4rd International Conference on Public Policy (ICPP4) June 26-28, 2019 – Montreal, Canada

Panel T14P19 *Beyond Typologies: Innovation in the Study of Environmental Policy Instruments,* Session 2

Title of the paper

An investigation of the interactions between emission trading schemes and other urban environmental policy instruments: case studies of five cities in China

Authors

Lili Li and Araz Taeihagh

Lee Kuan Yew School of Public Policy, National University of Singapore

Friday, June 28th 2019 08:00 to 10:00 (Room MB 3.430)

Work in progress.

An investigation of the interactions between emission trading schemes and other urban environmental policy instruments: case studies of five cities in China

Abstract - The past decade has witnessed the policy efforts of the Chinese Government at the national and local levels to reduce its vast amount of greenhouse gas (GHG) emissions. Five cities of Beijing, Chongqing, Shanghai, Shenzhen, and Tianjin have experimented with subnational emission trading schemes (ETS) to reduce CO_2 emissions. Putting aside the criticisms about the effectiveness of ETS, imposing a price on CO_2 emissions sends the signal that emitters need to pay for their emissions. In each of the five cities, ETS as a novel policy instrument was added to a set of pre-existing policy instruments that regulated emissions in carbon-intensive energy technologies (e.g. conventional coal-fired power plants). This study investigates the following research questions: 1) how do city governments in China reduce emissions (CO_2 emissions or other major pollutants) in their jurisdictions and 2) how does CO_2 ETS interact with other urban environmental policy instruments that reduce pollutants, considering they all target heavily polluting energy technologies. To address these questions, we examine how ETS policy documents relate to policy documents for other environmental policy instruments, by coding contents of policy documents and applying network analysis and visualisations. The findings show that 1) policy documents relating to CO_2 ETS forms network communities that have few connections with policy documents that related to other environmental policy instruments; 2) the five cities show variations in the density of the policy documents developed, policy focus and types of policy instruments used. The study makes empirical contribution to policy instrument literature by presenting structure and temporal evolution of mixes of multiple policy instruments that are implemented in the five cities of Beijing, Chongqing, Shanghai, Shenzhen, and Tianjin in China and makes methodological contribution to policy instrument literature by using network analyses and visualisations to map out interactions between policy instruments.

Keywords: Emission trading; environmental policy; policy instruments; China; network analysis; network visualisation.

1 Introduction

A policy mix or a policy package refer to the case where a set of policy instruments are adopted by decision makers to achieve one or multiple policy goals, with the aim of enhancing the overall outcome of the policy by maximising desirable interactions among the policy instruments while minimising contradictions between policy instruments within the package/mix. The use of complex mixes of policy instruments is a new orientation of the policy design literature (Howlett et al., 2015; Taeihagh et al. 2013). Policy instruments, also known as policy tools, refer to the concrete means or devices that are chosen to implement or give effect to public policies (Howlett et al., 2009). The formulation of a policy is often path-dependent and incremental process over years (Mir-Artigues and Del Río, 2014). Instruments are often adopted in a context of pre-existing policy mixes, with the exception of the adoption of novel technologies that do not have pre-existing policies in place (Taeihagh, 2017).

From the perspective of policy instrument choice, policy design is about matching instruments to policy goals. Contemporary studies on policy mixes/packages address interactions and interdependencies between policy instruments which affect the extent to which policy goals are realised (Flanagan et al., 2011). Taeihagh et al. (2009, 2013, 2014) have extensively explored the relation between policy instruments and policy goals. They classified types of policy interactions as: precondition, facilitation, synergy, potential contradiction or contradiction (Taeihagh et al. 2013)[1].

An existing gap in the policy mix and packaging literature is the lack of empirical research and temporal analyses, particularly surrounding instrument interactions (Taeihagh 2017; Trencher and Heijden 2019). This study investigates policy interactions between ETS and other urban environmental policy instruments with actual policy document data in five cities in China, making empirical contribution to the literature on policy instruments and their interactions.

[1] Accordingly, 1) precondition refers to the case where a policy instrument is strictly required for the successful implementation of another one; 2) facilitation refers to the case where the successful implementation of a policy instrument can make another policy instrument work better; 3) synergy refers to the case where two policy instruments "facilitate" each other; 4) potential contradiction refers to the case where two policy instruments conflict with each other in terms of outcomes or incentives given certain contingencies; 5) contradiction refers to the case where two policy instruments generate "strictly" conflicting outcomes or incentives (Taeihagh et al. 2013).

2 China's Policy Experiments on the Adoption of CO_2 ETS in the Five Cities

Climate change is a super-wicked problem which exists in complex socio-technical systems, where there is a lack of a central authority, the problem becomes more acute with the passage of time, and often the entities aiming to provide solutions are in fact the ones that created the problem in the first place by extensively contributing to the GHG emissions (Levin et al., 2012; Peters, 2017). While climate change is a global issue, local actions are vital to make substantive progress on mitigating GHG emissions.

CO_2 emission is a dominant form of GHG emission. To address the environmental externalities of CO_2 emissions, the prevalent approach is to introduce a high price on the CO_2 emissions through building an emission trading market or imposing a CO_2 tax (Nordhaus, 2013). ETS is also referred to as the "cap and trade" approach, where the "cap" refers to setting the levels of allowed emissions in a jurisdiction, and creating a market that allows regulated firms to trade the emission allowances if they emit beyond their allocated quota (Carl and Fedor, 2016; Ekins and Barker, 2001; Goulder and Schein, 2013; Kosnik, 2018).

As the largest CO_2 emitter, China faces great international pressure to take CO_2 mitigation actions. Since 2013, China has experimented with ETS as a policy instrument for CO_2 emission reduction in the mega-cities of Beijing, Tianjin, Shanghai, Chongqing, and Shenzhen, and provinces of Hubei and Guangdong. Table 1 provides the general social-economic statistics for these five mega-cities. These cities all have large populations and high gross domestic product (GDP), while having different economic structures as evident from the breakdown of their primary, secondary, and tertiary industries. For instance, Tianjin and Chongqing have higher ratios of secondary industry and have higher industrial emissions of SO_2, NOx and particulate matters (PM). Shanghai on the other hand is dominated by the tertiary industry but also has a quite high level of industrial emissions, which is likely related to its severe transportation pollution. Market structures of these five cities are also different, which may affect how enterprises perceive and comply with the environmental regulations. For instance, most enterprises in Beijing are state-owned and have close interactions with the government while in Shenzhen most are private.

Table 1. General social-economic statistics

Indicators	Year	Unit	Beijing	Shenzhen	Shanghai	Tianjin	Chongqing
Population	2016	10000 persons	2173	1191	2420	1562	3048

