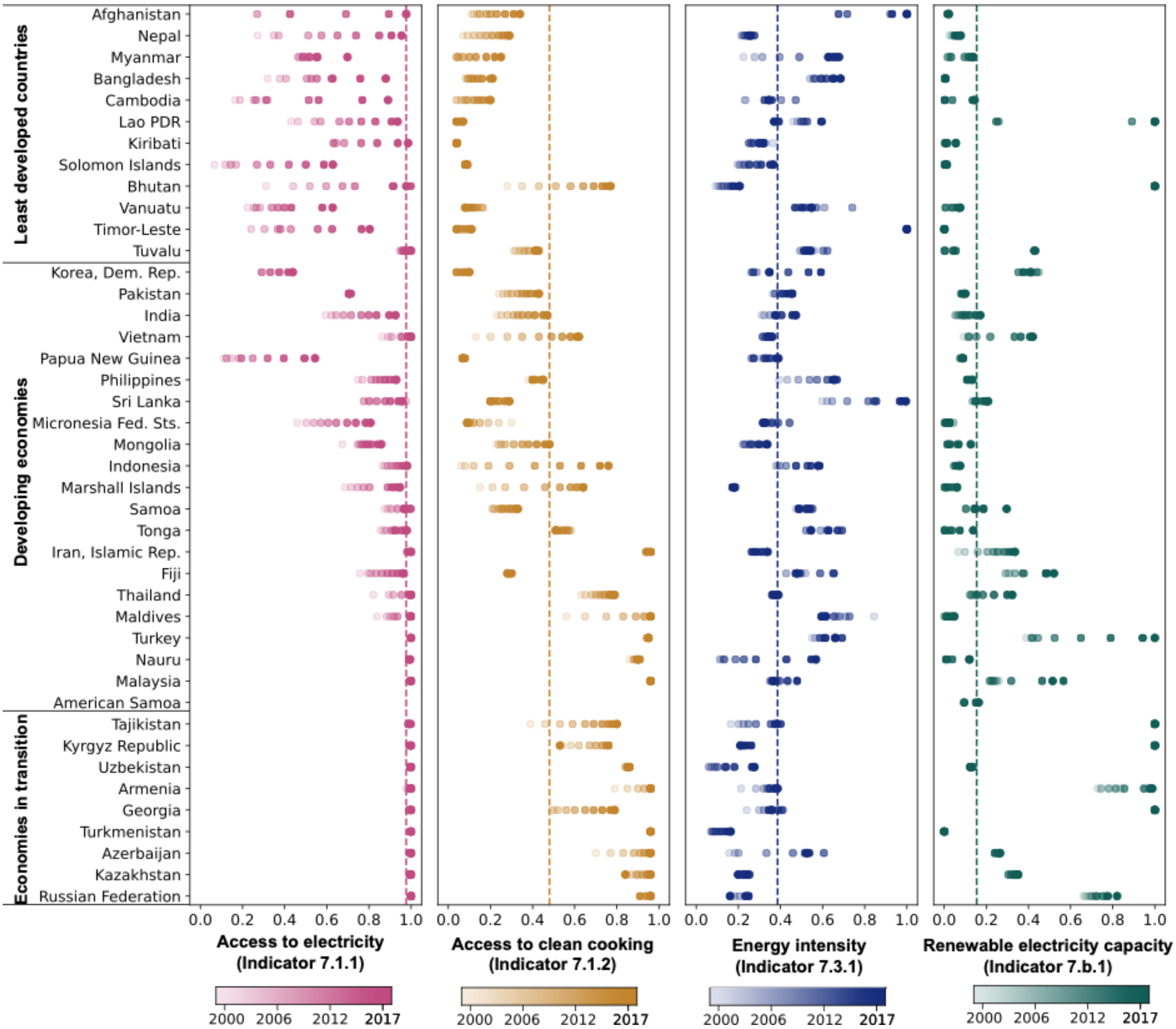

Fig. 1 Progress toward energy transition in the APAC emerging economies during 2000-2017. Values ranging from 0 to 1 represent the progress towards the energy transition targets, i.e. the ratio of the annual value of the indicator over the target value defined in the Global SDG database (low energy intensity values represent high indicator scores), the higher the value, the higher the level of progress towards the energy transition targets. A value of 1 means the target is met. The dashed lines in the figure show the median value of the standardised progress for each target in 2017. Countries within each economic development category are ranked from lowest (top) to highest (bottom) in terms of the average GDP per capita over 2000-2017. Here PDR means People's Democratic Republic; Korea, Dem. Rep. means Democratic People's Republic of Korea; Micronesia Fed. Sts. means Federated States of Micronesia.

