

Regional Cooperation on Carbon Markets in East Asia

JIAJIA LI AND JUNJIE ZHANG*

The People's Republic of China, Japan, and the Republic of Korea have launched individual emission trading schemes to control greenhouse gas emissions cost-effectively. This paper reviews key carbon market design elements in the three countries in terms of emission allowances, covered sectors, allowance allocations, monitoring, reporting and verification, compliance and penalties, and offset markets. We assess the performances of the emission trading schemes among the three countries based on secondary-market allowance transactions. Considering heterogeneous climate policy designs in the region, we explore various approaches for the linkage of East Asian carbon markets. Cooperation on carbon markets is instrumental for regional and global climate governance. It could not only help achieve cost-effective emission reductions in the region, but also signal the commitment of the three countries to climate change mitigation.

Keywords: carbon markets, climate change, East Asia, linkage

JEL codes: Q54, Q58

I. Introduction

The People's Republic of China (PRC), Japan, and the Republic of Korea together account for almost a quarter of global gross domestic product (GDP) and a third of global greenhouse gas (GHG) emissions. In order to control GHG emissions cost-effectively, each country has started to pilot emission trading schemes (ETSs). Japan launched two regional ETSs in 2010 and 2011. The PRC has launched seven regional ETSs since 2013 and announced the initiation of a national market in 2017. The Republic of Korea started its nationwide ETS in 2015. The three countries' active engagement in climate actions not only contributes to global efforts in tackling climate change, but also ameliorates concerns that the major East Asian countries might race to the bottom in climate policy.

*Jiajia Li: Assistant Professor, College of Economics, Sichuan Agricultural University. E-mail: jiajia_li108@hotmail.com; Junjie Zhang (corresponding author): Associate Professor, Environmental Research Center, Duke Kunshan University and Nicholas School of the Environment, Duke University. E-mail: junjie.zhang@duke.edu. We thank Xuhui Jin, Donghui Liu, Zhenghui Ni, Yumin Wang, Zhenxuan Wang, Honglin Wu, the participants at the Asian Development Review Conference in Seoul in August 2017, the managing editor, and two anonymous referees for helpful comments and suggestions. We also thank Hao Cheng and Shuo Li for excellent research assistance. ADB recognizes "China" as the People's Republic of China and "Korea" as the Republic of Korea. The usual disclaimer applies.

A major incentive for the three countries to pilot carbon markets is a desire to curb their ever-increasing GHG emissions. The PRC, Japan, and the Republic of Korea are among the leading GHG emitters in the world. Their combined emissions accounted for over 33% of global emissions in 2016. Individually, the PRC overtook the United States to become the world's largest emitter in 2007. Japan has been the fifth-largest global emitter for a long period of time. The Republic of Korea was the eighth-largest emitter in 2015 (Olivier, Janssens-Maenhout, and Peters 2016). While Japan's emissions have stabilized, the GHG emissions of the PRC and the Republic of Korea continue to grow rapidly.

All three countries have signed and ratified the major climate agreements such as the Kyoto Protocol, Copenhagen Accord, and Paris Agreement. With pressure from international climate negotiations, Japan was the first East Asian country subject to legally binding emission reduction requirements in the Kyoto Protocol. Although the PRC and the Republic of Korea had no obligations under the Kyoto Protocol, the two countries pledged to reduce carbon emissions in the recent treaties. In particular, the PRC agreed in the Paris Agreement to peak its GHG emissions around 2030. Likewise, the Republic of Korea committed to reduce its GHG emissions by 37% from the business-as-usual (BAU) level by 2030.

Carbon markets can minimize the cost of compliance for the PRC, Japan, and the Republic of Korea to achieve their GHG emission targets. Compared with command-and-control policies, market-based instruments allow more flexibility for emitters to reduce emissions. By equalizing marginal abatement costs among emitters, the overall cost of carbon emission control can be minimized. Carbon markets also enable low-carbon industries to gain a comparative advantage, which facilitates the efforts of these countries, especially the PRC, to upgrade industrial structures.

The cobenefit of reducing local and regional air pollution is another important incentive for the three countries to control their GHG emissions. Since GHG is mainly emitted through the burning of fossil fuels, reducing carbon emissions will result in the abatement of many other toxic air pollutants. Air pollution in the PRC has drawn international attention in recent years as Chinese cities rank among the most polluted in the world. The transboundary air pollution problem is also complicating the already complex diplomatic relationships among the three countries. Therefore, coordinated regional carbon markets have the potential to mitigate regional air pollution concerns.

The PRC, Japan, and the Republic of Korea have engaged in separate endeavors in controlling GHG emissions. The timing is ripe for the three countries to explore possible carbon market linkage in order to achieve greater efficiency. The benefits of market linkage mainly lie in the following two aspects. First, market linkage in East Asia can increase the cost-effectiveness and stability of carbon markets; different marginal abatement costs among the firms being regulated by each market in different countries can lead to cost savings. A lower cost of climate

mitigation achieved by market linkage can incentivize these countries to engage in more aggressive GHG emission control. Second, geographic proximity is a crucial factor for linkage among the PRC, Japan, and the Republic of Korea. The three countries have close ties in economic exchanges, and a linked carbon market will contribute to these relationships. Consequently, the expanding carbon markets ensure “Factory Asia” will grow in an environmentally sound and climate-friendly manner.

Carbon markets in East Asia could be linked in two ways. The first approach is to link the well-performing markets such as the Shanghai, Beijing, Guangdong, and Shenzhen ETSs in the PRC, and the Tokyo and Saitama ETSs in Japan. These are well-designed pilots in regions with similar levels of economic development. Another approach is to link the carbon markets with similar trading systems. Specifically, Japan and the Republic of Korea have adopted the cap-and-trade system, and the markets within these two countries could be linked more smoothly. However, the PRC’s carbon markets are basically a system of tradable performance standards, which is more difficult to be linked with a cap-and-trade system. Thus, as expected, the power generation industry of the seven pilots in the PRC just started to combine in 2017. In the long term, multilateral links could be achieved in East Asia through establishing cross-regional links and bilateral links.

However, linking these carbon markets still presents major challenges and obstacles. First, heterogeneous and even incompatible market designs across countries makes linkage quite difficult. In particular, the PRC, Japan, and the Republic of Korea have distinct rules on monitoring, reporting, and verification (MRV); allowance allocation; and covered sectors. Second, the potential transboundary wealth transfer among linked markets is another controversial issue. Third, some countries might have incentives to overallocate allowances, which depresses market prices and transaction volumes. Lastly, the linkage could fall victim to geopolitical conflicts and disputes. The successful linkage of East Asian carbon markets needs to overcome these obstacles.