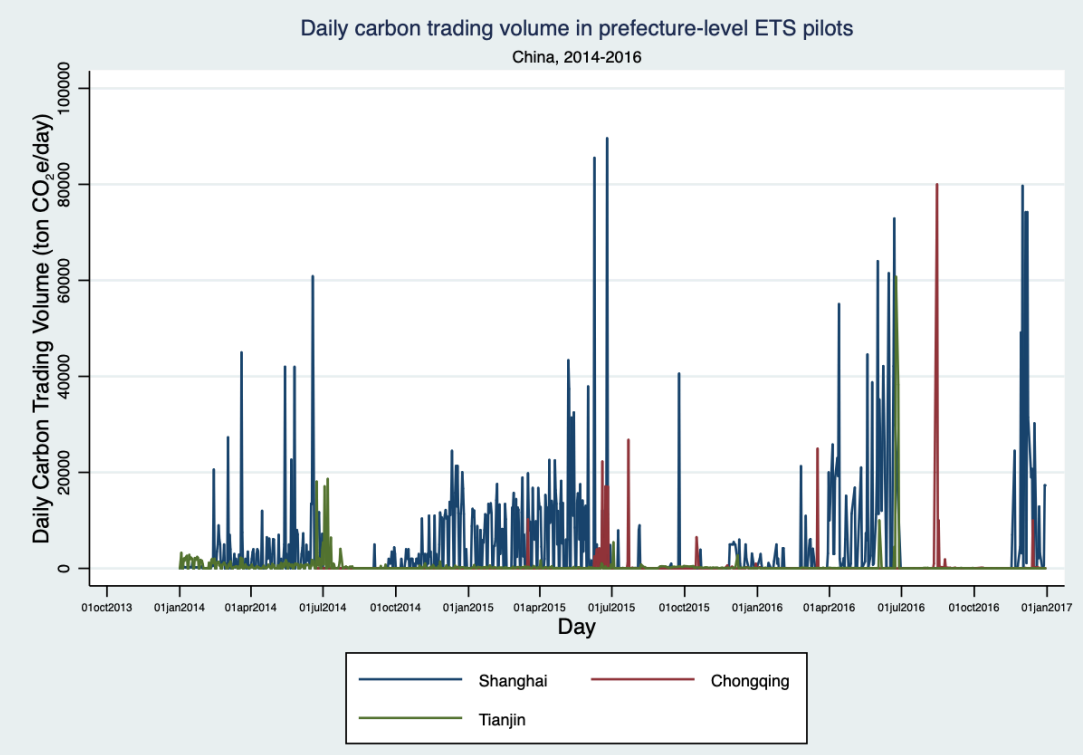
GDP per capita	2016	1000 yuan	118	172	117	115	59
Composition of GDP: primary industry	2016	%	0.50	0.00	0.40	1.20	7.30
Composition of GDP: secondary industry	2016	%	19.30	41.00	29.80	42.30	44.50
Composition of GDP: tertiary industry	2016	%	80.20	59.00	69.80	56.40	48.10
Number of state-own industrial enterprises	2016	Unit	697	8	680	530	511
Number of private industrial enterprises	2016	Unit	1047	3028	3534	2458	4242
Number of large and medium-sized industrial enterprises	2016	Unit	676	2054	1396	906	1386
Ratio of environmental protection expenditure in the general public expenditure	2016	%	0.06	0.03	0.02	0.02	0.03
Amount of industrial SO_2 emission	2016	10000 tonnes	1.03	0.47	6.74	5.67	17.30
Amount of industrial NOx emission	2016	10000 tonnes	2.34	1.14	7.87	8.83	10.05
Amount of industrial particulate matters	2016	10000 tonnes	0.79	0.17	7.28	5.73	8.38

Note: Data collected from the CEIC database (www.ceicdata.com) and Shenzhen Statistical Yearbook (2017).

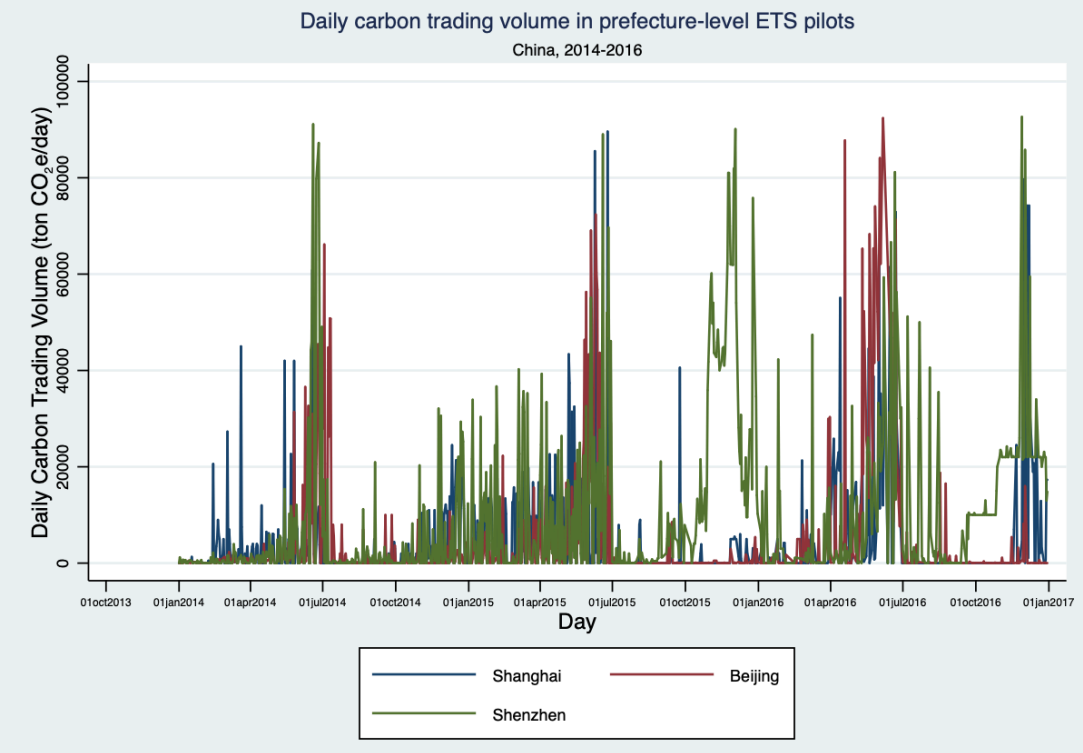
The designs of the piloting ETSs in China have been summarised in various studies (Chang et al., 2017; Li, 2018; Munnings et al., 2016; Zhang et al., 2014, 2017). There are variations in sector coverage, emission allocation methods, reporting and verification rules, and penalties for non-compliance across the five ETS policy pilots. Each city established an Emission Exchange as a platform for conducting emission allowance transactions. These Emission Exchanges disclose the daily CO_2 prices and trading volumes. An ETS is considered a cost-effective policy instrument for emission reduction if it is designed and implemented well, and facilitates achieving cost savings because firms can trade emission allowances with each other (Chen et al., 2013; Thompson et al., 2018; Wu et al., 2014).

According to the price and trading volume data (see Figures 1 and 2), Tianjin and Chongqing's ETS markets do not function as well as ETS markets in Beijing, Shanghai, and Shenzhen. Tianjin and Chongqing's ETSs have been criticised for their lax enforcement, inactive transactions, and low market liquidity (Dong et al., 2016; Li, 2018; Tan and Wang, 2017; Zhang, 2015). For instance, all cities impose monetary penalties on non-compliant enterprises except Tianjin and Chongqing, and Chongqing allows ETS-regulated firms to

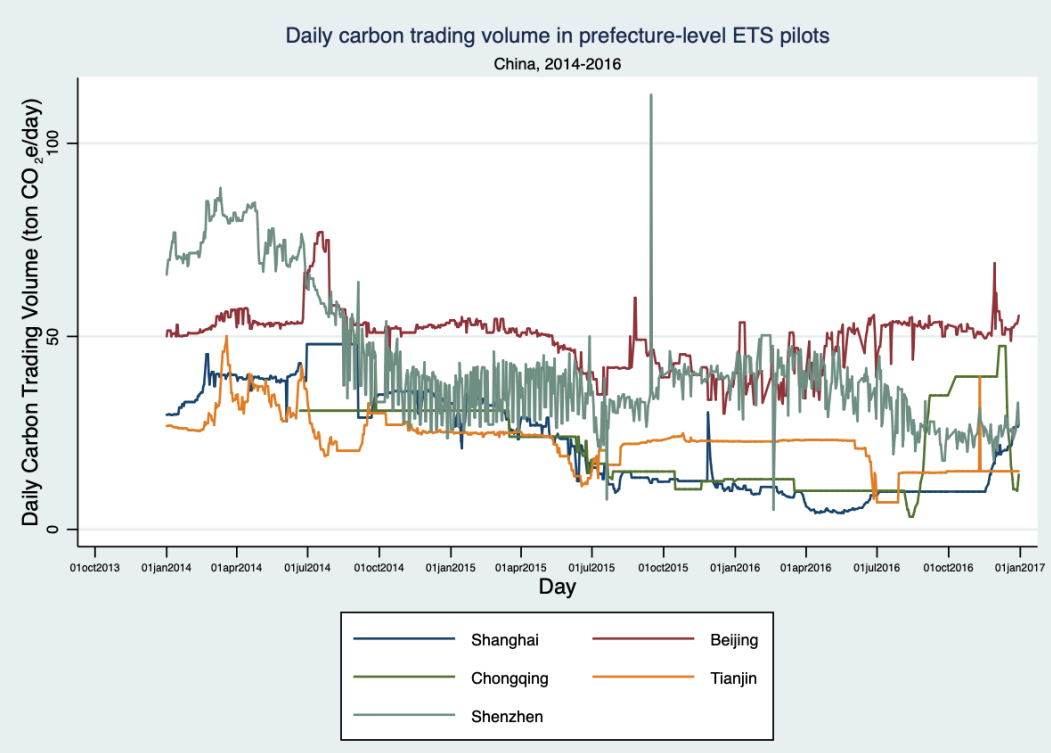
decide on the amount of emission allowances they should have which leads to oversupply of emission allowances.