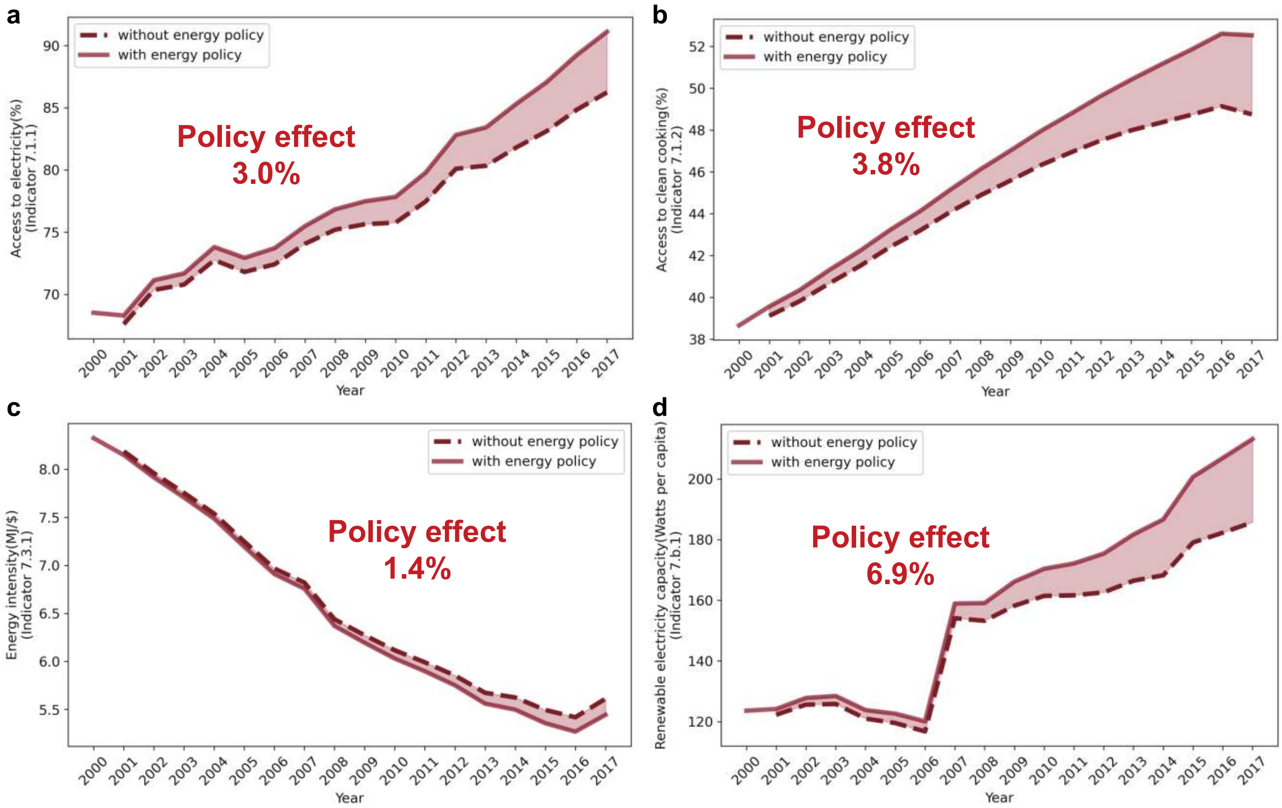

Fig. 2 Performance of APAC emerging economies' energy transition with and without energy policy. The calculation goes from 2000 to 2017 because the basic model is lagged by one year. Observed SDG7 performance is represented by solid lines. Counterfactual performance is represented by dashed lines. **a**, the performance of access to electricity (Indicator 7.1.1). **b**, the performance of access to clean cooking (Indicator 7.1.2). **c**, performance of energy intensity (Indicator 7.3.1). **d**, the performance of renewable electricity capacity (indicator 7.b.1). The values in the figure indicate the percentage change in the average of indicators without energy policies to the average with energy policies, thus reflecting the effect of the energy policy (for energy intensity, energy policy lowers this indicator; but for the energy efficiency target, policy effect is a positive improvement).

