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Energy-Related Environmental Policy and Its Impacts on Energy Use in Asia

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Energy-Related Environmental Policy and its Impacts on Energy Use in Asia[1]

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A Policy Paper prepared for **"Energy and the Environment"** Conference

Abstract

Economic growth in Asia has increased in the past three decades and has heightened energy demand, resulting in rising greenhouse gas emissions and severe air pollution. To tackle these issues, fuel switching and the deployment of renewables are essential. In this paper, we discuss the environmental regulations, mainly carbon pricing, implemented in Asia and discuss their achievements. Empirical studies using microdata found that carbon pricing in Asia reduced carbon emissions by promoting energy efficiency. At the macro level, we observe some evidence of fuel switching from coal to natural gas among major emitters. However, more carbon pricing is necessary in Asia if we aim for the decarbonization of the economy.

Research Highlights

1. Environmental problems such as climate change and air pollution are inducing regulations that may influence energy demand and supply in Asia.
2. Market instruments, such as Emissions Trading Schemes and carbon taxes, are becoming common in Asian countries and have begun to contribute to improvements in energy efficiency.
3. Many regulations have been implemented to promote the decarbonization of the economy. However, pricing regulations have not been extensive enough to reach an "effective carbon rate" of $30 per ton of CO_2.
4. In some Asian economies, we observe a trend of fuel switching from coal to natural gas.

Key Words (five): Climate Change, Air Pollution, Asia, Carbon Pricing, Renewables

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1. Introduction

Asia has been the engine of global economic growth in the 21st century. Following the economic growth of Japan, South Korea and Taiwan in the 20th century, China has been growing rapidly in the first two decades of this century. Consequently, China surpassed Japan to become the second largest economy after the U.S. Now, India is trying to follow China's success. ASEAN countries such as Thailand and Indonesia have been successfully industrialized by hosting investments from developed Asian economies. They are also steadily growing and are expected to become developed economies.

This economic growth in Asia has entailed an increase in energy demand, as in other economies. In Asia, fossil fuel has been a major source of energy supply. Therefore, economic growth is accompanied by growth in greenhouse gas (GHG) emissions. China became the largest GHG emitter in 2006. India became the third largest fossil fuel CO_2 emitter in 2017. Japan is the fifth largest emitter, and South Korea ranks 7th in the world. Given the economic and population growth in Asia, GHG emissions in Asia are expected to grow even more. Asian economies, similar to other economies, are becoming responsible for the risk of climate change.

In addition, this growing demand for fossil fuel is now challenged by concerns about environmental issues. A critical environmental concern in Asian cities is air pollution issues. Major Chinese cities such as Beijing have received the worst air quality rankings (Li et al. 2017). Seoul, the capital of South Korea, also suffers from air pollution (Kim et al. 2017). Currently, Indian cities such as Mumbai and Delhi are overtaking Chinese cities in the ranking of worst air quality. In 2019, 21 of the world's 30 cities with the worst air quality were in India[5].

In response to this situation, Asian countries began to take actions to mitigate climate change. Following the first Asian cap and trade scheme for CO_2 in Tokyo (Roppongi et al. 2016), China launched pilot emissions trading schemes (ETS) in 2013 (Munnings at al., 2016) to reduce GHG emissions along with some motivation to tackle air pollution (Goulder et al.2017). In 2015, South Korea implemented the first nationwide cap and trade scheme for GHG in Asia (Jun et al. 2020).

This paper discusses the environmental regulations focused on climate change implemented in Asia and discusses their achievements. Our focus is on large economies and emitters in the region: China, India, Japan, South Korea and ASEAN countries. Specifically, we focus on energy-related environmental regulations implemented on fixed sources of pollution and facilities. In terms of policy instruments, we are interested in market mechanisms that reduce carbon emissions and air pollution. Thus, we outline the situation and the impact of carbon pricing, which has been a major policy instrument to address GHG emissions. Some countries have introduced market mechanisms to promote energy efficiency. Moreover, implicit carbon pricing also plays an important role in

[5] https://www.iqair.com/world-most-polluted-countries (accessed on March 2nd, 2020).

controlling carbon emissions. For example, energy tax or feed-in tariffs are considered to be part of "implicit carbon pricing" in the sense that they contribute to carbon emission reduction. The effects of these regulations are captured by the "effective carbon rate", which is defined as the cost that emitters pay for one ton of CO_2 emissions (OECD, 2016). In some developing economies, fossil fuel subsidies also affect the effective carbon rate. Thus, we will touch on fuel subsidies. Furthermore, we will conduct a review of the literature examining the ex post analysis of the carbon pricing implemented in Asia. Finally, we will study the impact of these regulations by examining the energy demand in the region.

The following section describes the important environmental saliency to energy use, that is, air pollution and climate change in Asia. Section 3 explains the carbon pricing policies implemented in Asia. We will discuss policies influencing the effective carbon rate, i.e., explicit and implicit carbon pricing, including energy taxes and feed-in tariffs. Section 4 discusses the impact of carbon regulations in each country by examining the energy demand in Asia. Section 5 concludes the paper.

2. Environmental Concerns in Asia

This section describes the major environmental problems influencing energy use in Asia. We begin with air pollution issues. Then, we move to climate change issues. The section ends with a discussion of the growth of CO_2 emissions from Asia.

2.1 Air Pollution

In the past decade, air pollution problems have attracted attention as an urgent environmental issue in Asia. First, the city of Beijing became known for having one of the worst air qualities in the world (Li et al, 2017) due to PM2.5, which is heavily caused by coal combustion. The capital of Mongolia now suffers from severe air quality problems during the winter. The city of Seoul, the capital of South Korea, has also been experiencing problems with PM2.5 (Kim et al. 2017). Recently, the issue of air pollution has begun to improve in China (UNDP, 2017), although Indian cities such as Mumbai and Delhi are listed among the cities with the worst air quality.

The economic cost of air pollution in Asia is not negligible. The OECD (2014) estimated that the economic cost of the health impacts from outdoor air pollution in China was approximately 1.4 trillion US dollars. They also estimated that the cost for India was approximately 0.5 trillion in 2010. The combined cost is larger than the OECD total of 1.7 trillion USD.

The OECD (2016) updated its estimate of the air pollution cost. At the global level, its projections are close to USD 3.2 trillion in 2015 and are expected to increase to USD 18-25 trillion in 2060. Welfare costs from premature deaths are projected to more than double in OECD countries, going from USD 1.4 trillion in 2015 to USD 3.4-3.5 trillion in 2060. Nevertheless, the cost for non-OECD economies is estimated to be larger. The OECD (2016) shows that premature death is highest in China, followed by India in 2010 (Figure 1). In 2060, premature death in India is expected to double, making India the country with the highest number, surpassing China. Thus, we can understand the importance of air pollution issues in major Asian economies.

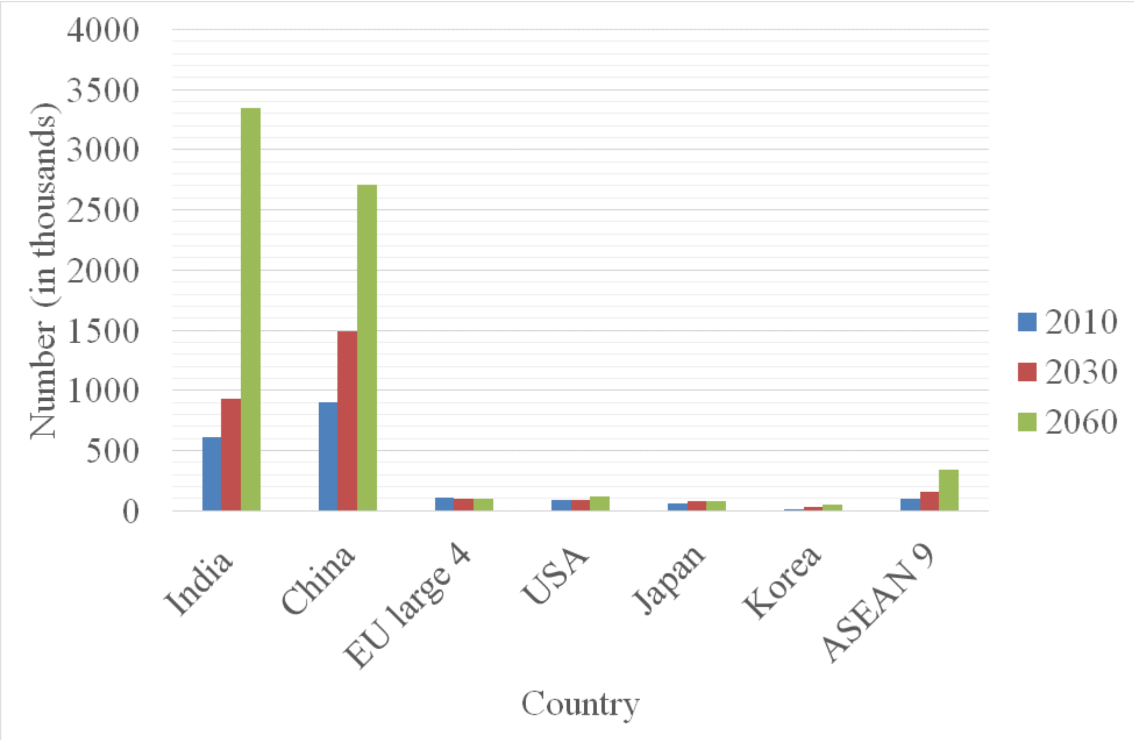


Figure 1 Premature deaths from exposure to particulate matter and ozone

Data Source: OECD (2016). Projected number of deaths caused by outdoor air pollution per year per million people ()