(a) Daily carbon trading volume comparison: Shanghai, Chongqing, and Tianjin



(b) Daily carbon trading volume comparison: Shanghai, Beijing, and Shenzhen
Data source: websites of Emission Exchanges in Beijing, Chongqing, Shanghai, Shenzhen and Tianjin; www.tanpaifang.com, which compiles market data of all local ETSs in China
Figure 1. Daily trading volume of CO_2 emission allowances in prefecture-level ETSs



Data source: websites of Emission Exchanges in Beijing, Chongqing, Shanghai, Shenzhen and Tianjin; www.tanpaifang.com, which compiles market data of all local ETSs in China

Figure 2. Daily trading volume of CO_2 emission allowances in the five prefecture-level ETSs

3 Method and Data

To examine how governments of the five cities reduce emissions in their jurisdictions and how the policy instruments that the city governments use interact with one another, we conducted sequencing analysis (Taeihagh et al. 2009; Boons and Spekkink 2015) and used the event sequence analysis visualisation in Gephi network analysis and visualisation software (Bastain et al 2009). The study is based on evidence found in the policy document data of the five cities. Policy documents issued by governments contain information about the policy instruments they use. In our analysis the issuance of a policy document is considered as a policy event. Each policy event occurs at a certain time point with the aim of helping achieve the policy goal of emission reduction. We consider sequential issuance of a number of policy documents as a sequence of policy events and map out the information gleaned from the policy documents to and explore the potential patterns in the development of the policy events and investigate connections between these policy events.

We collected the data in form of policy documents from the *pkulaw* database[2] that compiles policy documents (in Chinese language) issued by the central and local governments

[2] The database can be found at www.pkulaw.cn.

of China. We collected policy documents that were issued from 2006 onwards because 1) the Kyoto Protocol became effective from 2005 and since then concerns over CO_2 emissions have started to be integrated more into China's public policies, and 2) the 11th Five Year Plan (FYP, 2006-2010) indicated a shift in China towards a more sustainable development path. 11th FYP set goals of a) reducing energy intensity[3] by 20% by 2010, b) increasing share of non-fossil fuels used in primary energy consumption to 10% by 2010, and c) reducing SO_2 and NOx emissions by 10% by 2010. Before the 11th FYP not explicit goals were set for energy intensity reduction, increasing share of non-fossil fuels, or reduction of NOx emissions. To achieve the goals of 11th FYP, the central government implemented a large number of policy instruments and programmes to reduce energy consumption and emissions (Ke et al., 2012; Price et al., 2011) and many policy instruments to encourage the adoption of renewable energy technologies (Kang et al., 2012). The central government also went through some institutional changes from 2006 to 2010 that affected environmental regulations. In 2007, China established a National Leading Group on Climate Change that worked under the National Development and Reform Commission (NDRC)[4] to cope with climate-change related issues. In 2008, Ministry of Environmental Protection (MEP) was launched as a cabinet-level department of the State Council[5] to regulate environmental issues, replacing the previous State Environmental Protection Administration that was a ministerial-level agency. MEP has the legal authority to influence the State Council's decisions, including strengthening the environmental concerns in the FYPs.

Against this background, policy documents issued by governments of the five cities from 2006 onwards were collected to see policy instruments adopted by local governments to reduce CO_2 emissions and pollutants. We searched for policy documents with titles containing the terms "emission reduction" (*jian pai*) and "CO_2 emission" (*tan pai fang*)[6]. The initial search resulted in 92 policy documents in Beijing, 80 policy documents in Chongqing, 263 policy documents in Shanghai, 41 policy documents in Shenzhen, and 28 policy documents in Tianjin. Full texts of the policy documents were obtained and then coded. To make the coverage of our policy document data comprehensive, when a local policy document referred to a policy document issued by the central government, the latter was also added to our data; when a local

[3] Energy intensity here refers to energy consumption per unit of GDP.
[4] NDRC is a cabinet level ministry under State Council. It has crucial role of planning social and economic development in China and has the right to organize other cabinet level ministries together to deal with a policy issue.
[5] The main administrative body of Chinese government
[6] The research is ongoing and more relevant policy documents are going to be included in future.

policy document referred to another local policy document that had been missed in the initial policy document search, the latter was added. After removing duplicates and screening based on relevance, we eventually performed the analysis based on data from 458 policy documents, with 87 Beijing's policy documents (including 39 documents containing the term "CO_2 emission"), 74 Chongqing's policy documents (including 20 documents containing the term "CO_2 emission"), 189 Shanghai's policy documents (including 41 documents containing the term "CO_2 emission"), 45 Shenzhen's policy documents (including 14 documents containing the term "CO_2 emission"), 26 Tianjin's policy documents (including 5 documents containing the term "CO_2 emission") and 40 policy documents issued by the central government of China.

We examined the density[7] of the policy events and centrality[8] of a policy event. In our analysis, a node represents a policy document, and the sequence of events were depicted from left to right indicating the time in which the policy documents were issued by the governments. In our coding, each policy document contains an ID, a time stamp, description, authority level, the government agency that issued this policy document, and other policy documents that this policy document referred to. The last indicator was used to analyse interactions between policy documents. When policy document A mentioned policy document B as its reference, an edge was added from policy document B to policy document A. Section 4 presents the graphs of the event sequences, summarises the characteristics and interaction of the policy documents in the five cities, and provides an analysis of their temporal development.