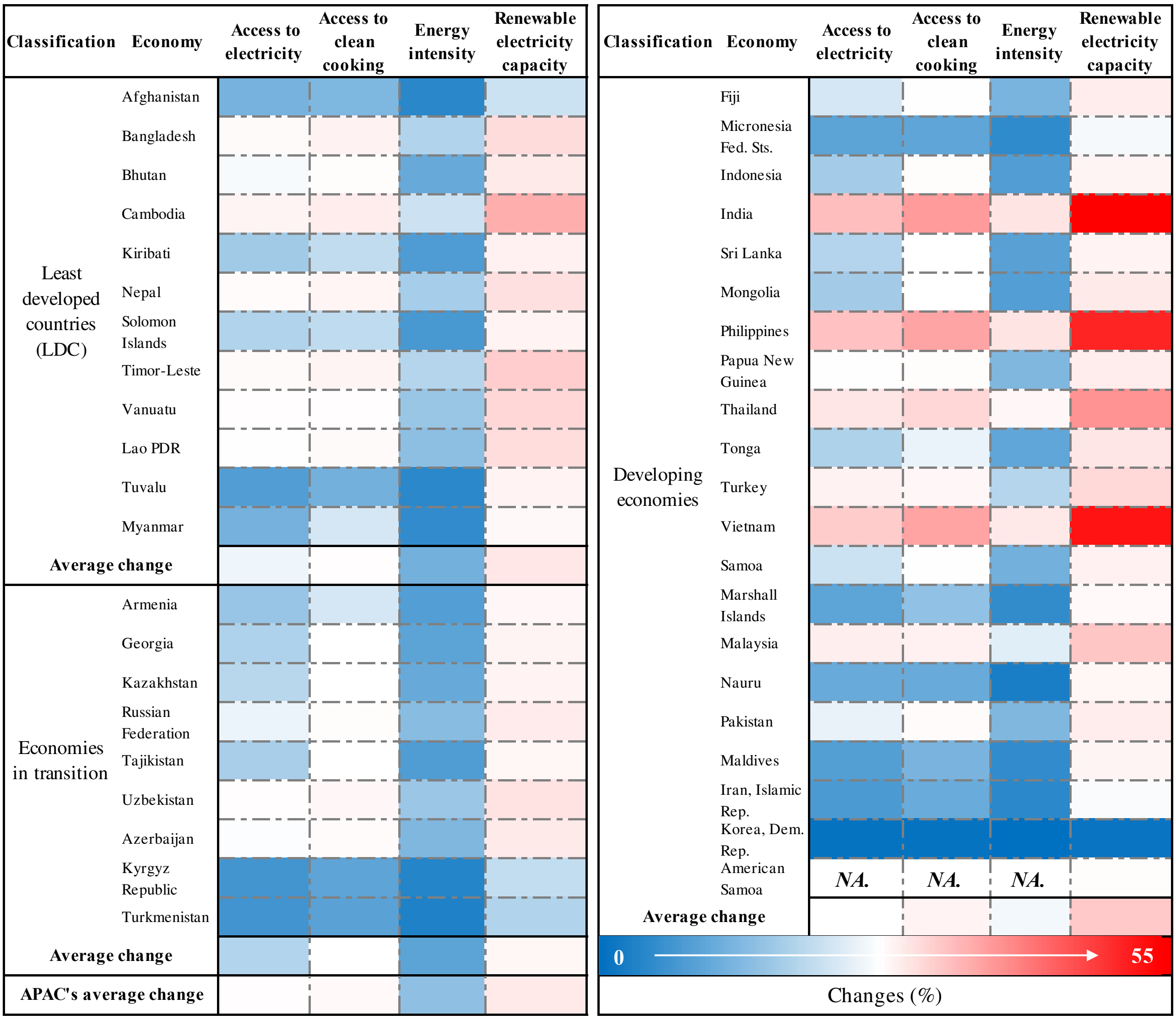

Fig. 3 Impact of energy policies on energy transition by country during 2000-2017.

The coloured cells show the range of dispersion of the difference between energy transition with and without energy policies, across different economies. The colours indicate the percentage of changes. For energy intensity, changes are negative as lower intensity means higher energy efficiency.