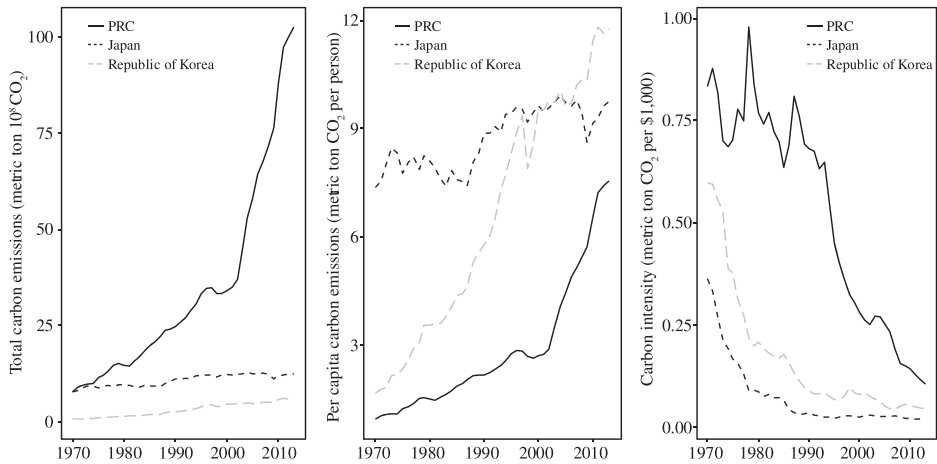
The remainder of the paper proceeds as follows. Section II introduces carbon emissions and international climate treaty participation in East Asia. Section III compares six design elements of carbon markets. Section IV assesses market performances by analyzing general trends of carbon prices and trading volumes. Section V discusses the potential benefits and concerns of linkage in East Asia. Section VI concludes the paper with further discussions.

II. Background

A. Carbon Emissions

The PRC, Japan, and the Republic of Korea are among the major GHG emitters in the world (Figure 1). Japan has had relatively stable total and per capita

Figure 1. Carbon Emissions and Carbon Intensities in the PRC, Japan, and the Republic of Korea



CO₂ = carbon dioxide, PRC = People's Republic of China.

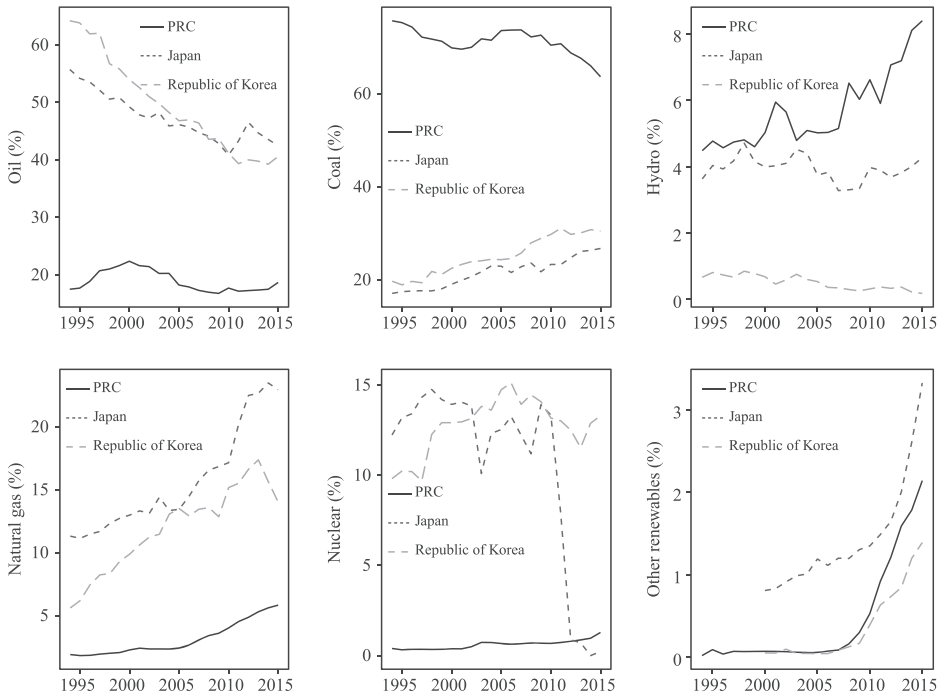
Sources: United States Department of Energy, Carbon Dioxide Information Analysis Center.

emissions since 1970. In comparison, GHG emissions in the PRC have grown dramatically over the past 40 years. The PRC's total emissions were about the same as Japan's in 1970, but had grown to more than 8 times that of Japan's by 2013. The PRC used to have low per capita emissions, but is now quickly approaching Japan's level. Additionally, per capita emissions in the Republic of Korea have grown rapidly and since 2005 it has been the highest per capita emitter among the three countries, averaging 11.75 tons of carbon dioxide equivalent (tCO₂e)/person in 2013. All three countries have massively reduced carbon intensity (emissions per unit of GDP) in the past 3 decades. In 2013, Japan had the lowest carbon intensity (less than 0.03 metric tons of CO₂ per \$1,000), while the PRC had the highest intensity (more than 0.1 metric tons of CO₂ per \$1,000).

GHG emissions are determined by population, per capita income, energy intensity (energy consumption per unit of GDP), and energy mix (emissions per unit energy consumption). While the PRC surpassed Japan in 2010 to become the world's second-largest single-country economy, the PRC's per capita GDP is still much lower than the two developed countries in East Asia. Although, the PRC's per capita GDP growth has been more stable in the last 2 decades.

In terms of energy consumption and energy intensity, the PRC has the largest total energy consumption, with an annual growth rate of about 1.5% since 2000. The Republic of Korea and the PRC had similar per capita energy consumption in 1970, but the Republic of Korea's per capita consumption has since grown much faster than the PRC's. Recently, energy consumption in the Republic of Korea exceeded 5 tons oil equivalent per person, while Japan's per capita energy consumption peaked

Figure 2. Energy Mix for the PRC, Japan, and the Republic of Korea



PRC = People's Republic of China.

Source: Data were obtained from the BP Statistical Review of World Energy.

in 2000. The energy intensity of the PRC is approaching the level of the Republic of Korea, while Japan remains the lowest among the three countries.

Figure 2 illustrates the energy mix for the three countries between 1995 and 2015. Coal accounted for more than 60% of the PRC's total energy consumption during the review period. Although the PRC's coal consumption declined rapidly between 1995 and 2015, it remained much higher than that of Japan and the Republic of Korea. The percentage of natural gas in the energy mix rose in all three countries during the review period. The overall shares of fossil fuels have declined across the three countries. By contrast, renewable energy has gained a share of the energy mix in the past decade in all three countries. The PRC has become the world's largest renewable energy producer. It has the most wind power installations and the highest growth rate in solar power use in the world. As for the share of hydropower in the energy mix, only the PRC has experienced significant growth, while the share in Japan has been stable and it has declined in the Republic of Korea. Furthermore, Japan's nuclear power industry collapsed in 2011 after the Fukushima nuclear accident.

Table 1. Commitments of the PRC, Japan, and the Republic of Korea in Major Climate Treaties

| Treaty | PRC | Japan | Republic of Korea | Target Year |
|-------------------|--|--|--|-------------|
| Kyoto Protocol | No requirement | Reduce emissions by 6% compared to 1990 | No requirement | 2012 |
| Copenhagen Accord | Reduce emissions intensity by 40%–45% compared to 2005 | Reduce emissions by 25% compared to 1990 | Reduce emissions 30% below the BAU level | 2020 |
| Paris Agreement | Peak emissions around 2030 | Reduce emissions by 26% compared to 2013 | Reduce emissions 37% below the BAU level | 2030 |

BAU = business as usual, PRC = People's Republic of China.

Sources: The State Council of the People's Republic of China (2013); and Environmental Defense Fund, Institute for Global Environmental Strategies, and Climate Challenges Market Solutions (2016a, 2016b).

B. Participation in Climate Treaties

The PRC, Japan, and the Republic of Korea have joined major international climate treaties and taken various domestic actions to control carbon emissions. The most important international climate agreements include the United Nations Framework Convention on Climate Change, Kyoto Protocol, Copenhagen Accord, and Paris Agreement. Table 1 lists the emission targets of the PRC, Japan, and the Republic of Korea under these last three climate treaties.