2.2 Climate Change and the Paris Agreement

Climate change is currently the most daunting global environmental issue, and international communities have attempted to fight it. The most notable international achievement in this regard was the Paris agreement. Although the agreement is a successor of the Koto Protocol, it draws a great contrast to the Kyoto Protocol in several aspects. First, under the Paris Agreement, developing countries must have some obligation to mitigate GHG emissions, which was not the case under the Kyoto protocol, in which developed economies such as the EU and Japan had to reduce emissions. Now, China and India must commit to mitigating GHG emissions. Second, different from the Kyoto Protocol, each country makes a plan regarding how to contribute to mitigation in the form of *intended nationally determined contribution* (INDC). Under the Kyoto protocol, Annex I countries were forced to have absolute emission reduction targets, which is known as the "top-down approach" (Edenhofer et al. 2013). For example, Japan had a six percent emission reduction target, while the EU had an eight percent emission reduction target. There was controversy regarding whether these targets were "fair" or not, ultimately leading the US to leave the Kyoto protocol. To address this controversy, the Paris Agreement allows each country to make their own pledge to control its GHG emissions. Some countries, such as Japan and the EU, set the target of an absolute cap. Other countries, such as China and South Korea, set intensity targets, e.g. CO_2/GDP. Third, INDCs are expected to be updated every five years depending on their capacity and willingness. As the capacity of climate mitigation develops in each country, these countries are expected to upgrade their emission reduction targets to achieve further emission reduction.

Table 1 exhibits the quantitative commitment by major Asian emitters, China, Japan, India and South Korea, together with ASEAN countries. Therefore, emerging economies in Asia, such as China and India, face pressure to reduce or at least control GHG emissions from their economic activities. ASEAN countries such as the Philippines and Thailand have also made their own INDCs. These pressures have led to emission regulations in Asian economies and are expected to have impacts on energy demand and supply in the region.

To what extent should we reduce GHG emissions? The IPCC AR5 Report (2014) urges the control of GHG emissions to limit the increase in global temperature within 2 degrees from pre-industrial levels. This report gave great momentum to the 2.0-degree goal of the Paris Agreement. The IPCC Special Report on Global Warming of 1.5°C (2018) reinforced the further reduction of GHG emissions to control GHG in order to further reduce emissions. The report concludes that the world will face a severe risk from climate change unless we contain the temperature increase up to 1.5 degrees from the pre-industrial level. The special report concluded that to aim for the target of 1.5 degrees, the world must achieve zero emissions by 2050.

The IEA (2019) estimated the CO_2 emission reductions with measures to achieve a "sustainable development scenario" relative to the stated policy scenarios. Figure 2 illustrates the pathway of changes required to meet to the GHG concentration target. First, the pledges from each country under the Paris Agreement are not good enough to achieve the sustainable development scenario. Globally, we should work harder to achieve this target. For example, energy efficiency is expected to account for 37% of the reduction. Fuel switching from coal to natural gas will account for 8 percent.

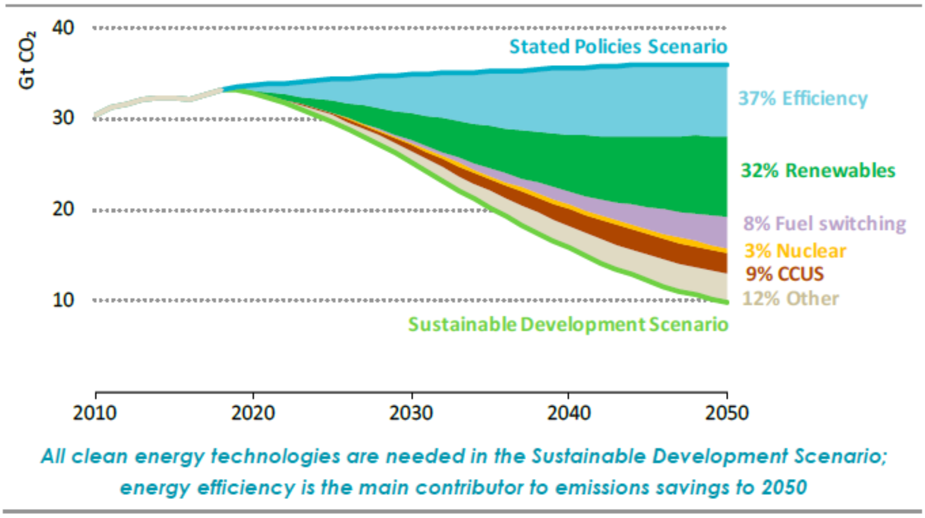
Table 1: Climate Pledges under the Paris Agreement and Policy Instruments

(ASEAN, China, India, South Korea, Japan and Mongolia)

Party	Climate Pledges				Domestic Policy Instrument	JCM Agreement	Expected GHG Reduction	JCM Agreement
	Mitigation Summary							
	Mitigation Type	Mitigation Target	Baseline Year	Target Year				
Brunei Darussalam	Policies and actions	63% of energy consumption reduction	BAU	2035	-	No	-	-
Cambodia	Absolute emission reduction	27%	Baseline emissions of 11,600 Gg CO2eq	2030	-	Yes	10,705	92
China	Carbon intensity reduction	60-65% carbon intensity reduction	2005	2030	Regional ETSs (National ETS)	No	-	-
India	Carbon intensity reduction	33 to 35% carbon intensity reduction	2005	2030	Energy Efficiency Market	Yes	-	-
Indonesia	Relative emission reduction	29% unconditional, 41% conditional	BAU	2030	Energy Efficiency Market	Yes	353,914	56,254
Japan	Absolute emission reduction	26%	2013	2030	Carbon Tax Regional ETSs		-	-
Korea (Republic of)	Relative emission reduction	37%	BAU	2030	National ETS	Yes	-	-
Lao People's Democratic Republic	Policies and actions	30% share of renewable energy in energy consumption	N/A	2020 and 2025	-	Yes	18333□	207
Malaysia	Carbon intensity reduction	35% unconditional plus 10% conditional	2005	2030	-	No	-	-
Mongolia	Relative emission reduction	14%	BAU	2030	-	Yes	107,098	18,311
Myanmar	Policies and actions	30% increase in renewable energies	N/A	2030	-	Yes	34,594	-
Philippines	Relative emission reduction	70%	BAU	2030	-	Yes	217,687	-
Singapore	Carbon intensity reduction	36%	2005	2030	Carbon Tax	No	-	-
Thailand	Relative emission reduction	20% unconditional and 25% conditional	BAU	2030	Voluntary ETS	Yes	197,484	2,819
Viet Nam	Relative emission reduction	8% unconditional - 25% conditional	BAU	2030	-	Yes	81,915	3,168

Source: IGES Database and Global Environment Centre Foundation Report [6]

[6] Constructed from IGES NDC Database : https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en and Global Environment Centre Foundation Report: http://gec.jp/jcm/en/wp-



Notes: CCUS = carbon capture, utilisation and storage. Reduced thermal losses in power generation account for 15% of efficiency improvements.

Figure 2 CO_2 Emission Reduction by Measure in the Sustainable Development Scenario Relative to the Stated Policy Scenario

Source: Figure 2.16, P102, IEA Energy Outlook (2019)

2.3 CO_2 Emissions from Asian Countries

Economic growth in Asia has brought growth in CO_2 emissions. Figure 3 shows the changes in global CO_2 emissions by region. The bottom and second layers show the CO_2 emissions from OECD countries in America and Europe, respectively. As shown in the figure, the emissions from the OECD countries stopped growing and have been declining in the past several years. The largest growth in CO_2 emissions came from the top layer, which represents the CO_2 emissions from China. The ninth layer shows the emissions from non-OECD Asian countries excluding China. This figure confirms that the growth of CO_2 emissions in Asia exceeds that of the rest of the world.

content/uploads/2020/01/200124list_en.pdf (both accessed on March 4th, 2020).