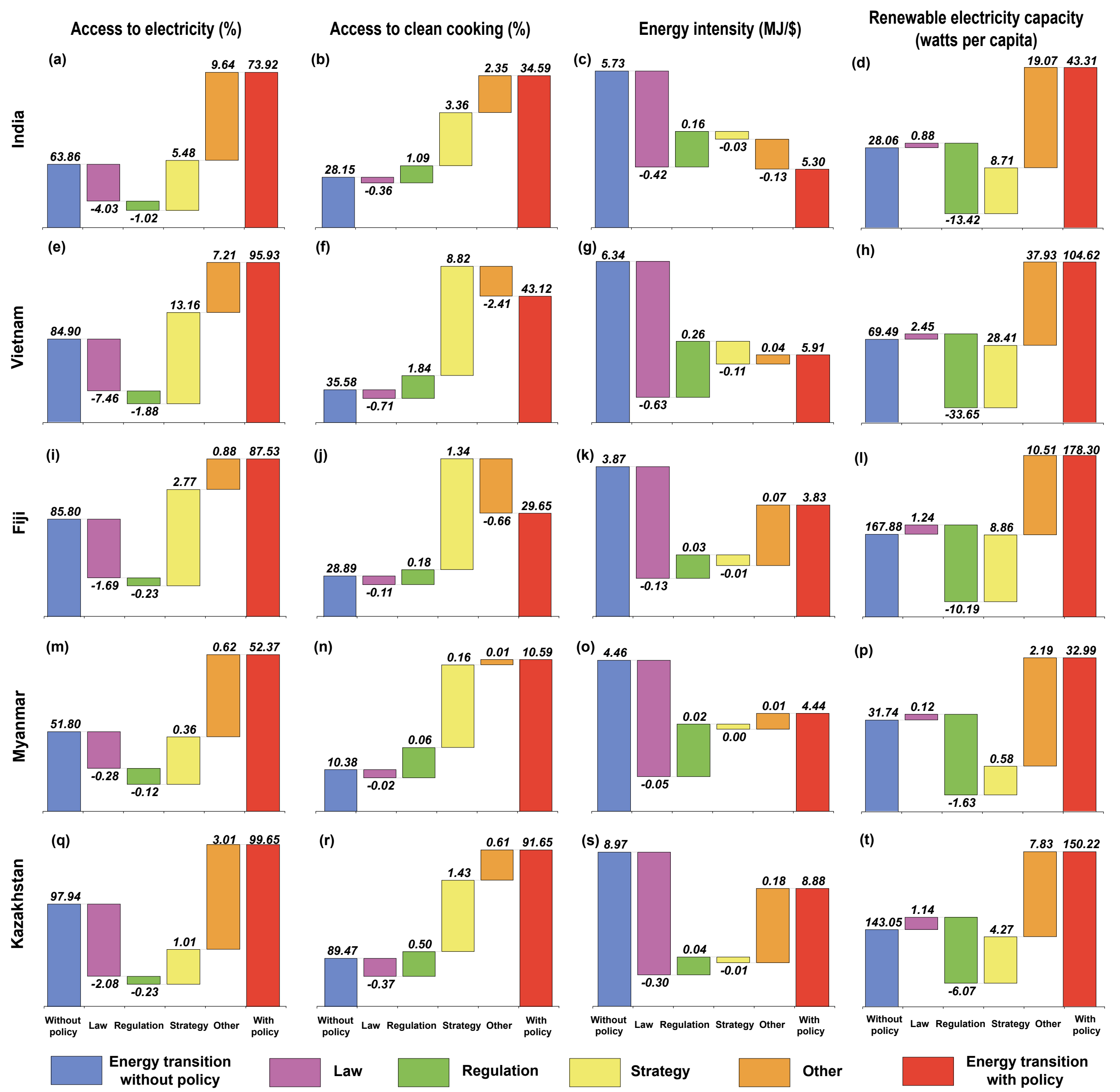

Fig. 4 Impact of different types of energy policies on energy transition in typical economies. Assessment of energy transition indicators (access to electricity, access to clean cooking, energy intensity and renewable electricity capacity) with and without policy in developing country India (a-d), developing country Vietnam (e-h), developing country Fiji (i-l), least developed country Myanmar (m-p), and transition country Kazakhstan (q-t), including the contributions of law, regulation, strategy, and other types of policies. The numbers above the first and the last bar in each panel, "Without policy" and "With policy", indicate the values of the energy transition indicators for each country (the units of the indicators are shown at the top of the figure), and the numbers above or below other bars indicate the change in the values caused by four types of policies (the units are as the same of indicators at the top of the figure).

References

1. IEA. Energy Transitions Indicators – Analysis. https://www.iea.org/articles/energy-transitions-indicators (2019).

2. Kittner, N., Lill, F. & Kammen, D. M. Energy storage deployment and innovation for the clean energy transition. *Nat. Energy* **2**, 1–6 (2017).
3. World Energy Council. *World Energy Scenarios Composing energy futures to 2050*. (2013).
4. APERC. *APEC Energy Demand and Supply Outlook 7th Edition Volume I*. http://aperc.ieej.or.jp/ (2019).
5. Koçak, E. & Şarkgüneşi, A. The renewable energy and economic growth nexus in black sea and Balkan Countries. *Energy Policy* **100**, 51–57 (2017).
6. Destek, M. A. & Aslan, A. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renew. Energy* **111**, 757–763 (2017).
7. ESCAP. Energy transition in Asia and the Pacific: pathways to ensure access to affordable, reliable, sustainable and modern energy for all. **14**, 189–202 (2018).
8. ESCAP. *Asia and the Pacific SDG Progress Report 2020*. https://www.unescap.org/publications/asia-and-pacific-sdg-progress-report-2020 (2020).
9. Schmidt, T. S. & Huenteler, J. Anticipating industry localization effects of clean technology deployment policies in developing countries. *Glob. Environ. Chang.* **38**, 8–20 (2016).