Following the principle of common but differentiated responsibilities in the United Nations Framework Convention on Climate Change, the Kyoto Protocol signed in 1997 set legally binding quantified emission limitations and reduction targets for Annex B parties, which are mainly industrialized countries. Japan was required to reduce emissions by 6% before 2012 compared to its 1990 level. The non-Annex B parties, such as the PRC, have no obligations to control emissions in the early stage. However, developing countries can be involved through the Clean Development Mechanism (CDM), which is a project-based carbon market that allows developed countries to partially comply with their emission reduction targets by investing in qualified mitigation projects in developing countries. The Republic of Korea is also a non-Annex B party under the Kyoto Protocol because it was not a member of the developed country club when the treaty was being negotiated.

The Copenhagen Accord signed in 2009 requires signatories to submit emission targets, but these pledges are not legally binding. In this agreement, the PRC pledged to reduce its carbon intensity, measured by emissions per unit of GDP, by 40%–45% by 2020 compared to the 2005 level (Yang, Zhang, and Wang 2018). Japan pledged to reduce carbon emissions by 25% from the baseline of 1990, while the Republic of Korea aimed to reduce its GHG emissions by 30% from the BAU level by 2020.

In addition to the above international treaties, the 2016 Paris Agreement is the first comprehensive climate treaty that requires the actions of both developed and developing countries. Each country determines and regularly reports its own contribution to global climate mitigation. The contributions of each country to achieve the global climate target are called nationally determined contributions. However, there is no enforcement mechanism for a country to set a specific target by a specific date, but all the participants are required to draw up stricter targets than their previous ones.

As part of the Paris Agreement, the PRC pledged that its carbon emissions would peak no later than 2030, and that it would reduce its emission intensity by 60%–65% from the 2005 level. In addition, nonfossil fuel energy should account for around 20% of total energy consumption, and forest coverage will rise to 4.5 billion cubic meters. Japan pledged to reduce GHG emissions by 26% by 2030 compared to the 2013 level. Furthermore, emissions of energy-originated CO₂ should eventually be reduced by 25%. The Republic of Korea also planned to reduce its GHG emissions by 37% from the BAU level across all economic sectors before 2030.

III. Comparison of Key Design Elements

A. Overview of Carbon Markets

The PRC, Japan, and the Republic of Korea have started piloting ETSs to limit GHG emissions in recent years. The PRC launched seven municipal or provincial carbon markets in 2013. The first phase of the experiment covered all four direct-controlled municipalities (Beijing, Shanghai, Tianjin, and Chongqing); two provinces (Guangdong and Hubei); and one special economic zone (Shenzhen). The total regulated emissions are about 1.2 billion tons of CO₂, or about 11.4% of total national emissions. At the end of 2017, the PRC launched the national carbon market that only covers the power generation industry. Japan established the Tokyo ETS in 2010 and the Saitama ETS in 2011. Tokyo is the largest municipality in Japan with annual emissions of 67.3 metric tons of CO₂e; the annual emissions of Saitama total 38.5 metric tons of CO₂e. The Republic of Korea launched its nationwide ETS in 2015, which covers 525 business entities that are together responsible for 68% of national GHG emissions.

The three countries have distinctive characteristics in terms of economic development and energy consumption. The PRC has the lowest GDP per capita (\$7,400) and the highest energy intensity. The Republic of Korea is approaching Japan in some key economic and energy indicators. Although energy intensity is not a perfect indicator for energy efficiency, combining many other factors such as higher GDP per capita and a lower percentage for the secondary industry that reflect a higher industrialized economy, Japan is comparably more energy efficient.

Table 2. Carbon Intensity Reduction Targets and Total Allowances Issued

| Country | Region | By 2015 | By 2020 | By 2030 | Annual Allowances | |
|-------------------|-------------------|----------|---------|---------|----------------------|---------------|
| PRC | Beijing | 18.0% | 38.5% | nil | 5.5 mt | |
| | Shanghai | 19.0% | 39.5% | nil | 510 mt (for 3 years) | |
| | Tianjin | 19.0% | 39.5% | nil | 100 mt | |
| | Chongqing | | 17.0% | 36.5% | nil | 131 mt (2013) |
| | | | | | | 126 mt (2014) |
| | | | | | | 121 mt (2015) |
| | Guangdong | | 19.5% | 40.0% | nil | 388 mt |
| | | Hubei | 21.0% | 40.5% | nil | 324 mt |
| | | Shenzhen | 17.0% | 37.5% | nil | 30 mt |
| Japan | Tokyo | 10.0% | 39.0% | nil | 56 mt (2014) | |
| | Saitama | nil | 22.4% | nil | 33 mt (2014) | |
| Republic of Korea | Republic of Korea | nil | 42.5% | 56.0% | 573 mt (2015) | |
| | | | | | 562 mt (2016) | |
| | | | | | 559 mt (2017) | |

mt = metric ton, nil = data are not available or applicable, PRC = People's Republic of China.

Sources: The State Council of the People's Republic of China (2013, 2016); International Carbon Action Partnership (2017a, 2017b, 2017c); and Government of the Republic of Korea, Ministry of Environment (2016).

With respect to regional markets, Beijing, Shanghai, and Shenzhen are prosperous metropolises in the PRC, as the three pilots have relatively higher levels of GDP per capita (above \$14,500) and lower levels of energy intensity (below 3 tons of standard coal equivalent [tce] per \$10,000).¹ Among the carbon markets, Tokyo is one of the most developed cities in the world, with GDP per capita of \$63,789 and energy intensity of 0.25 tce per \$10,000 in 2014. Some Chinese cities (Beijing, Shanghai, and Shenzhen) have similar levels of economic development as the Republic of Korea and Saitama; hence, their carbon markets are possibly more comparable.

B. Emission Targets and Allowances

Each carbon market has set its emission target to a certain degree (Table 2). In general, the PRC aims for the most ambitious intensity reduction targets, compared with Japan and the Republic of Korea, because of its higher carbon intensity at the baseline stage. Based on the emission intensity targets, each pilot determines the amount of its annual emission allowance.

In the near-term, Japan set a moderate target to reduce its carbon intensity (10% for Tokyo by 2015) because its energy efficiency was already advanced. For example, Japan's industrial sectors, such as steel and cement, have attained the world's highest level of energy efficiency. The Research Institute of Innovative Technology for the Earth (2008) finds fossil fuel power generation in Japan has

¹Energy intensity indicates the amount of output (normally measured in terms of GDP) given an amount of energy input. Based on this definition, the unit for energy intensity is tce per \$10,000. A smaller number for this indicator suggests greater economic benefits and higher energy utilization.

achieved one of the highest levels of energy efficiency among all developed countries. Hence, it is challenging for Japan to make further improvements.

In the aftermath of the Fukushima nuclear accident, the phasedown of nuclear power further limited the options for Japan to reduce its emissions. In 2012, Japan's nuclear power generation dropped to zero. However, in the long term, with booming energy demand, especially in the summer months, the supply of nuclear energy will resume under stricter regulations. Therefore, Tokyo seeks to achieve a more ambitious target with a 39% reduction in carbon intensity by 2020.

C. Covered Sectors

The three countries cover a wide range of industrial sectors with slight variations. The Republic of Korea and the PRC mainly focus on energy, transport, and building industries. Japan regulates almost all industrial sectors and some commercial sectors (Table 3).