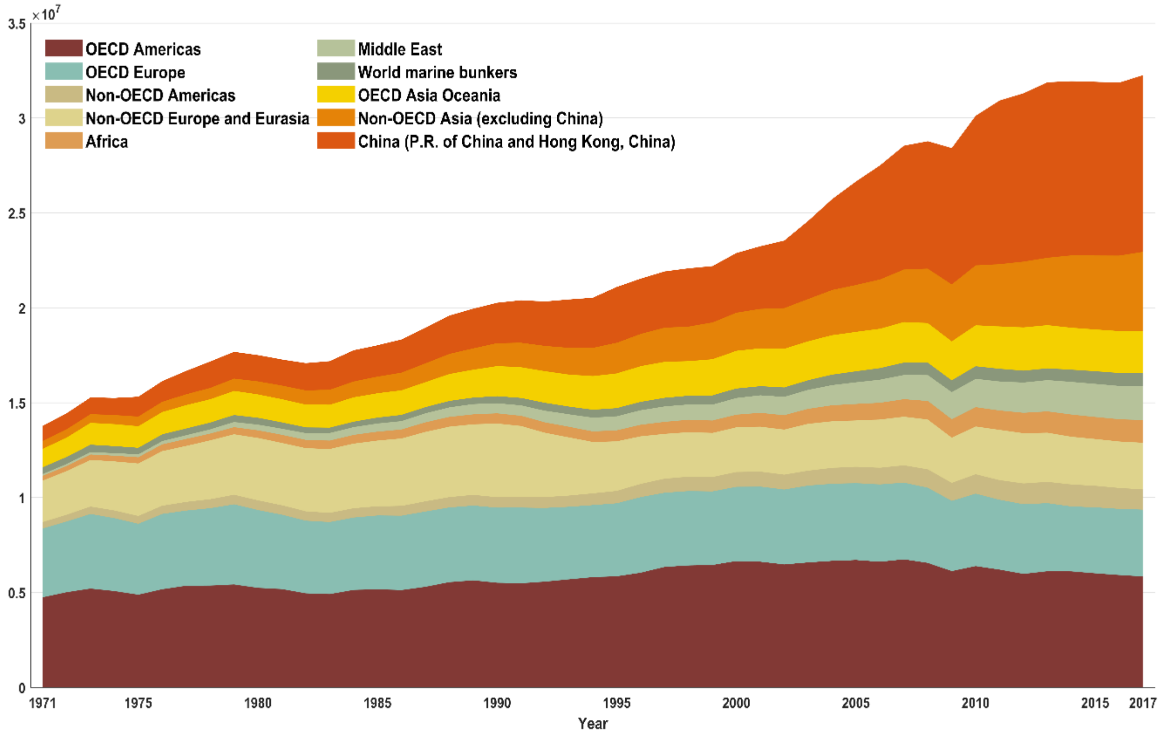


Figure 3 Fossil Fuel CO_2 Emissions from Each Region

Source: IEA's online data services

3 Market Policy Instrument

This section reviews the carbon mitigation policies implemented in Asia. We start from emissions trading schemes (ETS). Then, we explain the market mechanism in international context. Finally, we discuss carbon tax and effective carbon rate.

3.1 Emissions Trading Schemes (ETS) and related measures

To tackle climate change, Asian countries have begun to implement carbon emission regulations. As a policy instrument, following the success of the EU-ETS (Ellerman et al. 2016) and others, carbon pricing has become popular in major Asian countries, as well as in developed economies. Carbon pricing typically refers to either a carbon tax or a CO_2 emissions trading scheme.

Japan was the first mover in introducing carbon pricing in Asia. The first cap and trade scheme for carbon emissions in Asia was implemented in Tokyo In 2010, the Tokyo metropolitan government implemented the Tokyo ETS[7] (Wakabayashi and Kimura, 2018). The Tokyo ETS was unique in several aspects when it was introduced. First, it was the first cap and trade scheme targeting office buildings; approximately 80 percent of the regulated entities were commercial or office buildings. Second, the scheme regulated indirect emissions as well as direct emissions (Roppongi, 2016).

Saitama, neighborhood of the Tokyo prefecture also introduced an ETS in 2011 (Hamamoto, 2020a). In collaboration with Tokyo, Saitama borrowed the design of the Tokyo ETS. However, the measure was targeted mainly at manufacturing facilities, as is typical among other ETSs around the world. However, it is a unique system since it is a voluntary scheme in the sense that there is no penalty in violating the emission target. Thus, the Saitama ETS is also known as target-setting emissions trading (TSET) (Hamamoto, 2020b).

The size of the ETSs in these two regions is not negligible. The sum of the gross regional product in these two prefectures accounts for more than 22 percent of the national GDP. More than 1300 facilities were affected by the Tokyo ETS. The Saitama ETS regulates approximately 600 facilities. In terms of CO_2 emissions, GHG emissions from Tokyo and Saitama accounted for 4.9 percent and 3.1 percent of the national emissions, respectively.

What are the impacts of the two regional ETSs in Japan? Arimura and Abe (2020) found that the Tokyo ETS contributed to a sizable emission reduction: it reduced GHG emissions from office buildings by approximately 6.8 percent. Abe and Arimura (2020) examined GHG emissions from university buildings in Tokyo and found that the ETS reduced GHG emissions relative to universities in other regions by approximately 5 percent.

Regarding the Saitama ETS, Hamamoto (2020b) found that the Saitama ETS reduced GHG emissions. Moreover, Hamamoto (2020a) examined investment behaviors under the Saitama ETS and found that the Saitama ETS stimulated the adoption of high-efficiency machines and devices for the first three years of the second compliance period.

There is no auction or exchange market for the Tokyo ETS and Saitama ETS. Because the trading of permits under the Tokyo ETS is bilateral, the price of permits is hidden. This is also true for the Saitama ETS: no auction of permits and bilateral trading. The Tokyo government conducted an interview to investigate the price and publicized the results. They report that the price of the permit started from 10,000 yen (US$125) per CO_2 ton and fell to 4500yen (US$37) in 2014. Arimura and Abe (2020) found that the price of permits in Tokyo's Phase I (2010-2014) was roughly $50 per CO_2 ton based on an econometric model, which is somewhat consistent with the report from the Tokyo government.

Neither Tokyo nor Saitama has large power plants. Therefore, the adoption of the ETS in the two

[7] The details of the ETS design is illustrated in Table A1 in the appendix together with Saitama ETS and Korean ETS.

prefectures did not increase the price of electricity. Despite the success of the two regional ETSs in Japan, there is no ETS at the national level in Japan.

In contrast to Japan, since 2015, South Korea has implemented a nationwide cap and trade scheme (K-ETS). In Phase I, which lasted from 2015 to 2017, K-ETS regulated 525 large-scale emitters in certain subsectors, including manufacturing, power generation, transportation, and waste management. It covered approximately two-thirds of national GHG emissions. Phase II is scheduled for 2018 to 2020 and moves from 100 percent free allowances to auctioning.

The design of K-ETS is similar to that of EU-ETS in a sense that it covers power sectors and the manufacturing sector. The price of K-ETS has steadily increased over the years, from roughly from 12,028 KR (US$11) to 22,089 KRW (US$20). K-ETS has been the largest ETS at a national level[8] (larger than one country in the EU).

Jun et al. (2020) examined the impact of the first phase of K-ETS using firm-level data. They found that K-ETS was effective in improving the carbon intensity of the regulated entities in the manufacturing and building sectors. However, they did not find an impact on the power sector. They conclude that a pricing scheme in the power sector should reflect carbon costs in electricity prices in order for carbon pricing to have an impact on emission reduction.

China has the goal of 40 to 45 percent carbon intensity reduction by 2020 compared to 2005. For 2030, its goal is 60-65 percent CO_2 intensity reduction by 2030 compared to the 2005 level. The Chinese government is aiming for a peak of CO_2 emissions in 2030. To achieve these goals, China has adopted ETSs in five cities and two provinces – Beijing, Tianjin, Hubei Chongqing, Guangdong, Shanghai, and Shenzhen – since 2013. Each scheme has different targets for GHG emission reduction and different regulated sectors. The sum of GDP and CO_2 from these seven cities/regions accounts for 25 percent and 20.3 percent of the aggregated levels, respectively. Thus, the impact of these pilot programs on CO_2 emissions at the national level is not negligible. Fujian also began an ETS. See the map of the locations of ETSs in Figure 4.

Most of the pilot ETSs covers the power sector, and there are variations in the coverage.[9] The Shanghai ETS covers shopping centers and the aviation sector, while Hubei and Chongqing focus on the manufacturing industry and the energy sector. The amount of CO_2 emissions regulated differs across pilots. The cap for Shenzhen is the smallest at 55 Mt CO_2, while the cap for Guangdong is the largest at 388 Mt CO_2 (Yang et al., 2016). CO_2 intensity varies across programs from 0.6 t-CO_2 /$1000 in Shenzhen to 1.4 in Chongqing (Munnings et al., 2016). The price of permits ranged from 20(US$3.26) to 60 CNY(US$9.78) per CO_2 ton in 2014 (Yang et al., 2016).

One of the motivations of the pilot scheme is severe air pollution (Goulder et al. 2017). By

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[8] https://carbonpricingdashboard.worldbank.org/ (Accessed on February 27th, 2020).

[9] Table 1 in Wang et al. (2019) illustrates the charasteristics of the seven pilot ETSs.

reducing CO_2 emissions from coal power plants, SO2 or PM2.5 from coal power plants can be reduced. In the past few years, improvement in air quality has been reported (UNEP, 2019).

In 2015, the Chinese government announced that it will develop a national-level carbon market. Starting from the power sector, it will develop the national market focusing on eight energy-intensive sectors (Duan *et al*., 2018).