10. Rogge, K. S. & Reichardt, K. Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Res. Policy* **45**, 1620–1635 (2016).
11. Kern, F. & Howlett, M. Implementing transition management as policy reforms: A case study of the Dutch energy sector. *Policy Sci.* **42**, 391–408 (2009).
12. Erdiwansyah, Mamat, R., Sani, M. S. M. & Sudhakar, K. Renewable energy in Southeast Asia: Policies and recommendations. *Sci. Total Environ.* **670**, 1095–1102 (2019).
13. Weber, K. M. & Rohracher, H. Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Res. Policy* **41**, 1037–1047 (2012).
14. Kern, F. & Rogge, K. S. The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? *Energy Res. Soc. Sci.* **22**, 13–17 (2016).
15. Yang, L. *et al.* Environmental-social-economic footprints of consumption and trade in the Asia-Pacific region. *Nat. Commun.* **11**, 4490 (2020).
16. Shan, Y. *et al.* Impacts of COVID-19 and fiscal stimuli on global emissions and the Paris Agreement. *Nat. Clim. Chang.* (2020) doi:10.1038/s41558-020-00977-5.
17. O'Neill, B. C. *et al.* Achievements and needs for the climate change scenario framework. *Nat. Clim. Chang.* **10**, 1074–1084 (2020).
18. Markard, J. The next phase of the energy transition and its implications for research and policy. *Nat. Energy* **3**, 628–633 (2018).
19. Carley, S. & Konisky, D. M. The justice and equity implications of the clean energy transition. *Nat. Energy* **5**, 569–577 (2020).
20. Spyridaki, N. A. & Flamos, A. A paper trail of evaluation approaches to energy and climate policy interactions. *Renewable and Sustainable Energy Reviews* vol. 40 1090–1107 (2014).
21. Sorrell, S. & Sijm, J. Carbon Trading in the Policy Mix. *Oxford Rev. Econ. Policy* **19**, 420–437 (2003).
22. Del Río González, P. The interaction between emissions trading and renewable electricity support schemes. An overview of the literature. *Mitig. Adapt. Strateg. Glob. Chang.* **12**, 1363–1390 (2007).
23. Flanagan, K., Uyarra, E. & Laranja, M. Reconceptualising the 'policy mix' for innovation. *Res. Policy* **40**, 702–713 (2011).
24. Kivimaa, P. & Kern, F. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Res. Policy* (2016) doi:10.1016/j.respol.2015.09.008.