4 Results and Analysis of the Policy Events in the Five Cities

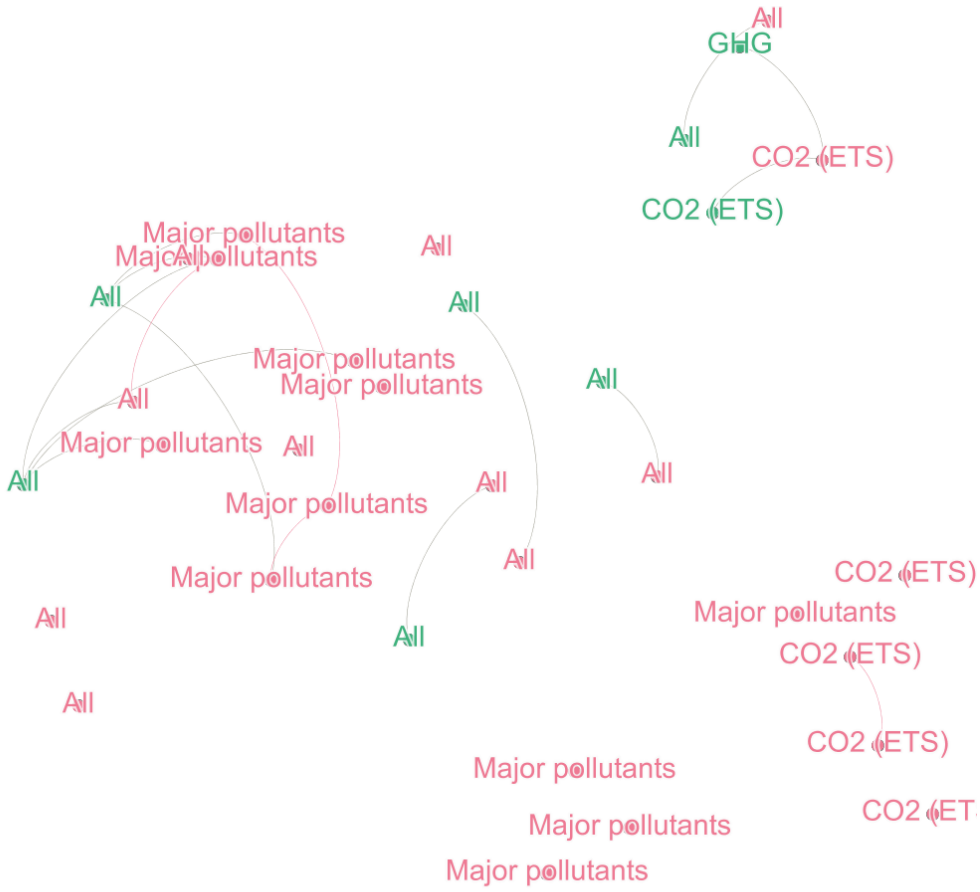
4.1 Tianjin

Figure 3 displays the event sequence graph of Tianjin that is based on the data from the policy documents. Each node displays a policy document. Tianjin government issued 11 policy documents to reduce major pollutants, including air pollutants such as SO_2 and NOx and water pollutants such as chemical oxygen demand (COD) and ammonia nitrogen (NH_4^+); 5 policy documents to administer policy instrument of CO_2 ETS from 2013; 10 policy documents to reduce all emissions including CO_2 emission, with a focus on reducing energy-related emissions. When identifying the policy instruments based on the content of policy documents, it is found that the city government tends to focus on the notion of responsibility, by assigning

[7] Here, density refers to the number of policy documents. If a city has a higher number of policy documents, the density of policy documents is high.
[8] Here, centrality of event A refers to its out-degree in the network, measured as the number of outgoing neighbours of a vertex.

responsibility of emission reductions to lower-level governments and considering this as a performance indicator that affects government officials' promotions or dismissal. Comparing to other four cities, Tianjin has fewer policy documents administering the implementation of CO_2 ETS. Tianjin government issued an *Interim Administrative Measures for CO_2 ETS in Tianjin* in 2013 to give general implementation rules, which was amended in 2016 and again in 2018.

Tianjin government follows certain policy documents issued by the central government. For instance, the first node on the left is the policy document of *Comprehensive Work Plan for Energy Conservation and Emission Reduction* that the State Council released in May 2007. The policy document made a comprehensive work plan to achieve 11th FYP's goals of energy intensity reduction and emission reduction, asking provincial level governments to take serious policy measures to reach the goals allocated to their jurisdictions. It asked local governments to close small and old industrial plants in energy-intensive industries (such as electricity, iron and steel, and cement) for the purpose of energy saving and emission reduction. Tianjin's implementation of CO_2 ETS follows the policy document *Notice on Piloting the Work of Carbon Emissions Trading* issued by NDRC in 2011. In the policy document, NDRC specifically asks Development and Reform Commissions (DRC) of Beijing, Chongqing, Shanghai, Shenzhen, and Tianjin to make implementation plans for CO_2 ETS and to establish Emission Exchanges as the platforms for firm-to-firm trading of emission allowances.



Note: Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. Pink colour indicates the policy document was issued by the city government of Tianjin; green colour indicates the policy document was issued by the central government. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+). "All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission[9].

Figure 3. Event sequence graph-Tianjin

4.2 Shenzhen

Figure 4 displays the event sequence graph of Shenzhen. It shows a higher density of policy documents. Shenzhen issued 9 policy documents to reduce major air pollutants and major water pollutants; 4 policy documents to reduce solid waste from construction activities; 14 policy documents to administer implementation of CO_2 ETS from 2012; 18 policy documents to reduce energy-related emissions.

Similar to Tianjin, in the period of 11th FYP (2006-2010), Energy Conservation and Emission Reduction policies in Shenzhen also followed the overarching *Comprehensive Work Plan for Energy Conservation and Emission* Reduction that the State Council released. As the State Council's *Comprehensive Work Plan* emphasised the use of responsibility-based approach, Shenzhen also designated target of emission reduction to lower-level governments.

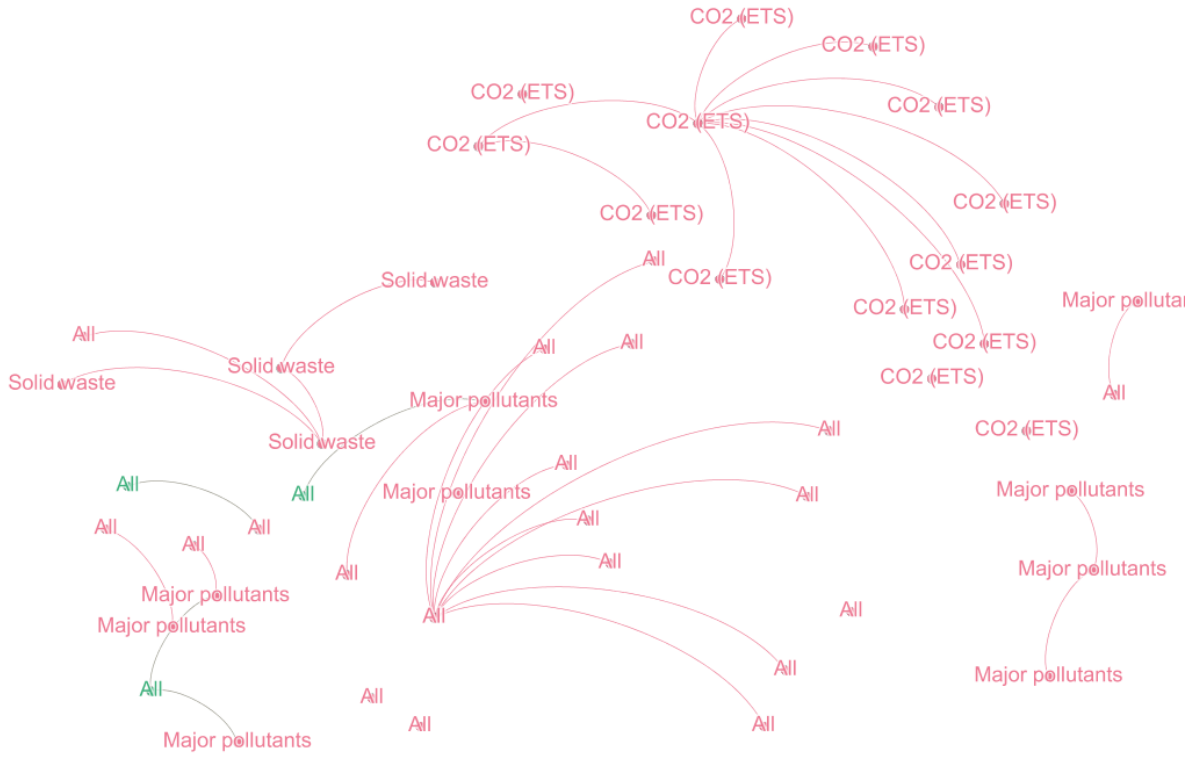
[9] Currently, CO_2 emission is not considered as a type of pollutants in China.

In 2007, Shenzhen government issued policy document *Work Plan of Reducing Emissions from and Upgrading of Heavily Polluting Industries* to reduce pollution in heavy industries such as electricity and paper industries. It asked urban district-level governments to shut down heavily polluting industrial plants that were unable to reduce their emissions.

Given the abundance of treasure resources at disposal of Shenzhen government, Shenzhen DRC set up a *Special Fund for Circular Economy, Energy Conservation and Emission Reduction* in 2012 to offer lump-sum subsidies to closed-loop projects that minimise emissions and make the most use of resources, to projects that effectively reduce energy consumption, and to projects that effectively reduce emissions. Shenzhen DRC issued a few follow-up policy documents to guide firms' application for the subsidy.

In March 2014, Shenzhen government issued the *Interim Administrative Measures for CO_2 ETS in Shenzhen,* setting up general rules of implementing ETS. Other ETS-related policy documents mostly refer to this *Interim Administrative Measures* in text. The policy documents to administer implementation of CO_2 ETS in Shenzhen are more comprehensive than those in Tianjin. Other than setting up general administrative rules, the policy documents also contain 1 policy document about allocating emission allowances, 1 policy document about organising a training for the regulated firms, 2 policy documents about firms' reporting of their CO_2 emissions, 6 policy documents about verifying firms' emission reports, 1 policy document to force firms to comply with allowed emission levels, and 1 policy document disclosing non-compliant firms.