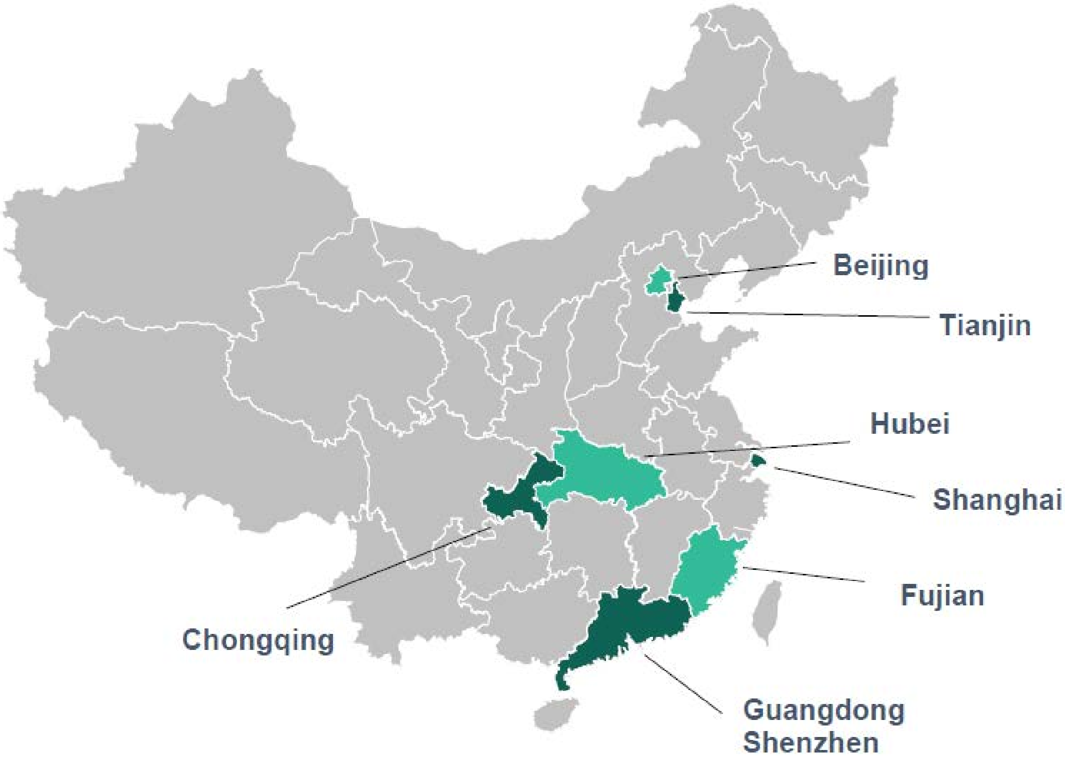

Figure 4 Cities and Provinces with ETSs in China

What was the impact of the seven pilot schemes in China? Zhou et al. (2019) conducted an ex post quantitative analysis by adopting the propensity score matching-difference in differences (PSM-DID) approach to explore the overall effect of emission trading pilots on carbon intensity (based on 19 forms of energy) by aggregating data from six different industries. The main finding is that the carbon intensity of the pilot provinces decreased by approximately 0.026 tons/10,000 CNY per year on average, which is 1.9 percent of GHG emission intensity from 2013 to 2016. Moreover, the effect of emission trading pilots on carbon intensity was sustained and stable, which indicates that the current pilot markets are efficient for carbon intensity reduction. They also decomposed the improvement in carbon intensity into changes in the industrial structure and energy structure and found that the improvement in carbon intensity was achieved mainly by the changes in the industrial structure and not by changes in the energy structure.

One must note that institutional and political aspects as well as monitoring, reporting and verification (MRV) are important for the success of ETSs. Munnings et al. (2016) assessed how Guangdong, Shanghai, and Shenzhen ETSs have adapted carbon emissions trading in the Chinese economic and political context. They chose these three pilots because their key elements have a strong likelihood of being replicated at the national level and because they are the most developed pilot ETSs in China. The authors found that the three pilot schemes demonstrated that the pilot regulators have deftly adapted carbon emissions trading to China's institutions, including a unique approach covering electricity production and consumption that improves efficiency. Deng et al. (2018) showed that the pilot MRV and compliance rules have not yet been fully implemented at an early state because of the lack of force of the regulations and policy awareness within firms. MRV and political aspects are essential for implementing ETSs, especially in emerging economies or ASEAN countries. Thus, these experiences in Japan, South Korea and China will provide valuable lessons for those who are considering introducing ETSs in their own countries.

Other Asian countries are considering the introduction of ETSs. Kazakhstan already introduced an ETS in 2013. In addition, India, Indonesia, Thailand, and Vietnam are considering the introduction of ETSs (ADB, 2016). For example, Thailand implemented several voluntary schemes to promote the mitigation of GHG emissions. Specifically, the government began the Thailand Voluntary Emission Reduction (TVER) and Thailand Carbon Offsetting Program (TCOP) in 2013 (ADB, 2016). Credits from the Joint Crediting Mechanism (JCM, see below) are used in these schemes (Thailand Greenhouse Gas Management Organization, 2019). These voluntary schemes are also considered to be a pathway to market-based mechanisms to regulate carbon emissions (ADB, 2016).

As a step toward ETSs, some countries have implemented a market for efficiency, which will contribute to GHG emission reduction. The Indian government has adopted a mechanism that contributes to the reduction of GHG emissions through the promotion of energy efficiency: the Perform, Achieve and Trade (PAT) mechanism. The PAT scheme was launched in continuation of the National Mission for Enhanced Energy Efficiency. The PAT scheme resembles the EU-ETS and is designed to achieve energy intensity targets at the lowest cost by trading in energy-saving certificates (Dasgupta et al., 2016). PAT aims to lower the emission of CO_2 by 26 million tons and save 6.6 million tons of oil equivalent through energy efficiency measures over its first compliance period. Additionally, the “designated consumers” are obliged to improve energy efficiency by 1-2% per annum (Kumar and Agarwala, 2013).

The Energy Conservation Act mandated energy efficiency targets for 15 energy-intensive large-scale industry sectors, of which 8 complied: the aluminum, cement, chlor-alkali, fertilizer, pulp and paper, power, iron and steel and textiles sectors. The PAT targeted 478 facilities out of the 8 sectors. These facilities are referred to as designated consumers.

Under the PAT scheme, energy efficiency targets are calculated in terms of specific energy consumption (SEC), for which the baselines are chosen at the April 2007-March 2010 average. The target of lowering the average SEC is 4.8% per installation, and the achievement of this target costs approximately US$5.4 billion (Upadhyaya et al., 2010). Post-installation, the targets should be achieved within the three-year compliance period. If any installation exceeds its SEC target, it is eligible to sell certificates called ESCerts equivalent to the amount of its surplus energy. Trading of ESCerts began in April 2013 at designated exchanges (Upadhyaya et al., 2010); however, no trading has taken place to date. In order to enable market liquidity before the market of ESCerts was launched, some ESCerts were auctioned ex ante, some were allocated freely to designated companies, and targets for individual facilities were established. However, the rules regarding the banking of ESCerts have yet to be determined.

In addition to these mechanisms, in India, a pilot program for emission trading schemes has been designed to create ambient air quality and incentivise industries to achieve the National Ambient Air Quality Standards. The focus of this pilot ETS is SO_2, NO_x and SPM, which impact human respiratory health. The pilot program was implemented in more than 1000 facilities in Gujarat, Maharashtra and Tamil Nadu in 2011.

3.2 International Cooperation: Instruments across Country Borders

In addition to domestic market mechanisms, international schemes have been proposed and used in Asia. One type of international scheme is offset mechanisms such as the CDM and JCM. Another form of international scheme involves linking domestic ETSs.

Joint Crediting Mechanism (JCM)

The Kyoto protocol's CDM has contributed to decelerating the growth rate of GHG emissions in developing countries. The projects that are approved by the UN, however, have been inclined towards major developing countries such as China and India (Simon et al. 2017). Thus, other countries have not benefited from this mechanism, which is a key factor that needs to be addressed. The Japanese government has proposed and implemented JCM, which funds technological transfer to developing countries and aids sustainable development in the host country. Unlike CDM, JCM is conducted bilaterally between countries that have signed agreements with the Japanese government. Starting with Mongolia, which signed the agreement in 2013, 17 countries had bilateral agreements as of June 2019, accounting for 58 registered projects[10].

JCM aids the diffusion of leading low-carbon technologies, products, systems, services and infrastructure along with mitigation actions that contribute to sustainable development in developing

[10] Global Environmental Centre Foundation web page, http://gec.jp/jcm/jp/about/ (last accessed March 13, 2020).

countries.

JCM is conducted bilaterally between host countries and Japan but is not a replacement of CDM. For example, the monitoring, reporting and verification process is in line with the rules set by CDM. In addition, the reference emissions under JCM are set conservatively, i.e., lower than the baseline emissions under CDM to ensure a net decrease in emissions. The credits issued are allocated to both the host country and Japan. The credits distributed to the host country can be used within the host country, as in the case of Thailand.

Is JCM justified by international law as a mechanism under the UNFCCC? Article 6 of the Paris Agreement discusses three possible mechanisms that support domestic emission reduction actions: cooperative approaches, a mechanism that realizes both emission reduction and sustainable development, and a nonmarket approach. JCM can be considered as an example of a cooperative approach because JCM meets three criteria: the involvement of "internationally transferred mitigation outcomes", a goal "towards nationally determined contributions" and "apply robust accounting to ensure the avoidance of double counting" (Koakutsu et al., 2016).

A total of 1.393Gt-CO_2 is expected to be reduced annually by the 58 registered projects. The eighth row in Table 1 shows the estimated annual emission reduction for selected East Asian countries. Projects that are registered in Indonesia account for one-quarter of the total annual emission reduction (0.35 Gt-CO_2) from JCM. Other countries with large emission reductions are the Philippines, Thailand and Mongolia with 0.21Gt-CO_2, 0.19Gt-CO_2 and 0.10Gt-CO_2, respectively. The ninth column in Table 1 also shows the amount of credits issued by the registered projects. The total number of credits issued as of Feb. 2020 totaled 81,887 t-CO_2e. Indonesia accounts for more than 68% (56,254t-CO_2e) of the credits issued, followed by Mongolia with 22% (18,311t-CO_2e).