25. ESCAP. *Energy Transition Pathways for the 2030 Agenda SDG 7 Roadmap for Georgia*. (2020).
26. Munro, P., van der Horst, G. & Healy, S. Energy justice for all? Rethinking Sustainable Development Goal 7 through struggles over traditional energy practices in Sierra Leone. *Energy Policy* **105**, 635–641 (2017).
27. Bertheau, P. & Blechinger, P. Resilient solar energy island supply to support SDG7 on the Philippines: Techno-economic optimized electrification strategy for small islands. *Util. Policy* **54**, 55–77 (2018).
28. Adenle, A. A. Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals. *Energy Policy* vol. 137 111180 (2020).
29. United Nations. Sustainable Development Goal Indicators. https://unstats.un.org/sdgs/indicators/database// (2020).
30. ESCAP. Asia Pacific Energy Portal. https://asiapacificenergy.org/ (2019).
31. IEA. *Clean Energy Transitions Programme 2019*. https://www.iea.org/reports/clean-energy-transitions-programme-2019 (2020).
32. United Nations. *World Economic Situation and Prospects 2018: Annex*. https://www.un.org/development/desa/dpad/publication/world-economic-situation-and-prospects-2018/ (2017).
33. Van Der Kroon, B., Brouwer, R. & Van Beukering, P. J. H. The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renew. Sustain. Energy Rev.* **20**, 504–513 (2013).
34. ESCAP. *Status of and progress towards achieving Sustainable Development Goal 7 in Asia and the Pacific*. vol. 00762 (2019).
35. Khare, V., Nema, S. & Baredar, P. Status of solar wind renewable energy in India. *Renewable and Sustainable Energy Reviews* vol. 27 1–10 (2013).
36. Malahayati, M. Achieving renewable energies utilization target in South-East Asia: Progress, challenges, and recommendations. *Electr. J.* **33**, 106736 (2020).
37. Chang, Y., Fang, Z. & Li, Y. Renewable energy policies in promoting financing and investment among the East Asia Summit countries: Quantitative assessment and policy implications. *Energy Policy* **95**, 427–436 (2016).
38. Sharvini, S. R., Noor, Z. Z., Chong, C. S., Stringer, L. C. & Yusuf, R. O. Energy consumption trends and their linkages with renewable energy policies in East and Southeast Asian countries: Challenges and opportunities. *Sustainable Environment Research* vol. 28 257–266 (2018).
39. Eskander, S. M. S. U. & Fankhauser, S. Reduction in greenhouse gas emissions from national climate legislation. *Nat. Clim. Chang.* **10**, 750–756 (2020).
40. Baldwin, R., Cave, M. & Lodge, M. *Understanding Regulation: Theory, Strategy, and Practice*. (Oxford University Press, 2011). doi:10.1093/ACPROF:OSOBL/9780199576081.001.0001.
41. Townshend, T. *et al.* How national legislation can help to solve climate change. *Nat. Clim. Chang.* **3**, 430–432 (2013).
42. Shem, C., Simsek, Y., Hutfilter, U. F. & Urmee, T. Potentials and opportunities for low carbon energy transition in Vietnam: A policy analysis. *Energy Policy* vol. 134 110818 (2019).
43. Eskander, S., Fankhauser, S. & Setzer, J. Global Lessons from Climate Change Legislation and Litigation. *Environ. Energy Policy Econ.* **2**, 44–82 (2021).
44. International Bar Association. The energy transition in Central Asia: drivers, policy and opportunities. https://www.ibanet.org/energy-transition-central-asia (2021).
45. Daszkiewicz, K. & Daszkiewicz, K. *Policy and Regulation of Energy Transition*. *The Geopolitics of the Global Energy Transition* vol. 73 (Springer, Cham, 2020).
46. Bhamidipati, P. L., Haselip, J. & Elmer Hansen, U. How do energy policies accelerate sustainable transitions? Unpacking the policy transfer process in the case of GETFiT Uganda. *Energy Policy* **132**, 1320–1332 (2019).
47. IEA. *India Energy Outlook 2021*. (2021).
48. Nong, D., Wang, C. & Al-Amin, A. Q. A critical review of energy resources, policies and scientific studies towards