In Shenzhen, policy documents concerning CO_2 ETS also are a separate body, with limiting connection with policy documents to reduce other emissions. Shenzhen DRC take charge of allowance allocation affairs and enforces compliance of firms regulated by CO_2 ETS and, while Shenzhen Market Supervision Administration regulates institutions that verify firms' emission reports. Regarding policy documents to reduce major air and water pollutants, in the data we collected, it is the city government of Shenzhen, rather than its Environmental Protection Bureau (EPB) that release those policy documents.



Note: Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. Pink colour indicates the policy document was issued by the city government of Shenzhen; green colour indicates the policy document was issued by the central government. "CO_2 (ETS)" indicates the policy document is relating to implementation of ETS to reduce CO_2 emissions. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+).
"All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission. "Solid waste" indicates the policy document is to reduce solid waste (such as construction waste).

Figure 4. Event sequence graph-Shenzhen

4.3 Chongqing

Figure 5 displays the event sequence graph of Chongqing. Two communities of policy documents stand out. One is the group of policy documents (totalling 20 documents) to administer implementation of CO_2 ETS. The other one is the group of policy documents (totalling 14 documents) to reduce major air and major water pollutants during the period of 11th FYP (2006-2010). Other policy documents are relatively sparse. Chongqing has a few sector-specific policy instruments contributing to emission reductions, including 8 policy documents (released in 2012-2013) to reduce emissions (such as animal waste) in the agriculture sector[10]; one policy document (released in 2007) to reduce emissions in the construction sector that follow two other policy documents (released in 2007) issued by the central government; 5 policy documents (released in 2010-2013) to reduce emissions in the

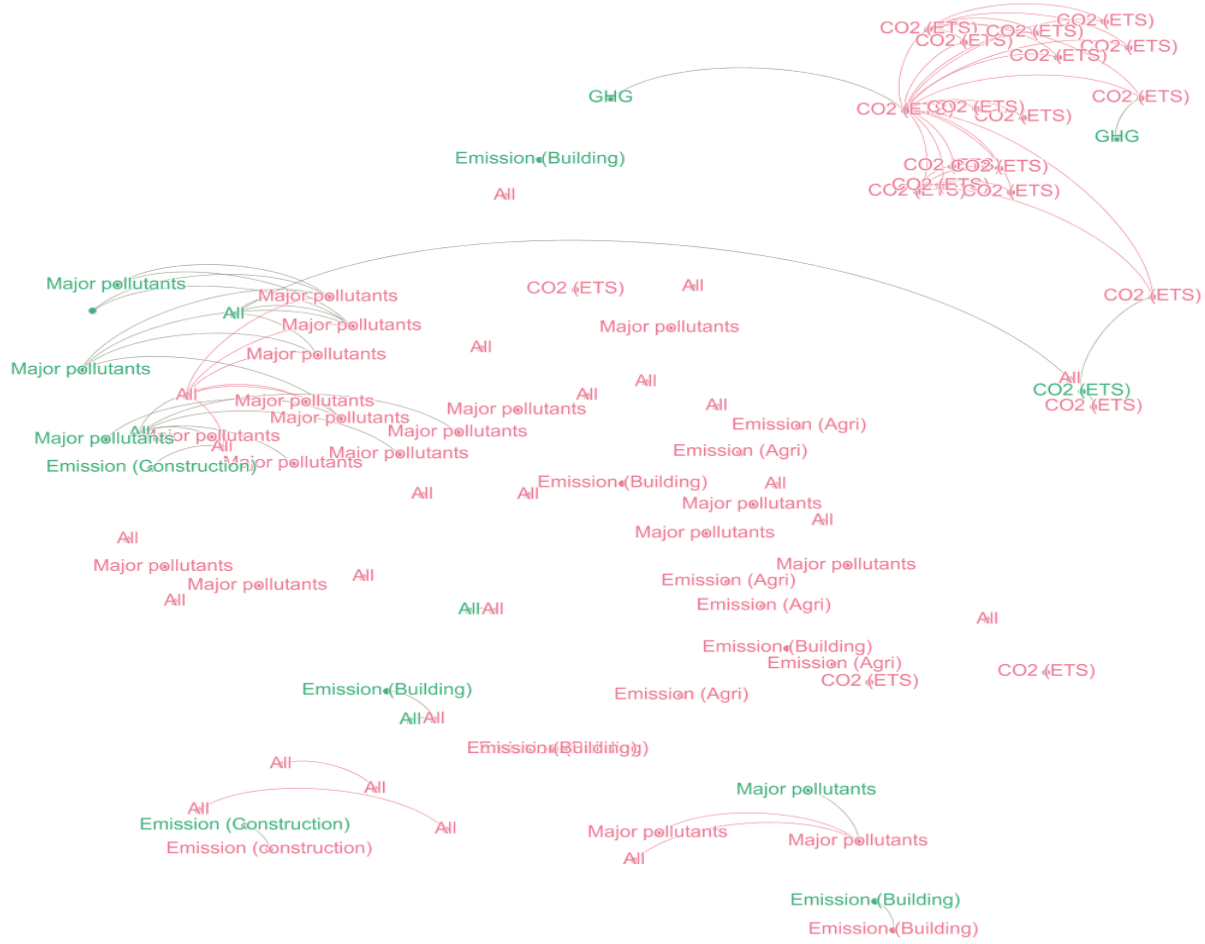
[10] The policy documents are mainly to support and follow up emission reduction projects in agriculture sector.

building sector that follow three other policy documents (released in 2008-2013) issued by the central government.

In April 2014, Chongqing government released the *Interim Administrative Measures for CO_2 ETS in Chongqing* to guide implementation of CO_2 ETS. Soon after, Chongqing DRC released the *Administrative Measures for Allocating CO_2 Emission Allowances (Trial)* in May 2014 to set rules for the allocation of emission allowances. To follow NDRC's plan of establishing the national ETS, Chongqing DRC released two documents (in 2015 and 2016) to disclose the list of the firms that may participate in the national ETS. Other policy documents concerning CO_2 ETS are mostly about allocation of emission allowances in the following compliance year, asking firms to report their emissions in the previous compliance year, and organising verification of firms' emission reports. Chongqing ETS allows firms to decide on the quota of CO_2 emission allowances by themselves, while the other four ETS pilots assign the emission allowances to firms in the top-down approach. Chongqing's emission allowance method tends to cause oversupply of emission allowances, giving firms little incentive to substantially reduce their emissions.

At instrument level, Chongqing government also uses responsibility-based governance approach. The city government sets annual environmental targets (i.e. the allowed level of emissions) for urban district-level governments and county-level governments. Every three months, governments at the county-level (or urban district-level) need to report the amount of major pollutants in their jurisdictions to the city government of Chongqing. If the environmental targets cannot be met, the relevant government officials will be likely denied promotions and rewards.

In August 2007, Chongqing government set up a Leading Group to oversee Energy Conservation and Emission Reduction work. It is a temporary office but continues to be active. It indicates the city government's willing to reduce energy consumption and reduce emissions. At instrument level, Chongqing government assigns energy intensity reduction targets for lower-level governments, discloses names of government officials that have done well to reach the targets, provides lump-sum subsidies for energy conservation or emission reduction projects, and promotes a range of low-carbon technologies (or products) and energy efficient technologies (or products).



Note: Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. Pink colour indicates the policy document was issued by the city government of Chongqing; green colour indicates the policy document was issued by the central government. "CO_2 (ETS)" indicates the policy document is relating to implementation of ETS to reduce CO_2 emissions. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+).
"All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission. "Emission (Agri)" indicates the policy document is to reduce emissions in agricultural sector such as animal waste pollution. "Emission (Building)" indicates the policy document is to specifically reduce emissions in the building sector. "Emission (Construction)" indicates the policy document is to specifically reduce emissions in the construction sector.