Looking at the figures for annual emission reduction and issued credits, the scale of JCM is limited compared to its CDM counterparts. However, the registered projects are tailored so that the host country's needs are satisfied. In addition, the projects are conducted in countries that have not benefited from CDM projects. Thus, JCM has the potential of contributing to environmental and economic goals simultaneously.

Linking ETSs

In theory, linking domestic ETSs internationally is expected to increase economic efficiency. There are two ways to link domestic or regional ETSs: direct links and indirect links. A direct link refers to linking different ETSs so that the emission permits traded in one ETS can also be traded within another ETS. On the other hand, an indirect link refers to a link that indirectly merges two different ETSs by using emission credits that are issued by third parties, such as credits from CDM, without trading emission permits issued by each ETS. In any case, the price gap between the two linked ETSs will decrease so that both ETSs will have similar prices. If the link between competing countries can be realized, then competitiveness and carbon leakage issues can be minimized.

There is some interest among policy makers and academics in linking domestic or regional ETSs in Asia. Stavins and Stowe (2018) discussed the opportunities and challenges for linking ETSs in the regions. ADB (2016) also illustrated the issues in ETS linking in Asia. With the Chinese government initiative, China, Japan and South Korea began to hold annual meetings on linking ETSs among the three countries in 2016. At these annual meetings, scholars, researchers and policy makers report recent developments in domestic climate change policies and related topics to gain a common understanding of vital issues so that a link can materialize.

Similarly, the Asian Society Policy Institute (ASPI) initiative, "Toward a Northeast Asia Carbon Market", aims to link Northeast Asian countries' carbon market since Japan, China and South Korea are moving towards domestic and sub-domestic ETSs. The ASPI has held roundtables on a regular basis since 2016 to establish a foundation for a linked carbon market. The first policy roundtable found that a linked carbon market could significantly reduce CO_2 emissions in Northeast Asia (Ewing, 2016).

3.3 Carbon Tax and Effective Carbon Rate

Emission trading schemes are not the only policy instrument to reduce fossil fuel usage. For example, a carbon tax is also an economically efficient instrument that can be used to cut CO_2 emissions. ETSs and carbon taxes are explicit carbon pricing policies that directly signal the cost of CO_2 emissions. However, implicit carbon pricing, such as energy taxation and other taxes and regulations on energy usage, raises the cost of emitting CO_2 indirectly. In the following subsection, carbon taxes, energy taxes, renewable portfolio standards (RPSs) and efficient carbon rates for selected Asian countries are reviewed.

Carbon Tax

In 2012, the Japanese government successfully implemented an economy-wide carbon tax starting at the rate of 95 JPY/t-CO_2, which increased to 289 JPY/t-CO_2 by 2016. The new carbon tax was added to the existing energy tax.

The tax rate was lower than those in European countries for two reasons. First, the government needed an agreement from industry stakeholders such as energy-intensive industries. Second, the government is trying to reduce CO_2 by using tax revenues to promote energy efficiency and renewable energy.

Though the tax rate seems to be small compared to those imposed in Europe, the coverage of the Japanese carbon tax is greater than 66% of total CO_2 emissions. Tax cuts and exemptions are granted to specific fuels and processes for energy-intensive industries and industries at risk of losing international competitiveness, which lowers the coverage of the carbon tax.

Singapore passed the Carbon Pricing Act (CPA) in 2018, which includes the carbon tax, as a part of its commitment under the Paris Agreement. In January 2019, the CPA came into effect, which taxes the direct emissions of GHG for industrial emitters with annual emissions higher than 25,000 t-CO_2e. These industrial emitters are taxed 5 SGD/t-CO_2 from 2019 to 2023. The tax rates are planned to increase between 10 and 15 SGD/t-CO_2 by 2030. The carbon tax does not cover medium- and small-sized emitters, which lowers the price signal.[11]

Energy Tax

Energy-related taxes in Japan are imposed at the national and local levels. At the national level, there are six energy-related taxes: the gasoline tax, local gasoline tax, liquefied petroleum gas tax, aviation fuel tax, petroleum and coal tax and the promotion of power-resource development tax. In addition, a light-oil delivery tax is imposed as a local tax. Thus, 7 energy-related taxes have been imposed in Japan[12].

The gasoline tax and local gasoline tax are imposed on gasoline at rates of 48,600 JPY/kL and 5,200 JPY/kL, respectively. The liquefied petroleum gas tax is imposed on LGP at the rate of 17,500 JPY/t, whereas the aviation fuel tax is implemented on aviation fuel at the rate of 26,000/JPY kL. The petroleum and coal tax is imposed upstream on crude oil, petroleum products, coal and LNG/LGP. The tax rates for crude oil, LNG/LPG and coal are 2,040 JPY/kL (780 JPY/t-CO_2), 1,080 JPY/t (400 JPY/t-CO_2) and 700 JPY/t (290 JPY/t-CO_2), respectively. The final indirect tax on energy is the promotion of the power-resources development tax, which is imposed on the usage of electricity at the rate of 0.375 JPY/kWh. This tax covers all economic agents that purchase electricity from the 10 major power companies in Japan, including the self-consumption of power companies. The light-oil delivery tax is imposed on light-oil (diesel fuel) at the rate of 32,100 JPY/kL.

Unlike the Japanese taxes on energy, the Chinese government implemented the refined oil excise tax in 2009, which taxes all oil refined products. Focusing on fuel, the original tax on diesel and light fuel was 0.8 CNY/L, whereas unleaded gasoline and leaded gasoline were 1.0 CNY/L and 1.4 CNY/L, respectively. In 2015, the tax rates increased to 1.52 CNY/L for gasoline and 1.2 CNY/L for diesel and fuel oil (OECD, 2019).

Other energy sources, such as coal and natural gas, are not taxed. Furthermore, even though oil products are taxed, the government allows subsidies and tax cuts for industries and households that are expected to suffer from such tax payments. Thus, the burden of the energy tax is limited to the transportation sector.

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[11] See Singapore Government Agency website for details on the Carbon Pricing Act 2018 at https://sso.agc.gov.sg/Act/CPA2018 (last accessed on March 13, 2020).

[12] See Arimura and Iwata (2015) for details on the energy tax implemented in Japan.

South Korea has implemented 4 tax systems, an individual consumption tax (ICT), a transportation energy environment tax (TEET), education tax and local automobile tax, which mainly cover liquid fossil fuels. ICT covers liquid, gaseous and solid fossil fuels, including coal. The per-unit taxes for gasoline, light oil, kerosene and heavy oil are 475 KRW/l, 340 KRW/l, 90 KRW/l, and 17 KRW/l, respectively. For propane, butane, natural gas and coal, the tax rates are 20 KRW/kg, 252 KRW/kg, 60 KRW/kg, and 30 KRW/kg, respectively. The TEET applies to gasoline and diesel at 529 KRW/l and 375 KRW/l, whereas the education tax imposes a 15% tax rate on the ICT for liquid and gaseous fuels and an additional 15% tax rate on the TEET for gasoline and diesel. The local automobile tax applies a tax rate of 26% of the TEET rate for gasoline and diesel (OECD, 2019).

Indonesia's major energy tax as of 2018 was the provincial motor vehicle fuel tax, which is applied to premium gasoline and diesel used for mobility at the rate of 5% of the sales price of motor fuels for most provinces. The district government also imposes a street lighting tax, which taxes the usage of electricity. Thus, the taxes on fuel are very limited in Indonesia (OECD, 2019).

Energy Subsidy

The effectiveness of carbon pricing policies, explicit or implicit, is reduced when other policies exist that distort the market, such as energy subsidies. Table 2 shows the estimated volume of subsidies on energy usage (IEA, 2018) in Asia. The IEA report lists 25 countries that have energy subsidies, accounting for more than 400 billion USD. Of these 25 countries, 5 are Asian countries, which account for 26% of global energy subsidies. China provides 44.5 billion USD worth of subsidies. Indonesia and India provide 31.3 billion and 25.4 billion USD worth of subsidies for energy use. A large proportion of subsidies are geared towards oil except in China, where electricity is highly subsidized. In the future, these subsidies must be phased out.

Table 2. Energy Subsidies in Asian Economies

Billion USD

	Oil	Electricity	Gas	Coal	Total	
					Volume	Ratio
China	18.0	24.9	1.6	0.0	44.5	10.8%
Indonesia	24.0	7.3	0.0	0.0	31.3	7.6%
India	17.3	4.4	3.7	0.0	25.4	6.1%
Pakistan	0.1	0.0	3.3	0.0	3.4	0.8%
Bangladesh	0.0	1.1	1.7	0.0	2.8	0.7%
Total of 20 other countries	113.9	101.9	86.9	3.0	305.7	74.0%
Total	173.3	139.6	97.2	3.0	413.1	100.0%

Data source: IEA (2018) .

Effective Carbon Rate (Japan, China, South Korea, India, and Indonesia)

The Carbon Pricing Leadership Coalition (2017) estimates that the price of carbon emissions should be at least $50 by 2030 to achieve the Paris agreement target. Likewise, the OECD (2016) recommends that the minimum effective carbon rate of 30 Euros/t-CO_2 is necessary to cover the damage caused by these emissions.

The concept of effective carbon rates refers to the amount of taxes and carbon-related costs levied on CO_2 emissions. Taxes include energy taxes, which are usually implemented on a physical quantity basis rather than on the carbon content, and environmental taxes, including carbon taxes and feed-in tariffs imposed on the usage of electricity. Carbon-related costs refer to market-based carbon pricing schemes, namely, a cap-and-trade type ETS.