The regulated entities are determined by the magnitude of their emissions or energy consumption. All pilots in the PRC except Hubei use annual emissions as the threshold; using energy consumption as the threshold is mainly due to concerns over data availability (Zhang, Wang, and Du 2017). The Republic of Korea uses annual emissions of 150 kilotons as the threshold. The threshold for the two pilots in Japan is 1,500 kiloliters of crude oil equivalent.

Overall, the Republic of Korea's ETS covers the highest percentage of total emissions. The PRC's regional ETS pilots cover 33%–60% of municipal or provincial emissions. Japan's two ETSS cover the lowest percentages: Tokyo's carbon market covers 20% of emissions and Saitama's covers only 18%.

D. Allowance Allocation

Allowances can be allocated using benchmarking, grandfathering, or auction. By setting performance standards, benchmarking rewards environmentally friendly entities and penalizes inefficient ones. It is also a useful way to measure the emission performances of peer firms. Benchmarks can be set through several approaches, among which the most popular is to follow the European Union (EU) ETS by establishing the 10% most efficient installations as a benchmark. Grandfathering allocates allowances according to historical emissions or intensities. Auction assigns allowances to the highest bidder, which is preferred by many researchers because it can quickly discover marginal social abatement costs.

The methods of allowance allocation for each carbon market are summarized in Table 4. Most pilots in the PRC use grandfathering, except for the electricity and cement sectors in Beijing, Guangdong, Shanghai, Shenzhen, and Tianjin, which use benchmarking. Guangdong is the PRC's only regional ETS that auctions partial allowances, but the percentage of allowances by auction is below 3%. Similarly, the

Table 4. Allowance Allocation

| Country | Region | Benchmarking | Grandfathering | Auction |
|-------------------|-------------------|---|-------------------|--|
| PRC | Beijing | New entrants | Existing entities | |
| | Shanghai | Electricity, aviation, airports, ports | Other sectors | |
| | Tianjin | Electricity, heating | Other sectors | |
| | Chongqing | | All sectors | |
| | Guangdong | Electricity, cement, iron and steel | Other sectors | 8 mt (2.06% in 2014), 2 mt (0.51% in 2015) |
| | Hubei | | All sectors | |
| | Shenzhen | Electricity, heating, water supply, manufacturing | Other sectors | |
| Japan | Tokyo | | All sectors | |
| | Saitama | | All sectors | |
| Republic of Korea | Republic of Korea | Cement, oil refinery, aviation | Other sectors | 0% 2015–2017, 3% 2018–2010, >10% 2021–2025 |

mt = metric ton, PRC = People's Republic of China.

Sources: Information compiled from official documents and relevant reports from 10 carbon markets, including Beijing Development and Reform Commission (DRC) (2014); China-Beijing Environmental Exchange (2014); General Office of the Beijing People's Government (2013, 2014); Chongqing DRC (2014); Hubei DRC (2014); Shanghai DRC (2013); Guangdong DRC (2013); Tianjin DRC (2013); Tianjin People's Government (2013); Shanghai People's Government (2013); Committee of the Shenzhen People's Congress (2012); Hubei People's Government (2013); Chongqing People's Congress (2014); and International Carbon Action Partnership (2017c).

Republic of Korea mainly uses benchmarking and grandfathering. Benchmarking is mainly applied to cement, oil refineries, and aviation, while grandfathering is used in other sectors. Furthermore, the Republic of Korea plans to auction allowances in the coming years, with the percentage of allowances awarded via auction increasing to 10% by 2025. In Japan, grandfathering has been adopted for all sectors at the current stage.

E. Monitoring, Reporting, and Verification

The PRC, Japan, and the Republic of Korea have each established their own MRV systems to ensure credible emission reductions. Table 5 summarizes the key features of MRV in each ETS. At the national level, the PRC's Standardization Administration has published general guidelines for GHG emissions accounting, with detailed protocols for 10 industries having been finalized. Some Chinese pilots require the covered firms to submit their monitoring plans, including the boundaries for emissions accounting. This may help to improve the quality of MRV.

The Government of the Republic of Korea issued a national decree to standardize the MRV system. Different from the PRC, after the third-party verifier has verified the report, it is submitted to a competent authority. Then, the competent authority is responsible for validating the report. If the company fails to submit

Table 5. Monitoring, Reporting, and Verification

| Country | Region | Threshold for Reporting | Threshold for Verification |
|-------------------|-------------------|---|---|
| PRC | Beijing | Energy consumption >2,000 tce | > 10 kt |
| | Shanghai | > 10 kt | > 20 kt |
| | Tianjin | > 10 kt | > 20 kt |
| | Chongqing | > 20 kt | > 20 kt |
| | Guangdong | > 10 kt or energy consumption > 5,000 tce | > 20 kt or energy consumption > 10,000 tce |
| | Hubei | Energy consumption > 60,000 tce | Energy consumption > 60,000 tce |
| | Shenzhen | > 1 kt | Industries > 1 kt Public buildings > 10 kt |
| Japan | Tokyo | 1,500 kl of crude oil | 1,500 kl of crude oil |
| | Saitama | 1,500 kl of crude oil | 1,500 kl of crude oil |
| Republic of Korea | Republic of Korea | Total emissions > 125 kt or facility emissions > 25 kt | Total emissions > 125 kt or facility emissions > 25 kt |

kl = kiloliter, kt = kiloton, PRC = People's Republic of China, tce = ton of standard coal equivalent.

Sources: Information compiled from the official documents and relevant report from 10 carbon markets, including Beijing Development and Reform Commission (DRC) (2014); China Beijing Environment Exchange (2014); General Office of the Beijing People's Government (2013, 2014); Chongqing DRC (2014); Hubei DRC (2014); Shanghai DRC (2013); Guangdong DRC (2013); Tianjin DRC (2013); Tianjin People's Government (2013); Shanghai People's Government (2013); Committee of the Shenzhen People's Congress (2012); Shenzhen Department of Housing and Urban-Rural Development (2013); Hubei People's Government (2013); Chongqing People's Congress (2014); and International Carbon Action Partnership (2017c).

the requested report, the authority shall conduct the fact-finding survey and only certify the actual amount of GHG emissions. Thus, the duty of report verification is transferred from the third-party verifier to the government. In Japan, besides reporting annual emissions, the covered firms shall also report their emission reduction plans to the government.

F. Compliance and Enforcement

The carbon markets in the three countries have different built-in penalties for noncompliance (Table 6). The entities that are eligible for an allowance allocation are required to keep their total emissions below the caps. This is a mandatory obligation.

In cases of violating MRV protocols or noncompliance with the emission target, financial and other penalties are applied in two stages. In the first stage, the regulators in Beijing, Tianjin, Chongqing, Guangdong, Tokyo, and the Republic of Korea order the entities to correct their excessive emissions. The Tokyo ETS orders the entities to reduce emissions by the amount of the shortfall multiplied by 1.3. Beijing, Shanghai, and Guangdong adopt financial penalties for failing to comply with the MRV protocols. Some pilots in the PRC also apply other penalties, including recording noncompliance in the business credit report system,

Table 6. Penalties for Noncompliance

| Country | Region | Financial Penalty | Deduction from Allowance |
|-------------------|------------------------------|---|--------------------------|
| PRC | Beijing | 3–5 times | Yes |
| | Shanghai | CNY50,000–CNY100,000 | |
| | Tianjin | | |
| | Chongqing | 3 times | Yes |
| | Guangdong | CNY50,000 | |
| | Hubei | 3 times but not to exceed CNY150,000 | |
| Japan | Shenzhen | Up to 3 times | Yes |
| | Tokyo | ¥500,000 and a surcharge of 1.3 times the shortfall | |
| Republic of Korea | Saitama Republic of Korea | Up to 3 times but not to exceed \$91 per ton of CO ₂ e | Yes |

¥ = yen, CNY = yuan, CO₂e = carbon dioxide equivalent, PRC = People's Republic of China.