Figure 5. Event sequence graph-Chongqing

4.4 Beijing

Figure 6 displays the event sequence graph of Beijing. It is based on the data from 87 relevant policy documents, so the density of nodes is higher than Chongqing, Shenzhen, and Tianjin. Similar to other cities, Beijing government would set emission reduction targets for lower-level governments. Air pollution is a great environmental concern in Beijing. Five policy documents have been released since 2011 for the goal of air pollution abatement. For instance, in April 2011, Beijing government made a *Clean Air Action Plan* (2011-2015) which packages policy instruments such as quantity-based emission cap and emission limits in transport sector to control air pollution level in 2011-2015. In October 2013, Beijing government issued an

Emergency Action Plan for Heavy Air Pollution Events (Trial)[11]. It packages strong policy instruments such as controlling the number of cars on the road and limiting production activities of polluting firms when the air pollution is extremely high for a short period of time (one to three days).

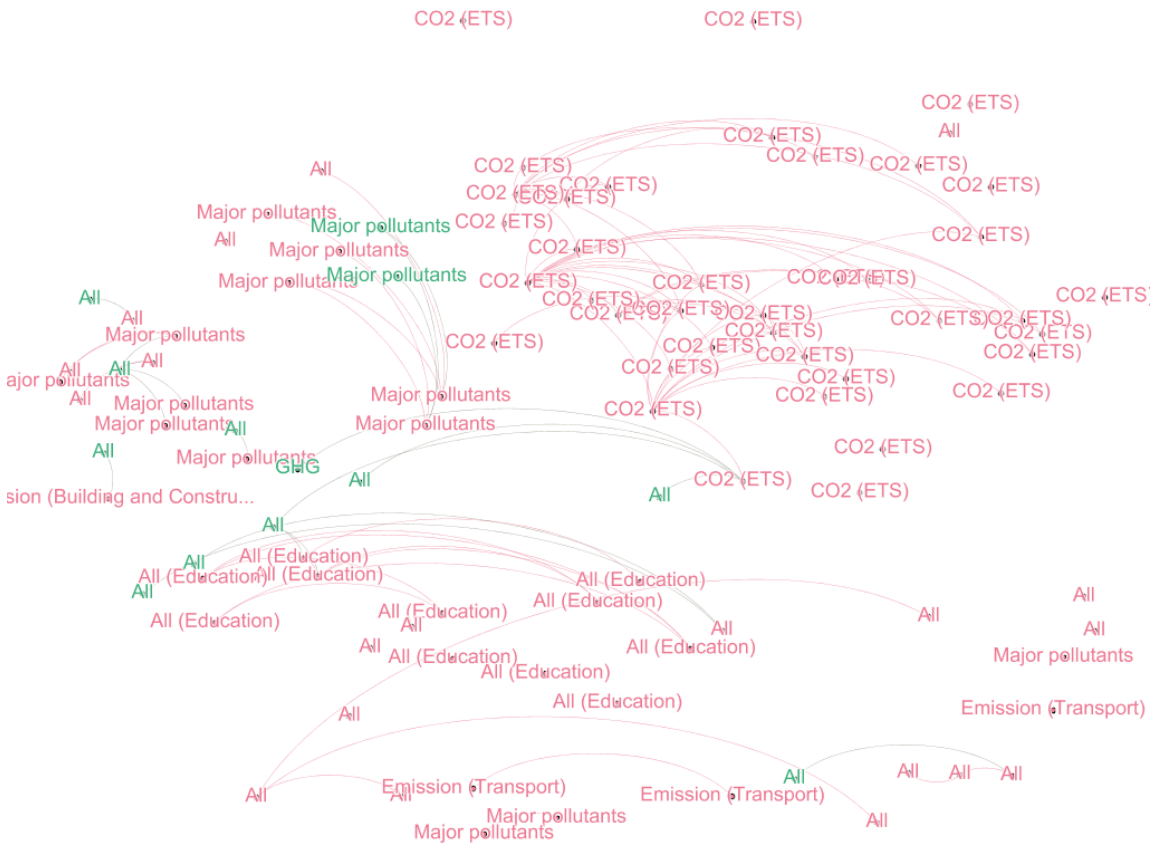
Beijing Municipal Education Commission (MEC) implemented many policy instruments to educate citizens to change behaviours for the purpose of energy saving and emission reduction. For instance, in January 2012, Beijing MEC made the *Action Plan of Schools for Energy Conservation and Emission Reduction in 12th FYP Period (2011-2015)*, which asks universities, middle schools, and elementary schools to 1) educate students with environmental knowledge and to 2) reduce their energy consumption and emissions. In February 2014, Beijing MEC organised a competition for developing public advertisements on energy conservation and emission reduction (*jie neng jian pai*). In April 2014, Beijing MEC organised *Knowledge Contest about Energy Conservation and Emission Reduction* among middle school students for the goals of improving students' social responsibility and encouraging students to take environmental actions.

Beijing government issued 39 policy documents to administer implementation of CO_2 ETS, 36 of which were issued by the Beijing DRC. The 36 policy documents issued by Beijing DRC covers a wide range of implementation issues, including annual allocation of emission allowances, enforcement of annual compliance with allowed emission levels, non-compliance penalty, reporting and verifying firms' emissions, knowledge and capacity trainings for firms, and operating rules for Emission Exchange. The other three policy documents were as follows. In December 2013, the Standing Committee of Beijing Municipal People's Congress[12] released the policy document of *Decision on Implementing CO_2 ETS in Beijing*. Beijing's CO_2 ETS was established and started to operate following the decision. In May 2014, Beijing government[13] released the *Interim Administrative Measures for CO_2 ETS in Beijing* to guide the policy implementation. In December 2015, Beijing government issued a policy document to change the scope of regulated firms specified in the *Interim Administrative Measures*, changing from firms with annual emissions larger than 10,000 tonnes to firms with annual emissions larger than 5,000 tonnes. The change would lead to more firms being regulated by CO_2 ETS in Beijing.

[11] In Chinese, it is *kong ai zhong wu ran ying ji yu an*. It has been amended every year. The *Emergency Action Plan for Heavy Air Pollution Events* with 2018 amendments is currently effective.

[12] Municipal People's Congress is the local legislature body. Standing Committee is responsible to and reports to the Municipal People's Congress. Standing Committee has meetings at least once every two months while Municipal People's Congress meets every year. Members of Municipal People's Congress are elected for a term of five years.

[13] Beijing DRC is a government agency working under the city government of Beijing.



Note: Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. Pink colour indicates the policy document was issued by the city government of Beijing; green colour indicates the policy document was issued by the central government. "CO_2 (ETS)" indicates the policy document is relating to implementation of ETS to reduce CO_2 emissions. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+).
"All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission. "Emission (Transport)" indicates the policy document is to reduce emissions in transport sector. "Emission (Building and Construction)" indicates the policy document is to specifically reduce emissions in the building sector and construction sector. "Emission (Education)" indicates the policy document is to reduce emissions by educational measures.

Figure 6. Event sequence graph-Beijing

4.5 Shanghai

Figure 7 displays the event sequence graph of Shanghai. Shanghai has the largest number of relevant policy instruments among the five cities. Appendix 1 provides an alternative visualisation of the policy documents, by using different colours to represent policy documents targeting different types of emissions.

Shanghai has 43 policy documents to administer the implementation of CO_2 ETS. In November 2013, Shanghai government released the *Interim Administrative Measures for CO_2 ETS in Shanghai* which contains rules for implementing CO_2 ETS. Besides the general rules given by the *Interim Administrative Measures*, Shanghai DRC has policy documents every compliance year to follow up on the allowance allocation, reporting and verification of the emissions, and submission of valid emission allowances. For instance, Shanghai DRC issues

government documents in 2013, 2016, 2017, 2018 with specific methods of allocating emission allowances that year[14]. Most of emission allowances are given to firms for free. In June 2014, June 2017 and July 2018, Shanghai DRC organised auctions to allocate a small share of emission allowances. Shanghai ETS expanded the coverage of regulated firms twice, increasing from 197 firms in 2013-2015 to 368 firms in 2016 and then to 381 firms in 2018. Shanghai DRC issues government documents every year to guide submission of emission reports by the regulated firms and to ask a third party to verify the emission reports. Before every year's compliance deadline, Shanghai DRC issues government documents to ask the regulated firms to report their verified emissions before the deadline. If firms emit more than the allowed amounts, they are encouraged to buy emission allowances through the Emission Exchange.