The OECD (2016) shows that 90% of emissions in 41 OECD and G20 countries are less than the minimum effective carbon rate, which implies that most of the emissions are not properly taxed even though individual countries have energy taxes and/or explicit carbon prices.

The OECD (2018) reports the changes in effective carbon rates from 2012 to 2015 (Table 3). The majority of the countries have decreased the carbon pricing gap, which is the difference between the minimum requirement and the estimated effective carbon rate. Table 3 shows Asian countries that are reported in the OECD (2018). If the change from 2012 to 2015 is negative, e.g., smaller value, then the effective carbon rate has improved. Four of the five countries have shown progress in the 3-year time span. The change for South Korea has increased drastically from 73 to 43 in the 3-year span.

Table 3 Effective Carbon Rate Gap for 2012 and 2015 for Asian Countries (Percentage)

Country	2012 ECR gap	2015 ECR gap	Change (2015-2012)
China	92	90	-2
Indonesia	91	95	+4
India	90	86	-4
Japan	75	69	-6
South Korea	73	43	-30

Data Source: OECD (2018) Effective Carbon Rate

3.4 Promotion of Renewable Energy: Feed-in Tariff /RPS

Renewable energy has been expanding rapidly in Asia as it has in the rest of the world. The main policies that have been used to stimulate renewables in Asia are feed-in tariffs (FITs) and renewable portfolio standards (RPSs). For example, Indonesia, Malaysia, the Philippines, Thailand, Vietnam, China, India and Japan have FIT programs, whereas Indonesia, Malaysia, the Philippines, China, India and South Korea have RTSs (REN21, 2016). In the following, we will review FITs and

RTSs in Japan, China, South Korea and India.

In November 2009, the Excess Electricity Purchasing Scheme for Photovoltaic Power was implemented to promote the use of photovoltaic power. The purchasing price ranged from 32 to 42 JPY/kWh in 2011, depending on the power capacity of the installation. The system was extended to include other renewable generations, such as wind, biomass, hydro and thermal generation, in 2012, when the system was altered to a FIT. The price ranged from 13 to 55 JPY/kWh depending on the size of the power capacity and renewables. For example, the price for PVs with less than 10 kW was 42 JPY/kWh, whereas PVs with higher than 10 kW was 40 JPY/kWh. Furthermore, the prices are fixed for 10 to 20 years depending on the type of renewable and size of the installation. The FIT price has been updated annually to reflect the changes in the production cost. As a result, the FIT price has fallen to 12 to 40 JPY/kWh.

China introduced FIT for wind power in 2003, which required power suppliers to purchase wind energy at fixed prices. The fixed prices were determined by bidding or individual negotiations, which resulted in prices ranging from 0.38 to 0.8 CNY/kWh. In 2009, the prices were updated, ranging from 0.51 to 0.61 CHY/kWh, on a regional basis to address price differentials. The FIT was extended to include solar power in 2011. In addition to FIT, the RPS type program was introduced in 2007. Chinese power generators are required to produce a certain ratio of electricity using renewables, particularly wind, solar and biomass. The targets set to be met by 2020 for biomass, hydro and solar are 30 GW, 350 GW and 100 GW, respectively.

South Korea implemented FITs in 2002, covering biomass, waste, fuel cells, wind and solar power. The program guaranteed a fixed tariff lasting for 15 to 20 years depending on the type of renewable source. One feature of the South Korean FITs was that the tariffs for hydropower and biomass could be chosen between a fixed price and a variable price. The FIT program ended in 2011 when the South Korean government decided to switch from FITs to RPSs due to the rise in the FIT budget. The RPS sets mandatory targets on power suppliers providing more than 500 MW, starting from 2% in 2012 and reaching 10% in 2023. The targets can be fulfilled by providing power generated from renewables or by buying renewable energy certificates (RECs).[13]

India is unique in promoting renewables. India has adopted market-based policy instruments to promote renewable energy. The Electricity Act of 2003 mandated renewable purchase obligation (RPO) targets. In this scheme, state electric regulatory commissions are required to purchase more than a fixed percentage of the total annual power requirement from renewable sources. The RPO varies across states and over years and depends upon total energy consumption, RE potential and retail tariffs.

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[13] See Korea Energy Agency website for further details on FIT at https://www.energy.or.kr/renew_eng/new/renewable.aspx (last accessed on March 13, 2020).

RPOs ranged from 4% to 17% between 2018 and 2019.

To mitigate the burden of this obligation, the government has introduced a market mechanism, REC trading. RECs represent the power generated by means of renewable energy as a primary source. The traits of RECs are unbundled from the electric power produced, and both are sold/purchased separately in India and are traded on specified platforms (Girish et al., 2017; 2015).

The trading of REC began in March 2011. Since then, Power Exchange India Limited (PXIL) has publicly announced information on the volume of REC transacted, the market-clearing price and the market-clearing volume at the end of each trading date on its official website. The number of RECs transacted L increased from 221806 RECs (48741 solar REC) in 2011 to 8408465 RECs (3375664 solar REC) in 2019. The number of buyers (sellers) of RECs through power exchanges has increased from 397 (168) participants in 2011-12 to 632 (966) participants in 2015-16 (Girish et al., 2017).

4 Discussion: Changes in Energy Usage in Asia

We have shown that Asian countries have made progress on the adoption of climate mitigation policies. However, what have these policies achieved? As we observed above, the literature shows that energy efficiency has been improved in the targeted sectors or areas in Japan, South Korea and China. However, have they had impacts on the fossil fuel demand in the fuel mix?

To tackle the climate issue, we first have to reduce carbon emissions, i.e., achieve a *low-carbon economy*. To realize a low-carbon economy, fuel switching from coal to natural gas is a critical step. Figure 5 illustrates the changes in the demand for coal from the selected Asian economies. The demand for coal in China seemed to peak in 2013, while the demand for natural gas continued to grow. This trend provides some evidence of fuel switching from dirty fossil fuel to cleaner fuel. We observe a somewhat similar pattern for India. Nevertheless, coal demand in India seemed to have flattened in the 2010s. Coal demand in Japan appears to have remained constant in the past decade.

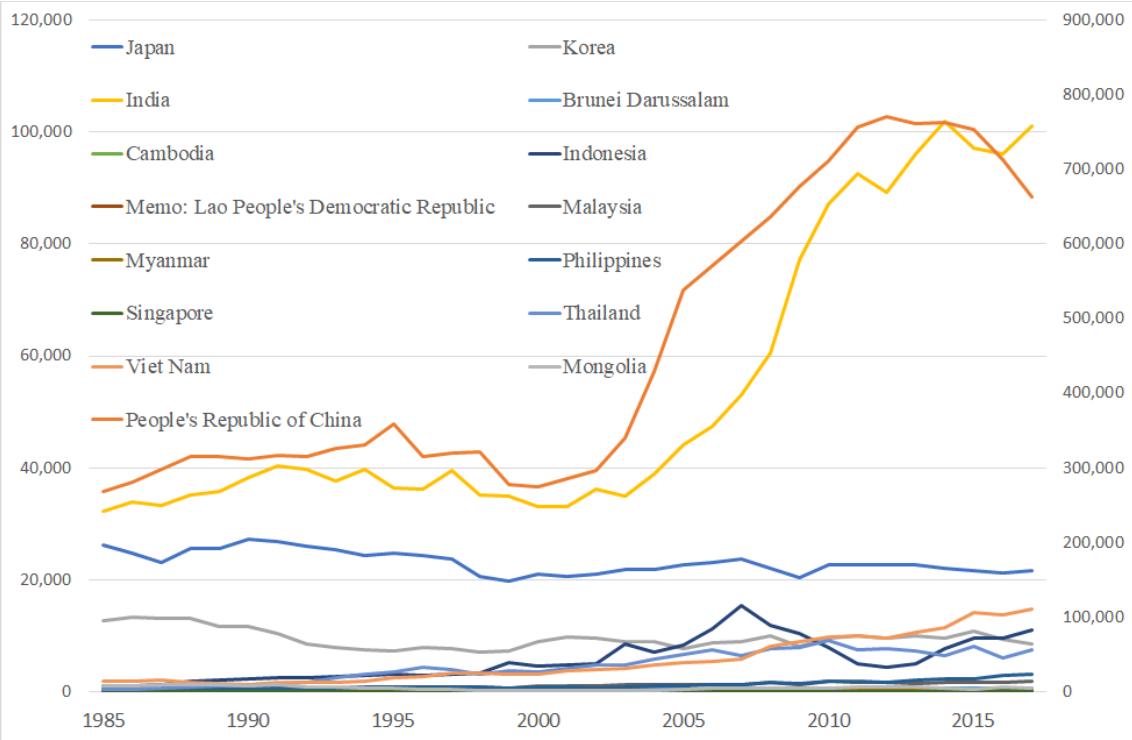

Figure 5 Changes in Coal Demand in Asia

Note: The right vertical axis measures the demand in China, while the left axis measures that in other Asian countries. Data Source: IEA's online data services.

Figure 6 shows the changes in natural gas demand from 1985 to 2017. Once again, the demand in China exceeds those in other Asian countries. Thus, the right y-axis denotes the demand from China and the left y-axis denotes those in other countries. In contrast to the coal demand in Figure 5, the demand for natural gas has been increasing in most Asian countries.