a cleaner and more sustainable economy in Vietnam. *Renew. Sustain. Energy Rev.* **134**, 110117 (2020).

49. Kern, F., Rogge, K. S. & Howlett, M. Policy mixes for sustainability transitions: New approaches and insights through bridging innovation and policy studies. *Res. Policy* **48**, 103832 (2019).
50. Rogge, K. S. & Dütschke, E. What makes them believe in the low-carbon energy transition? Exploring corporate perceptions of the credibility of climate policy mixes. *Environ. Sci. Policy* **87**, 74–84 (2018).
51. International Monetary Fund. *Regional Economic Outlook, April 2011: Asia and Pacific: Managing the Next Phase of Growth*. (2011) doi:10.5089/9781616350628.086.
52. Peñasco, C., Anadón, L. D. & Verdolini, E. Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments. *Nat. Clim. Chang.* **11**, 257–265 (2021).
53. ESCAP. *Asia and the Pacific's Progress towards Sustainable Development Goal 7*. (2021).
54. Khan, F. From science to policy. *Nat. Energy* **6**, 943–944 (2021).
55. Nunn, N. & Qian, N. The Potato's Contribution to Population and Urbanization: Evidence From A Historical Experiment. *Q. J. Econ.* **126**, 593–650 (2011).
56. Kaufmann, D., Kraay, A. & Mastruzzi, M. The worldwide governance indicators: Methodology and analytical issues. *Hague J. Rule Law* **3**, 220–246 (2011).
57. Eskander, S. & Fankhauser, S. *The impact of climate legislation on trade-related carbon emissions, 1997-2017*. www.cccep.ac.uk (2021).
58. World Bank. World Development Indicators | DataBank. https://databank.worldbank.org/source/world-development-indicators (2020).
59. IRENA. International Renewable Energy Agency. https://www.irena.org/ (2020).
60. World Bank. The Worldwide Governance Indicators. http://info.worldbank.org/governance/wgi/ (2020).

Supplementary information

Supplementary Information

Supplementary Figures 1–3 and Supplementary Tables 1–8.