Shanghai also sets quantity-based emission cap on major pollutants such as SO_2 emission, and to control total amount of emissions under the allowed level, it assigns emission reduction targets to county-level (or urban district-level) governments. To reduce emissions from coal electricity plants, subsidies are given to electricity plants that installed equipment to remove PM[15]; subsidies are also given to electricity plants that use denitrification equipment to substantially reduce NOx emissions[16]. Shanghai DRC, EPB and Municipal Finance Bureau (MFB) together implement the subsidy schemes. When electricity generators apply for the subsidies, DRC, EPB and MFB will reach a decision on approving the application or not. Once approved, MFB will allocate the subsidies directly to the electricity generators.

Shanghai government established the Special Fund for Energy Conservation and Emission Reduction in June 2008. Government agencies such as EPB, transport agency, construction agency and education agency would apply for the use of the Special Fund to support energy conservation projects and emission reduction projects under their responsibilities. Shanghai DRC has the authority to make decisions on allocating the funds — to whom and how much. In 2016, for instance, Shanghai DRC has approved the use of total 2.7 billion yuan to subsidise environmentally friendly projects in various sectors.

---

[14] Shanghai's CO_2 emission allowances for 2013-2015 are allocated at one time in 2013.

[15] According to the policy document *Implementation Plan for Efficient Dust Removal of Coal Electricity Plants in Shanghai* in August 2013, the subsidy rate is 25 yuan/kWh for coal electricity plant with 300 MW capacity and 6 yuan/kWh for coal electricity plant with 600-900 MW capacity.

[16] According to the policy document *Subsidies for the Use of Denitrification Equipment for Emission Reduction in Shanghai's Coal Electricity Plants* in August 2012, the subsidy rate is 3000 yuan/ton nitrogen (calculated based on ammonia-based nitrogen removal technique) and 4000 yuan/ton nitrogen (calculated based on urea-based nitrogen removal technique) if nitrogen removal efficiency is 70% (inclusive) to 75%; the subsidy rate is 4700 yuan/ton nitrogen (calculated based on ammonia-based nitrogen removal technique) and 5800 yuan/ton nitrogen (calculated based on urea-based nitrogen removal technique) if nitrogen removal efficiency is greater than 75%.

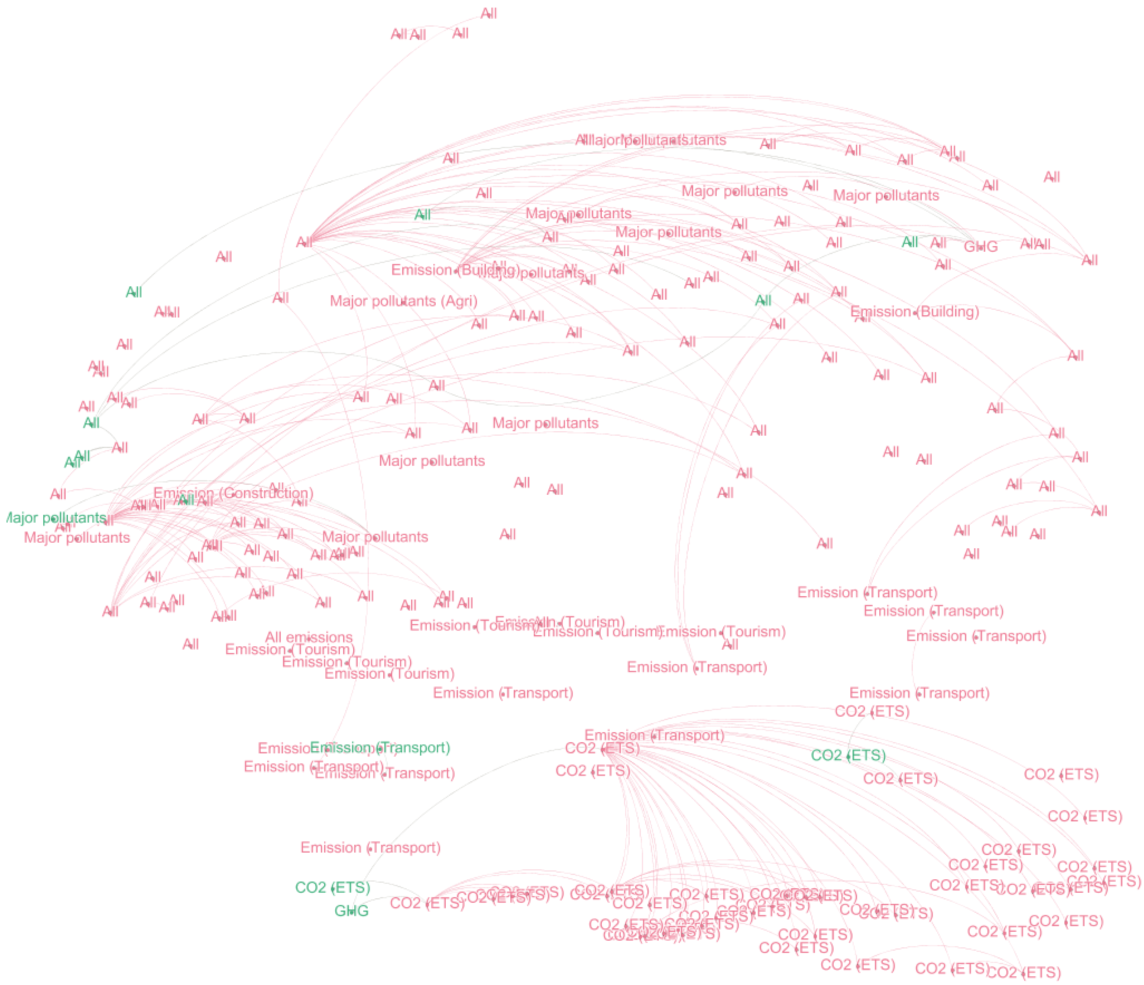
In August 2008, Shanghai Municipal Economic Commission[17] and Shanghai MFB released a policy document *Implementation Measures for Supporting Innovation and Upgrading of Energy Conservation Technologies*[18]. The aim is to allocate a certain share of the Special Fund every year to support technology innovation and retrofit that can bring energy savings. In July 2011, Shanghai DRC, Shanghai MFB and Shanghai Municipal Commission of Economy and Information issued a policy document[19] to allocate a certain share of the Special Fund every year to particularly support climate actions and to build capacity for coping with climate change-related issues. In September 2012, Shanghai DRC, Shanghai Commission of Housing and Urban-rural Development and Shanghai MFB released a policy document[20] stating that financial support (e.g. subsidies or grants) for energy conservation projects in the building sector should also come from the Special Fund.

In the transport sector, projects that contribute to energy conservation or emission reduction can apply for Shanghai's Special Fund for Energy Conservation and Emission Reduction or the national Special Fund for Energy Conservation and Emission Reduction in the Transport Sector that is administered by Ministry of Transport. An exemplar transport project can be applying renewable energy for operating transport infrastructure, or using natural gas-powered vessels in inland waterway transport. In May 2014, Shanghai government issued the policy document *Interim Measures for Encouraging Purchase and Use of New Energy Vehicles* that aims at nudging behavioural changes of consumers. It uses economic incentive to stimulate consumers to buy new energy vehicles such as fuel cell electric vehicles, with subsidies from both Shanghai government and the central government.