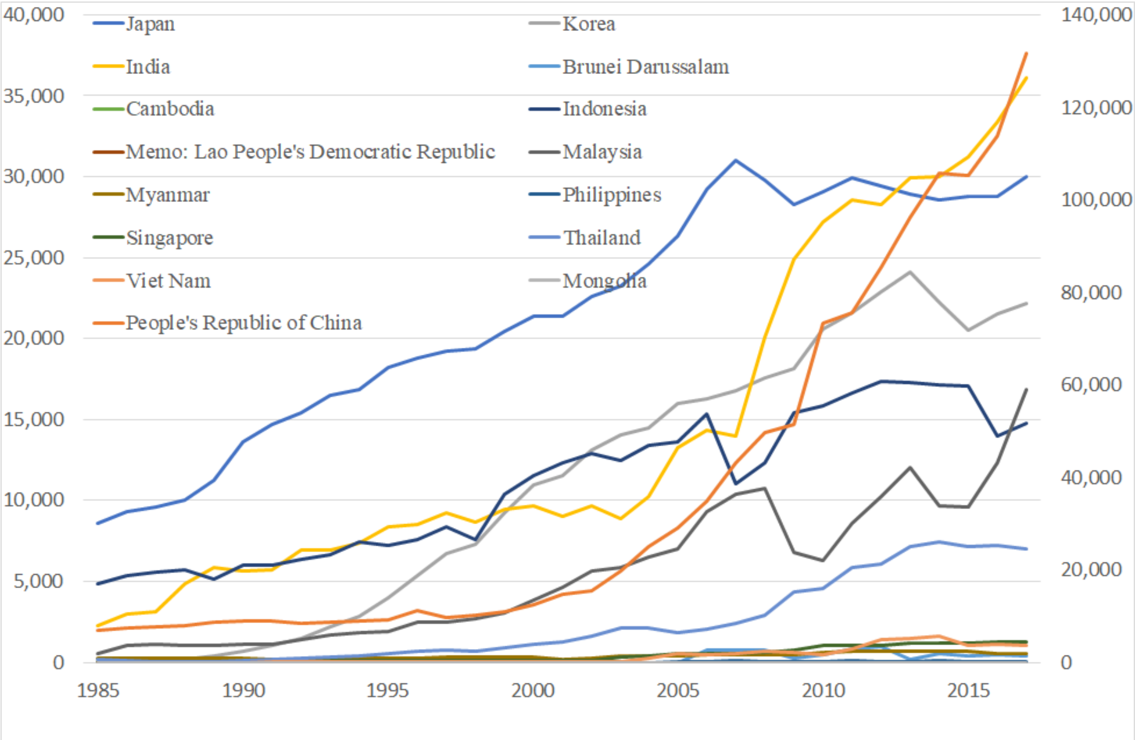

Figure 6 Changes in the Natural Gas Demand in Asia

Note: The right vertical axis measures the demand in China, while the left axis measures those in other Asian countries. Data Source: IEA's online data services.

Do we observe any evidence of fuel switching from coal to natural gas? To obtain some sense of fuel switching, we construct Figure 7, which shows coal (on the left y-axis) and natural gas (on the right y-axis) usage in four major GHG emitters in Asia: China, Japan, South Korea and India. Coal usage in the four countries seems saturated. In contrast, we observe the expansion of natural gas usage in the four countries. Thus, we see some trends of fuel switching from coal to natural gas at the macro level in the move to low-carbon economies.

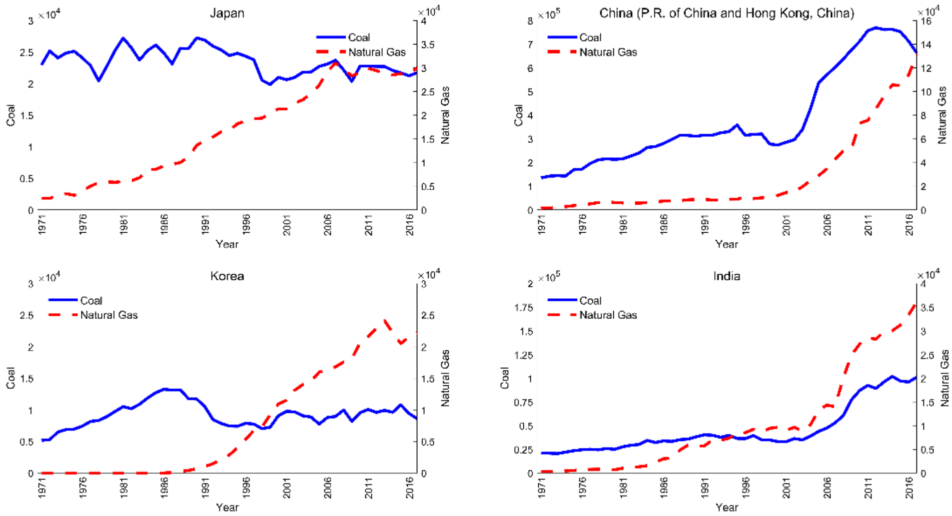

Figure 7 Coal and natural gas usage in four major GHG emitters in Asia

Source: IEA's online data services

Figure 8 depicts the coal and natural gas usage in four ASEAN countries, Thailand, Indonesia, the Philippines and Vietnam. In contrast to the four major emitters illustrated in Figure 7, coal usage has continued to increase in the Philippines and Vietnam. Hence, we do not observe any evidence of fuel switching in these countries. On the other hand, we see that coal usage stopped growing in Thailand, while the demand for natural gas increased sharply. Therefore, fuel switching may be occurring in Thailand.

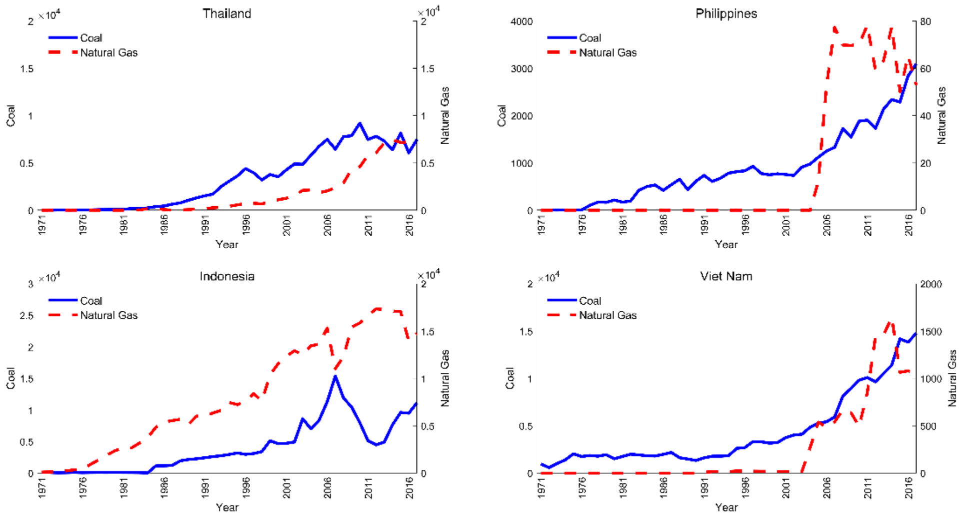

Figure 8 Coal and Natural Gas Usage in Four ASEAN Countries

Source: IEA's online data services

Figures 9 and 10 illustrate the diffusion of solar and wind power, respectively. Japan had the largest solar capacity until 2010. Then, China surpassed Japan and had the largest capacity in 2015. India is also increasing its capacity and ranked 3rd in 2017. Regarding wind power, China leads Asia and is followed by India.

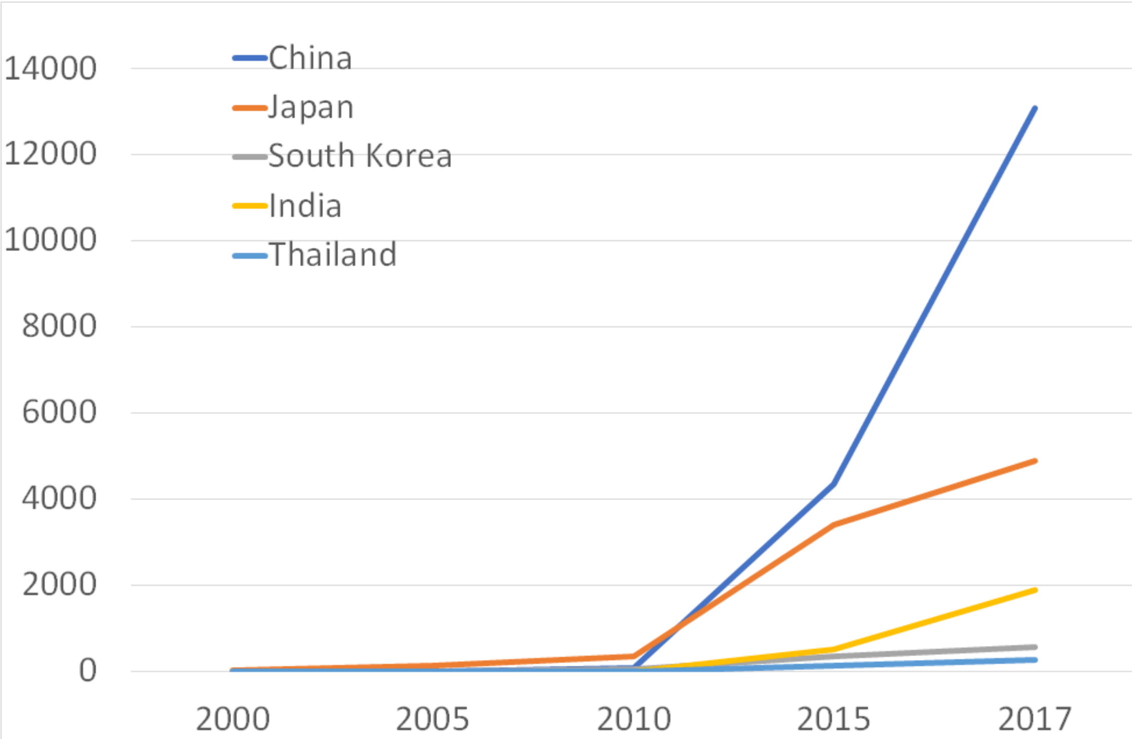

Figure 9 Diffusion of Solar Power in Asia (Unit:10MW)