Sources: Information compiled from official documents and relevant reports from 10 carbon markets, including Beijing Development and Reform Commission (DRC) (2014); China Beijing Environment Exchange (2014); General Office of the Beijing People's Government (2013, 2014); Chongqing DRC (2014); Hubei DRC (2014); Shanghai DRC (2013); Guangdong DRC (2013); Tianjin DRC (2013); Tianjin People's Government (2013); Shanghai People's Government (2013); Committee of the Shenzhen People's Congress (2012); Hubei People's Government (2013); Chongqing People's Congress (2014); and International Carbon Action Partnership (2017c).

annulling the qualification for government support, and recording noncompliance in the performance appraisal system for state-owned enterprises. In the second stage, any noncompliance by entities will be subject to financial penalties and possible surcharges, except in the Tianjin and Saitama ETs. Other penalties are also adopted by more carbon markets at this stage.

Financial penalties are the most common measures taken by all ETs. In this case, the regulators charge various financial penalties according to the market value of the excessive emissions, except in Guangdong. Nonfinancial penalties also play a crucial role. The deduction of the excessive emissions from future allowances can also be a credible threat because of the increasing difficulties in future compliance. Recording noncompliance in the business credit report system will increase an entity's cost of financing in financial markets. The Government of the PRC gives fewer grants and less support to entities that either violate MRV protocols or do not comply with the emission allowance.

G. Offset Market

Offsets may be used to meet compliance obligations in the PRC, Japan, and the Republic of Korea (Table 7). In the PRC, the voluntary emission trading market generates China Certified Emissions Reductions (CCERs). Like CDM, the CCER market is a project-based offset market that is dominated by wind, small hydropower, solar photovoltaic, and forest carbon sinks. Eligible entities can use CCER offsets, but the PRC's regional pilots limit the use of offset credits in terms

Table 7. Requirements of Using Offset Credits

| Country | Region | Offset Credit | Limit | Local Source | Other Restrictions |
|---------|-----------|--|---|--|--|
| PRC | Beijing | CCER; energy conservation and forestry offsets | <5% of allowance | >50% from Beijing | Offsets generated after 1 January 2013, excluding industry, gas, and hydro projects |
| | Shanghai | CCER | <5% of allowance | Not from covered firms | Offsets generated after 1 January 2013 |
| | Tianjin | CCER | <10% of verified emissions | Priority for Beijing, Tianjin, and Hubei offsets | Excluding hydro and pre-CDM projects |
| | Chongqing | CCER | <8% of verified emissions | | Offsets generated after 31 December 2010 (except for carbon sinks); excluding hydro projects |
| | Guangdong | CCER | <10% of verified emissions | >70% from Guangdong | >50% from CO ₂ and CH ₄ , excluding hydro, fossil fuel, and pre-CDM projects |
| | Hubei | CCER | <10% of allowance | All | Only small hydro |
| | Shenzhen | CCER | <10% of verified emissions | | Offsets from renewables, clean transport, ocean, forestry offsets, and agriculture |
| | Tokyo | Small and Midsize Facility Credit | Without limit | Within Tokyo | Generated since FY2010 |
| | | Renewable Energy Certificate | Without limit | Either within or outside Tokyo | Issued in and after FY2008 |
| | | Outside Tokyo Credit | Up to one-third of the reduction amount | Outside Tokyo | Emission reductions since 2010 |
| Japan | Saitama | Saitama Credit | Without limit | Outside Tokyo | Emission reductions since 2010 |
| | | Small and Midsize Facility Credit | Without limit | Within Saitama | Generated in Saitama since FY2011 |
| | | Outside Saitama Credit | Up to one-third (offices), or to one-half (factories) | Outside Saitama | Generated from large facilities from FY2015 |
| | | Renewable Energy Credit | Without limit | Either within or outside Saitama | Credits from solar (heat, electricity), wind, geothermal, or Hydro (under 1,000 kW) |
| | | | | | electricity production are counted at 1.5 times the value of regular credits. |

Continued.

Table 7. *Continued.*

| Country | Region | Offset Credit | Limit | Local Source | Other Restrictions |
|-------------------|-------------------|--------------------------|---|---|---|
| | | Forest Absorption Credit | Without limit | Either in or outside Saitama | Credits from inside the Saitama Prefecture are counted at 1.5 times the value of regular credits |
| | | Tokyo Credit | Without limit | Outside Saitama | Excess Credits from TMG ETS from FY2015, Small and Midsize Facility Credits issued by TMG ETS from FY2012 |
| Republic of Korea | Republic of Korea | KCU | <10% of allowance, international credit <5% (phase III) | Domestic (phases I and II), international offsets permitted (phase III) | Activities implemented after 14 April 2010 |

CCER = China Certified Emissions Reductions, CDM = Clean Development Mechanism, CH₄ = methane, CO₂ = carbon dioxide, FY = fiscal year, KCU = Korea Credit Unit, kW = kilowatt, PRC = People's Republic of China, TMG ETS = Tokyo Metropolitan Government Cap-and-Trade Program.
 Sources: Information compiled from official documents and relevant reports from 10 carbon markets, including Beijing Development and Reform Commission (DRC) (2014); China-Beijing Environmental Exchange (2014); General Office of the Beijing People's Government (2013, 2014); Chongqing DRC (2014); Hubei DRC (2014); Shanghai DRC (2013); Guangdong DRC (2013); Tianjin DRC (2013); Tianjin People's Government (2013); Shanghai People's Government (2013); Committee of the Shenzhen People's Congress (2012); Hubei People's Government (2013); Chongqing People's Congress (2014); and International Carbon Action Partnership (2017c).

of percentage, location, and issuing date. In Japan, offset credits from emission reduction activities in small and midsize facilities are qualified, including the credits from activities outside Tokyo and Saitama. Renewable energy credits can be used without limits. Forest credits are also qualified in the Saitama ETS. Meanwhile, the Korean ETS comprises three phases: phase I (2015–2017), phase II (2018–2020), and phase III (2021–2025). Domestic offset credits are only allowed in phases I and II for non-ETS entities.

Although offsets can reduce an entity's cost of compliance by providing access to a greater set of cost-effective mitigation opportunities, the use of offset credits is often constrained. All ETSs in the PRC and the Republic of Korea limit the proportion of offset credits in the total allowances. In contrast, many offsets in the Tokyo and Saitama ETSs can be used without limits.

IV. Market Performances

The PRC, Japan, and the Republic of Korea have set up institutions for carbon emissions trading. In the PRC, each of the seven pilots owns a local carbon exchange. In Japan, the Tokyo Metropolitan Government Cap-and-Trade Program defines reduction obligations in Japan; Tradable Reduction Credits are released only if these obligations are exceeded. Thus, the emission right is granted for free. Besides Tradable Reduction Credits, four sorts of offset markets are also traded on the Tokyo Metropolitan Government Cap-and-Trade Program ETS and another five are dealt in the Saitama ETS. In the Republic of Korea, three types of credits are available in its secondary market: Korea Allowance Units (KAUs), Korea Offset Credits (KOCs), and Korea Credit Units (KCU). The Korea Exchange is the official trading market designated by the Government of the Republic of Korea.² In principal, only KAUs and KCUs can be traded on the Korea Exchange, while KOCs are traded over the counter.

Carbon prices in the PRC and Japan follow a similar pattern: the price rises at the opening stage of a carbon market and then declines gradually. In contrast, the carbon price in the Korean ETS kept rising in its first compliance year, which could be due to more stringent allowance allocation. Table 8 reports the average carbon price of each market. Due to data limitations, the carbon prices in Japan and the Republic of Korea are only partly available. Among the three countries, the PRC's market stays at the lowest price, with a price-declining trend from \$6.92/tCO₂e in 2013 to \$3.38/tCO₂e in 2016. The average carbon prices in Shenzhen and Beijing in 2016 were higher than in the PRC's other five pilots at \$5.85/tCO₂e and \$7.05/tCO₂e, respectively. Japan had the highest average carbon price in 2015 at

²KAUs are allowances allocated to firms according to emission targets under the Korean ETS. KOCs are credits that are mainly issued from offset markets authorized by the government. KCUs are credits that transform from KOCs, but they cannot be transformed back to KOCs (Environmental Defense Fund, Institute for Global Environmental Strategies, and Climate Challenges Market Solutions 2016a).

Table 8. Annual Carbon Prices

| Country or Region | Average Price | Country or Region | Average Price |
|-------------------|---------------|-------------------|--------------------|
| Beijing | \$7.70 (2013) | Hubei | \$3.41 (2014) |
| | \$8.16 (2014) | | \$3.65 (2015) |
| | \$6.93 (2015) | | \$2.71 (2016) |
| | \$7.05 (2016) | | |
| Shanghai | \$4.45 (2013) | Shenzhen | \$9.11 (2013) |
| | \$5.71 (2014) | | \$8.69 (2014) |
| | \$3.17 (2015) | | \$6.00 (2015) |
| | \$1.24 (2016) | | \$5.85 (2016) |
| Tianjin | \$4.38 (2013) | PRC | \$6.92 (2013) |
| | \$4.28 (2014) | | \$6.06 (2014) |
| | \$3.31 (2015) | | \$4.16 (2015) |
| | \$2.08 (2016) | | \$3.38 (2016) |
| Chongqing | \$4.60 (2014) | Japan | \$31.50 (2015) |
| | \$3.15 (2015) | | nil |
| | \$1.96 (2016) | | nil |
| Guangdong | \$7.54 (2014) | Republic of Korea | \$14.60 (2015) |
| | \$2.92 (2015) | | \$18.03 (2017) |
| | \$2.02 (2016) | | \$20.66 (Jan 2018) |

nil = data are not available or applicable, PRC = People's Republic of China.

Sources: The data for the PRC's carbon prices are available from the Carbon Market Analysis Platform. <http://k.tanjiaoyi.com/> (accessed August 1, 2017). The data for the Republic of Korea's carbon prices in 2017 are available from the Korea Exchange. <http://ets.krx.co.kr> (accessed July 26, 2017). The data for Japan's carbon prices are from Environmental Defense Fund, Institute for Global Environmental Strategies, and Climate Challenges Market Solutions (2016a).

\$31.50/tCO₂e. The Republic of Korea's average carbon prices in 2015 and 2017 were \$14.60/tCO₂e and \$18.03/tCO₂e, respectively.

In summary, the PRC is still at a very early stage of carbon market experimentation. The allowances are generally abundant across the seven pilots. Once the regulated companies realized this, the price, as expected, declined. Tokyo's declining carbon price could be mainly due to energy-saving activities, especially after the Tohoku Earthquake and the nuclear meltdown in Fukushima in 2012. The allowance allocation in the Republic of Korea was not sufficient in 2015. Thus, the Government of the Republic of Korea released 900,000 tCO₂e of allowances between June 2015 and June 2016 to stabilize the market. Recently, the Republic of Korea published its carbon emission target for 2018 (0.54 billion tons of CO₂e), which is a 2.3% reduction compared with 2017.

Trading volume is another important indicator to assess the performance of a carbon market. Both the PRC and the Republic of Korea have observed dramatic increases in carbon allowance trading before the compliance date of each year. The volatility of trading volume around the compliance date in the PRC and Republic of Korea might be caused by (i) carbon markets in both countries banning third-party participants, which could decrease market liquidity; (ii) regulated companies having more flexibility in the PRC and the Republic of Korea, which may encourage them

to bank the credits rather than make transactions; and (iii) both countries being in their early stage of emission trading, with companies taking full advantage of trading opportunities. As for the Japanese ETSs, detailed secondary market information is not available except for the annual volume of transactions, which steadily increased from 2011 to 2015.

V. Linking Carbon Markets

A. Incentives for Market Linkage

The PRC, Japan, and the Republic of Korea can together build a strong regional economy. Furthermore, the three countries have already collaborated on energy and environmental issues over the past 3 decades. As early as the late 1980s, the PRC and Japan started to work together on natural gas development through Japanese Official Development Assistance. Since then, more areas of environmental collaboration have been initialized. The three countries have strengthened cooperation in recent years by forming regional agreements such as the Acid Deposition Monitoring Network in East Asia, Tripartite Environment Ministers Meeting, and Long-Range Transboundary Air Pollutants in East Asia. These existing cooperative programs paved the way for the three countries to link their carbon markets. In the long term, linked East Asian carbon markets have the potential to rebalance international carbon markets, implement global climate policies, and stimulate regional economic prosperity (Massetti and Tavoni 2012).

It is crucial for the PRC, Japan, and the Republic of Korea to strengthen cooperation in tackling climate change for the following three reasons. First, manufacturing is the key industry in each of the three countries. Regional climate collaboration ensures that no country will intend to make their manufacturing sector more competitive by relaxing climate regulations, thus avoiding the concern of a race to the bottom. Second, the collaboration will send a strong signal to the world about the determination of East Asian countries in mitigating climate change. This is particularly crucial for global climate governance after the United States announced its withdrawal from the Paris Agreement. Third, it will also benefit the regional environment. The deterioration of regional air quality has become a contentious debate among the three countries. The cobenefits of climate actions will help the region to improve air quality and solve potential environmental conflicts.

To date, East Asian countries have had limited regional collaboration on climate change, mainly through the Kyoto Protocol. In particular, the CDM plays an important role in climate actions, in which the PRC and the Republic of Korea were the host countries of CDM projects and Japan was an investor. Although the CDM was not designed for regional climate cooperation, its implementation provided important experiences for establishing interconnected carbon markets in the region. Furthermore, the CDM shed light on the indirect linkage between cap-and-trade

and emission-reduction-credit systems. Building upon the climate collaboration initialized by the CDM, linkage among the existing trading systems of the PRC, Japan, and the Republic of Korea can create an additional climate cooperation channel (Perdan and Azapagic 2011).