Source: EDMC (2019)

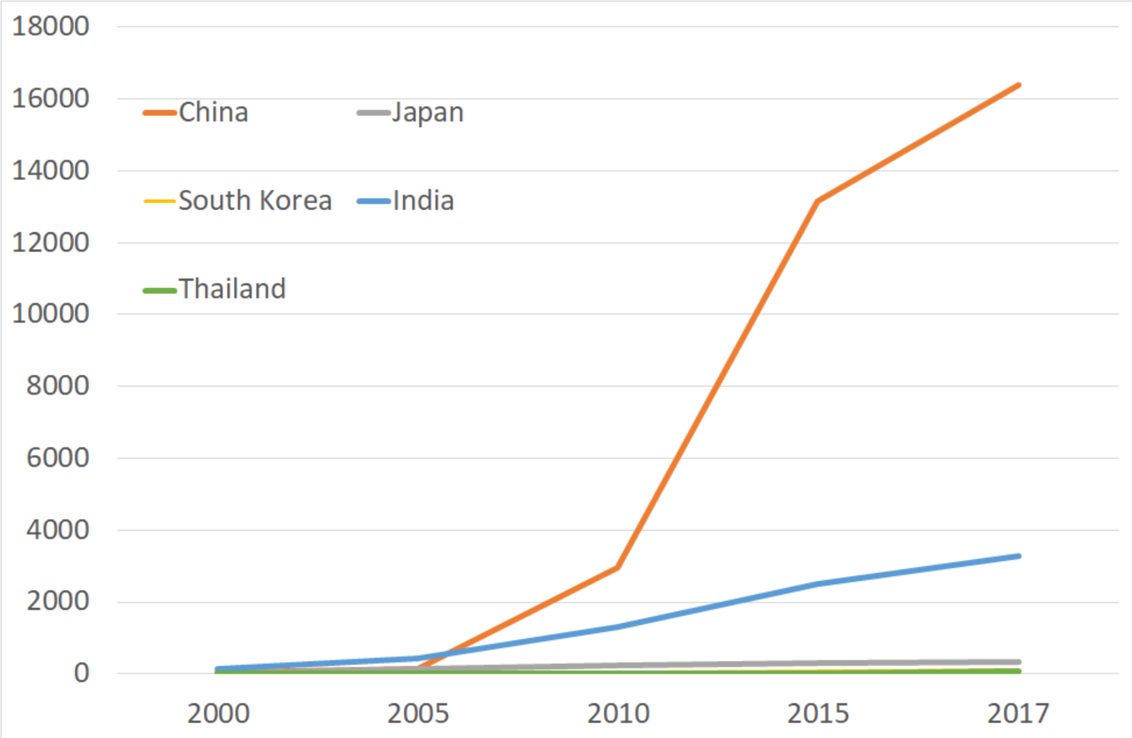

Figure 10 Diffusion of Wind Power in Asia (Unit:10MW)

Source: EDMC (2019)

5. Conclusion

In this paper, we described policy instruments to mitigate carbon emissions together with air pollution in major Asian economies with a focus on explicit and implicit carbon pricing. We confirm that the ETSs in Japan, South Korea and China have concrete impacts on improving energy efficiency. However, we still do not have strong evidence to support fuel switching from coal to natural gas using microdata on carbon pricing.

On the other hand, at the macro level, we observe some evidence of fuel switching from coal to natural gas among major emitters. For the decarbonization of the economy, as urged by the IPCC 1.5 degree special report, carbon emissions must be reduced to zero by the middle of the century. To achieve that goal, the economy must rely on renewable energy. We find that China has been deploying many renewable energy projects, followed by India.

Economic theory suggests that carbon pricing is the most efficient way to reduce GHG emissions. Considering the variety of policy instruments implemented in each country, the effective carbon rate is a sensible measure of how comprehensive carbon pricing is in each country. We observe that to achieve the long-term goal of a 2.0-degree increase, all countries have a gap to fill in order to reach the proper level of carbon pricing advocated by the OECD or Carbon Pricing Leadership Coalition. Thus, further implementation of carbon pricing is necessary in all Asian countries.

A new discussion of the border carbon tax by the European Commission may provide a potential economic motive for Asian economies to expand the adoption of carbon prices. In 2019, the new president of the European Commission announced the group's intention to implement a border carbon tax adjustment (BCA), i.e., the exporters to the EU must pay a carbon price at the border. BCA has been discussed in the EU under the Kyoto Protocol. The US congress also discussed BCA under their proposal of climate bills. Even Japan has discussed BCA (Takeda et al. 2014), but none of these proposals has ever been implemented. If implemented, the current EU BCA proposal is likely to be the first to be enacted. If so, Asian economies may lose a comparative advantage unless they adopt a more stringent mitigation policy promoting fuel switching and renewable energy.

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Appendix

Table A 1. Design features of ETSs in Japan, and Korea

Japan	**Phases**	**Cap**	**Coverage**	**Allocation**	**Percentage of all facilities surpassing their obligations**
Tokyo	Phase 1 (2010-14)	8% (commercial building), 6% (Manufacturing plants) ∗ Comparing to the base-year emissions	Main target: office building Manufacturing, commercial	1. Base-year emissions × (1 - compliance factor) × compliance period (5 years) 2. Facilities are permitted to leave the cap-and-trade program, when their energy consumption below the threshold for facilities (buildings/factories) eligible for an allowance allocation. 3. Credits are issued to facilities whose emissions fall below the baseline.	Surpassing the targets by their own energy-saving measure: 91%
	Phase 2 (2015-19)	17% (businesses), 15% (industrial facilities) ∗ Comparing to the base-year emissions	Main target: office building Manufacturing, commercial		Surpassing the targets by their own energy-saving measure: 76%
	Phase 3 (2020-23)	27% (businesses), 25% (industrial facilities) ∗ Comparing to the base-year emissions	Main target: office building Manufacturing, commercial		N/A
Saitama	Phase 1 (2011-14)	8% (office building), 6% (Manufacturing plants) ∗ Comparing to the base-year emissions	Manufacturing, commercial	1. Base-year emissions × (1 - compliance factor) × compliance period (5 years). 2. Grandfathering with free allocation	N/A
	Phase 2 (2015-19)	15% (office building), 13% (Manufacturing plants) ∗ Comparing to the base-year emissions	Manufacturing, commercial		N/A
	Phase 3 (2020-23)	N/A	Manufacturing, commercial		N/A

Korea	**Phases**	**Cap**	**Coverage**	**Allocation method for new and existing facilities with extension**	**Market participation**
	Phase 1 (2015-17)	1687 Mt CO_2	Refinery, cement, aviation	100% free allocation Expected: Prior-allocation Unexpected: Posterior-allocation	Covered entities, 3 Financial institutions
	Phase 2 (2018-20)	1796 Mt CO_2	Refinery, cement, aviation, power-generation, district energy, waste, industrial complex	3% free allocation Posterior-allocation	Covered entities, 3 Financial institutions
	Phase 3 (2021-25)	N/A	Plan to expand	At least 10% free allocation	3rd party & off-shore participation can be considered

Sources:. Arimura and Abe (2020), International Carbon Action Partnership "Japan - Tokyo Cap-and-Trade Program"
(https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&syst

ems%5B%5D=51), Bureau of the Environment Tokyo Metropolitan Government “Tokyo Cap-and-Trade Program: Japan’s first mandatory emissions trading scheme” (https://www.kankyo.metro.tokyo.lg.jp/en/climate/cap_and_trade/index.files/Tokyo-cap_and_trade_program-march_2010_T.pdf), Bureau of the Environment Tokyo Metropolitan Government “Tokyo Cap-and-Trade Program achieves 25% reduction after 5th year” (https://www.kankyo.metro.tokyo.lg.jp/en/climate/cap_and_trade/index.files/3c08a5ad895b5130cb1d17ff5a1c9fa4.pdf), Office of Market Mechanisms Ministry of the Environment “Consideration of Emissions Trading Scheme in Japan” (https://www.env.go.jp/en/earth/ets/mkt_mech/scheme-emissions_trading.pdf), International Carbon Action Partnership “Japan - Saitama Target Setting Emissions Trading System” (https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=84), Yoon and Oh (2019)

Notes: BJEA: BJ stands for Beijing, EA stands for emissions allowances. Similarly, TJEA, SHEA, GDEA, SZEA, HBEA, and CQEA represent emissions allowances in Tianjin, Shanghai, Guangdong, Shenzhen, Hubei, and Chongqing, respectively. CCER represents Chinese Certified Emission Reductions.