The PRC, Japan, and the Republic of Korea have engaged in separate endeavors in establishing carbon markets to curb their GHG emissions. Market linkage should become an important policy option for collaboration on this notable market-based instrument (Flachsland, Marschinski, and Edenhofer 2009). Carbon market linkage is associated with economic, environmental, and strategic benefits. From the economic perspective, linkage creates a cost-effective system for firms to reduce the cost of compliance. Heterogeneities among the firms being regulated by each market suggest different marginal abatement costs. This creates an opportunity for improving cost-efficiency and achieving the minimum cost in reducing carbon emissions (Stavins 2016). For example, the ETS with higher marginal abatement costs can benefit from purchasing relatively inexpensive allowances from other ETSs, thus achieving emission reduction goals at a lower cost. The differences among the PRC, Japan, and the Republic of Korea make inter-ETS trading appealing. The EU's ETS provides a good case study of where the heterogeneous size of installations enables cost savings for a unified market (Trotignon and Delbosc 2008).

In the long term, carbon market linkage can increase the liquidity of markets and decrease the volatility of prices because networked markets are broadened with more buyers and sellers, especially for those small-scale carbon markets. Admittedly, individual winners and losers exist within one linked market. Generally speaking, linked markets reduce regional costs of compliance and ultimately achieve reduction targets at the minimized cost.

The three East Asian countries are well positioned to link their carbon markets because of geographic proximity, which is an important strategic benefit in creating a universal linked market (Ranson and Stavins 2015). Geographic proximity can facilitate information interchanges. The similarity in cultures could also enhance mutual trust in climate collaboration. In this case, East Asian countries are geographically and culturally close to each other and therefore likely to link. Further, carbon market linkage among the three countries could foster cooperation in other aspects, for instance in international trade and investment.

B. Roadmap of Linkage

Climate collaboration mainly includes top-down (among governments) and bottom-up (among regions and firms) channels, with linkage belonging to the latter case (Jaffe, Ranson, and Stavins 2009). The bottom-up development of climate policy leads to fragmented carbon markets, which can be indirectly linked or formally linked (Flachsland, Marschinski, and Edenhofer 2009). This section

focuses on the roadmap for carbon market linkage in East Asia, accounting for the heterogeneous market designs that have been introduced in the previous sections. Specifically, we explore the possibility of evolving from unilateral markets to multilateral links, and propose frameworks for direct and indirect linkages.

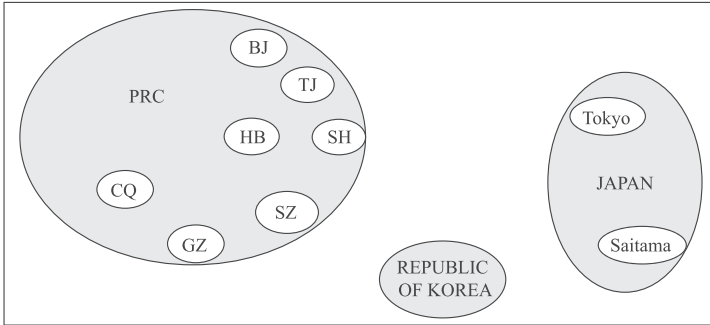
The complexity of market linkage is partly caused by different types of tradable permit systems. Japan and the Republic of Korea adopt the cap-and-trade system; the PRC adopts the tradable-performance-standard system. The direct linkage of cap-and-trade systems is common and economically viable (Montagnoli and de Vries 2010). Alternatively, indirect linkage across cap-and-trade and tradable-performance-standard systems is also conceivable but with uncertain results (Reuters 2012). For example, industrialized countries obtain carbon credits by investing mitigation projects in developing countries in the CDM. However, it is challenging to demonstrate that the proposed project results in real emission reductions compared with the baseline scenario. Nevertheless, linkage between the PRC and Japan could still be possible with an appropriate mechanism design. Jaffe, Ranson, and Stavins (2009) argued that mutual recognition and unified policy design are notable issues that can determine the possibility of linking.

In addition to the conceptual debate, there exists a large strain of literature that uses models to assess the possibility of linking carbon markets in Asia. For instance, Calvin, Fawcett, and Jiang (2012) and Calvin et al. (2012) evaluated the economic and environmental impacts of climate mitigation under the framework of the Asia Modeling Exercise, which provides insight for the consequence of linking heterogeneous carbon markets. Paltsev et al. (2012) investigated various scenarios of mitigating carbon emissions and their impacts on economic growth in the PRC. Their result suggests that the PRC has played a crucial role in climate collaboration and market linkage within Asia. Hübler, Löschel, and Voigt (2014) employ computable general equilibrium models to compare different climate policy scenarios for the PRC, highlighting the economic gains of linking the PRC's ETS to the EU's ETS.

Carbon market linkage can be implemented at the international, national, or regional level. It is beneficial to start from piloting subnational market linkage, which will engender economic, environmental, and strategic benefits. Currently, carbon markets in the PRC, Japan, and the Republic of Korea are unilateral without any linkage. Figure 3 plots each carbon market in the three countries. Japan is home to two carbon markets, while the Republic of Korea has one nationwide market. Although the Government of the PRC is establishing a national emission trading system, the national carbon market will not be fully functioning until 2020 and the seven provincial pilots are not currently linked with each other. Therefore, the seven carbon market pilots in the PRC are treated unlinked, but they are expected to be unified in a couple of years.

There are mainly two pathways for developing a cluster of carbon markets in East Asia. One approach is for the well-behaved carbon markets to establish two-way or one-way linkages. In Figure 4a, we suggest the ETSs in Beijing,

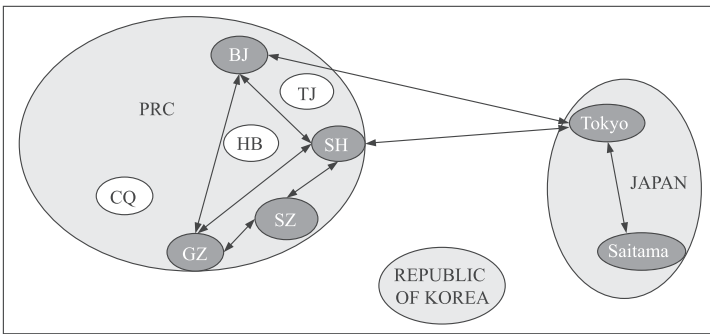
Figure 3. Unilateral Carbon Markets in the PRC, Japan, and the Republic of Korea



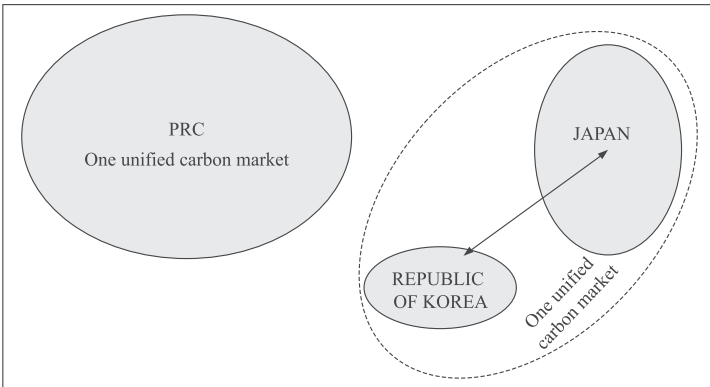
BJ = Beijing, CQ = Chongqing, GZ = Guangzhou, HB = Hubei, PRC = People's Republic of China, SH = Shanghai, SZ = Shenzhen, and TJ = Tianjin.
 Source: Authors' illustration.

Figure 4. Cross-Regional Links between the PRC, Japan, and the Republic of Korea

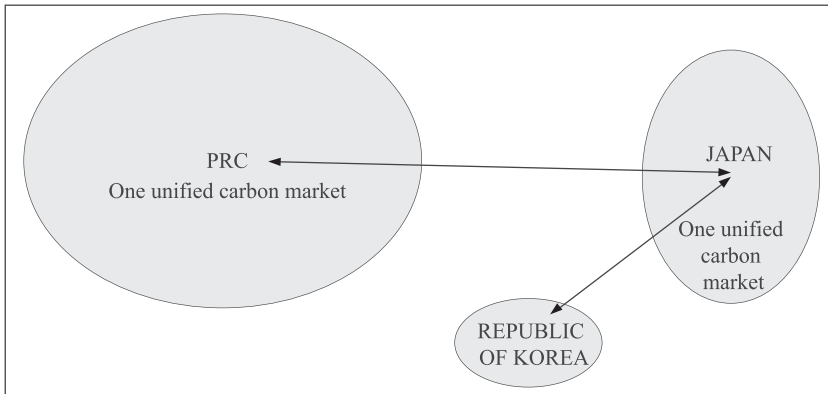
(a) Well-developed markets links



(b) Same tradable permit system markets links



BJ = Beijing, CQ = Chongqing, GZ = Guangzhou, HB = Hubei, PRC = People's Republic of China, SH = Shanghai, SZ = Shenzhen, and TJ = Tianjin.
 Source: Authors' illustration.

Figure 5. **Chained Bilateral Links in the PRC, Japan, and the Republic of Korea**

PRC = People's Republic of China.

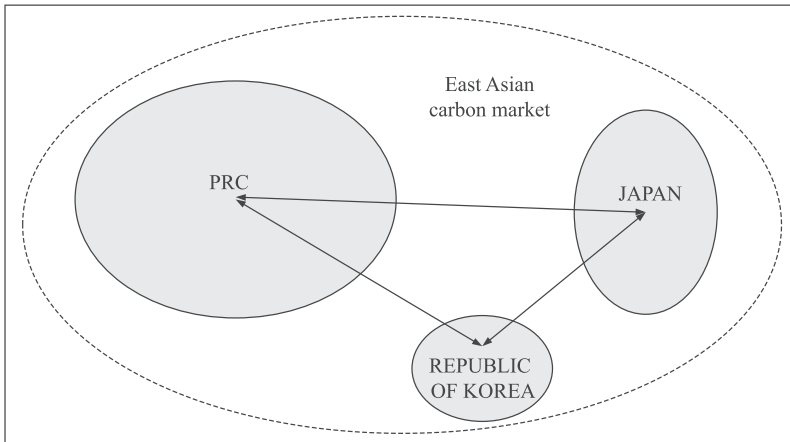
Source: Authors' illustration.

Shanghai, Guangdong, and Shenzhen show potential opportunities for linking within the PRC. Those four pilots could also be linked with the carbon markets in Tokyo and Saitama. These cities tend to set ambitious targets on emission reductions and have the ability to accomplish such goals. Alternatively, carbon markets under the same tradable permit system could link first, which is less challenging and has a lower risk (Figure 4b). Since both Japan and the Republic of Korea adopt the cap-and-trade system, they can start working together by promulgating compatible market regulations. Similarly, the seven pilots in the PRC could successfully combine into a national carbon market first.

The linkages above lead to chained bilateral links in which Japan builds a two-way linkage with the PRC and the Republic of Korea. The bilateral relationships set a promising vision for a fully linked carbon market in the final stage. Carbon markets in the PRC and the Republic of Korea can also be indirectly linked, as shown in Figure 5, with Japan as the common partner. However, this linkage is also associated with risks since either of the original linking partners can link with a third party; therefore, both of the original participants could access new and unlimited supplies of allowances from the third party. This indirect system becomes less efficient as the transaction costs gradually grow, but more firms could gain from the bilateral linkage in various aspects. The trade-offs between indirect linkage and direct linkage are discussed by Jaffe, Ranson, and Stavins (2009) in detail.

Consequently, Figure 6 illustrates full multilateral links between the PRC, Japan, and the Republic of Korea. Although it is premature to create this full linkage at present, it should be the ultimate goal of linking East Asian carbon markets.

Figure 6. Full Multilateral Links in the PRC, Japan, and the Republic of Korea



PRC = People's Republic of China.

Source: Authors' illustration.

C. Challenges and Recommendations

Linking carbon markets can improve liquidity, efficiency, and stability. However, market linkage in East Asia is not fully ready. If linked, the East Asian carbon market could be the largest in the world; hence, it would be more difficult to build and manage. First, incompatible market designs create difficulties since each carbon market has individual climate goals, which drives diverse emission targets and distinct levels of stringency of regulations. Various covered sectors, allowance allocations, MRVs, and even different market stabilization mechanisms cause fragmented markets as well. Second, some markets tend to overallocate allowances, arousing the moral hazard concern. Third, emission leakage is a serious threat to the carbon market, since linkage can make some firms relocate to other regions outside the scope of the linkage, causing emissions in other regions to increase (Aldy 2016). Fourth, carbon market linkage could lead to transboundary wealth transfers. Finally, geopolitics can be a concern when geopolitical conflicts and disputes complicate climate cooperation.

Nevertheless, linking East Asian carbon markets would be distinctly important and there are positive signals for such market linkage. In theory, heterogeneities among different markets suggest the expected cost savings in the linkage market could be large. In practice, Japan has prior experience in international carbon market linkage. Furthermore, the PRC launched the national ETS pilot in 2017, which makes inter-ETS linkages more convenient, while the Republic of Korea intends to link its domestic ETS with international markets. As a

first step, it is forming agreements with other ETSs that are recognized for credible GHG emission reductions.

We make the following recommendations in terms of carbon market linkage. The PRC, Japan, and the Republic of Korea should recognize each other's trading allowances reciprocally. Since it is politically infeasible to link carbon markets through legally binding international treaties, the mutual recognition of emission allowances is a sensible strategy toward connected carbon markets in East Asia. It is worth noting that carbon market linkage can lead to low-quality emission reductions in some markets without a uniform MRV system. For international linkage, participants can use global principles that provide key features and model rules in order to solidify the foundation of future market linkage. The conditions mentioned above do not have to restrain linkage among the PRC, Japan, and the Republic of Korea. Economic and political concerns are underlying problems that can prevent efforts to link markets or lead to their failure. Therefore, efforts to link carbon markets in East Asia do not need to be overhasty.

VI. Conclusion

This paper reviews and compares carbon markets in the PRC, Japan, and the Republic of Korea. The designs of these carbon markets are based on unique economic, industrial, and demographic backgrounds. In this context, we review the key elements of these markets including GHG emission targets, allowance allocations, MRVs, and offset markets. We assess the performances of these markets in terms of carbon prices and trading volumes. Based on this information, we explore the possibility of market linkage among the three ETSs by analyzing incentives, identifying obstacles, and providing policy suggestions.

Developing linked carbon markets in East Asia is essential and beneficial, but also challenging. Some questions remain for carbon market linkage in East Asia. For example, how can the MRV systems, ETSs, or new organizations take actions to ensure the integrity of the linkage? How can the linkage require national markets to give up some control over prices and GHG emission targets? How can small markets survive and be protected at the very beginning? These questions entail further study of linkage among East Asian ETSs.

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