Shanghai paid a special attention to emissions in the tourism sector compared to the other four cities. Shanghai Municipal Tourism Administration makes annual plan to reduce energy consumption and emissions of restaurants at the beginning of a year and asks the regulated restaurants to report their Energy Conservation and Emission Reduction work by the end of the year. Shanghai General Labour Union has made great efforts to organise games and activities (e.g. knowledge contest) to raise environmental awareness among workers and to

[17] In 2009, Shanghai Municipal Economic Commission was reorganized as Shanghai Municipal Commission of Economy and Information.
[18] In Chinese, the policy document is *Shanghai Shi Jie Neng Ji Shu Gai Zao Xiang Mu Zhuan Xiang Fu Chi Shi Shi Ban Fa*.
[19] The policy document is *Implementation Measures for Supporting Energy Conservation, Resource Utilization Efficiency Improvement, and Climate Actions* (in Chinese, *Shanghai Shi Jie Neng Jiang Hao He Ying Dui Qi Hou Bian Hua Ji Chu Gong Zuo Ji Neng Li Jian She Zi Jin Shi Yong Guan Li Ban Fa).*
[20] The policy document is Implementation Measures for Supporting Energy Conservation Projects in the Building Sector (in Chinese, *Shanghai Shi Jian Zhu Jie Neng Xiang Mu Zhuan Xiang Fu Chi Ban Fa*).

provide non-cash rewards to workers that have been active in reducing energy consumption and emissions.



Note: Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. Pink colour indicates the policy document was issued by the city government of Shanghai; green colour indicates the policy document was issued by the central government. "CO_2 (ETS)" indicates the policy document is relating to implementation of ETS to reduce CO_2 emissions. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+).
"All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission. "Emission (Transport)" indicates the policy document is to reduce emissions in transport sector. "Emission (Construction)" indicates the policy document is to specifically reduce emissions in the construction sector. "Emission (Building)" indicates the policy document is to specifically reduce emissions in the building sector. "Emission (Tourism)" indicates the policy document is to reduce emissions in the tourism sector, including emissions of restaurants.

Figure 7. Event sequence graph-Shanghai

5 Preliminary Conclusions and Future Steps

In the study, we addressed two research questions on how city governments in China reduce emissions (CO_2 emissions or other major pollutants) in their jurisdictions and how CO_2 ETS interacts with other urban environmental policy instruments. To answer these questions, we analysed contents of a total of 458 policy documents in five mega-cities of China: Beijing,

Chongqing, Shanghai, Shenzhen, and Tianjin. We used network structures to display temporal sequences of the policy documents and map out the connections between policy documents. We found that policy documents relating to design and implementation of CO_2 ETS form a separate community, with little interactions with other policy documents; and that the five cities are different in terms of density of policy documents, policy focus and the types of policy instruments they use.

Although CO_2 emissions and air pollutants largely come from common sources, policy documents concerning CO_2 ETS are separate from policy documents concerning reduction of major air pollutants. The reason may be that they respectively fall under the responsibilities of DRC and Environmental Protection Bureaus (EPB). NDRC and local DRCs are in charge of climate policies and energy policies. MEP[21] takes charge of pollution control policies, so does EPB of a local government. They are the major agencies that issue policy documents to reduce pollutants.

The variations over the five cities may be explained by their differing governing resources, the structure of their local economy, and the characteristics of the policy issues that they face. Cities such as Shanghai and Shenzhen tend to use treasure-based policy instruments to encourage emission reduction behaviours of firms and consumers, which may be attributable to the abundance of treasure at disposal of governments. Chongqing has a larger share of primary industry (e.g. agriculture) than the other four cities, so it has additional few policy documents focusing on reducing animal waste pollution. Beijing has experienced such severe air pollution in recent years that it has adopted policy instruments to strongly control production activities and the movement of vehicles on streets when the air quality is bad. Policy instruments adopted by city governments are also influenced by the national policy documents. For instance, all the city governments have the responsibility to reduce emissions to levels set by the central government and they in turn assign the emission reduction targets further to the lower-level governments.

The research is in its preliminary stage and further understanding of why city governments use certain policy instruments and how actor networks can possibly contribute to the understanding of the differences within these cities is the next step of the analysis.

[21] It was changed to Ministry of Ecology of Environment in 2018.

Reference

Bastian, M., Heymann, S., & Jacomy, M. (2009, March). Gephi: an open source software for exploring and manipulating networks. In *Third international AAAI conference on weblogs and social media*.

Boons, F., Spekkink, W., 2015. Internalizing Environmental Responsibility in the Dutch Chemical Industry.

Carl, J., Fedor, D., 2016. Tracking Global Carbon Revenues: A Survey of Carbon Taxes Versus Cap-and-trade in the Real World. Energy Policy 96, 50–77. doi:10.1016/j.enpol.2016.05.023

Chang, K., Pei, P., Zhang, C., Wu, X., 2017. Exploring the Price Dynamics of CO2 Emissions Allowances in China's Emissions Trading Scheme Pilots. Energy Econ. 67, 213–223. doi:10.1016/j.eneco.2017.07.006

Chen, L.-J., Zhu, L., Fan, Y., Cai, S.-H., 2013. Long-Term Impacts of Carbon Tax and Feed-in Tariff Policies on China's Generating Portfolio and Carbon Emissions: A Multi-Agent-Based Analysis. Energy Environ. 24, 1271–1293. doi:10.1260/0958-305X.24.7-8.1271

Dong, J., Ma, Y., Sun, H., 2016. From Pilot to the National Emissions Trading Scheme in China: International Practice and Domestic Experiences. Sustain. 8, 17pp. doi:10.3390/su8060522

Ekins, P., Barker, T., 2001. Carbon Taxes and Carbon Emissions Trading. J. Econ. Surv. 15, 325–376.

Flanagan, K., Uyarra, E., Laranja, M., 2011. Reconceptualising the "Policy Mix" for Innovation. Res. Policy 40, 702–713. doi:10.1016/j.respol.2011.02.005

Goulder, L.H., Schein, A.R., 2013. Carbon Taxes versus Cap and Trade: A Critical Review. Clim. Chang. Econ. 4, 1–28. doi:10.1142/S2010007813500103

Howlett, M., How, Y.P., del Rio, P., 2015. The Parameters of Policy Portfolios: Verticality and Horizontality in Design Spaces and Their Consequences for Policy Mix Formulation. Environ. Plan. C Gov. Policy 33, 1233–1245. doi:10.1177/0263774X15610059

Howlett, M., Mukherjee, I., 2014. Policy Design and Non-Design: Towards a Spectrum of Policy Formulation Types. Polit. Gov. 2, 57–71. doi:10.2139/ssrn.2461087

Howlett, M., Ramesh, M., Perl, A., 2009. Studying Public Policy: Policy Cycles & Policy Subsystems, 3rd ed. Oxford University Press, Oxford.

Kang, J., Yuan, J., Hu, Z., Xu, Y., 2012. Review on Wind Power Development and Relevant Policies in China during the 11th Five-Year-Plan period. Renew. Sustain. Energy Rev. 16, 1907–1915. doi:10.1016/j.rser.2012.01.031

Ke, J., Price, L., Ohshita, S., Fridley, D., Khanna, N.Z., Zhou, N., Levine, M., 2012. China's Industrial Energy Consumption Trends and Impacts of the Top-1000 Enterprises Energy-Saving Program and the Ten Key Energy-Saving Projects. Energy Policy 50, 562–569. doi:10.1016/j.enpol.2012.07.057

Kern, F., Kivimaa, P., Martiskainen, M., 2017. Policy Packaging or Policy Patching? The Development of Complex Energy Efficiency Policy Mixes. Energy Res. Soc. Sci. 23, 11–25. doi:10.1016/j.erss.2016.11.002

Kosnik, L.-R., 2018. Cap-and-trade Versus Carbon Taxes: Which Market Mechanism Gets the Most Attention? Clim. Change 151, 605–618. doi:10.1007/s10584-018-2330-z

Levin, K., Cashore, B., Bernstein, S., Auld, G., 2012. Overcoming the Tragedy of Super Wicked Problems: Constraining Our Future Selves to Ameliorate Global Climate Change. Policy Sci. 45, 123–152. doi:10.1007/s11077-012-9151-0

Li, L., 2018. Assessing the Implementation of Local Emission Trading Schemes in China: Econometric Analysis of Market Data. China Policy J. 1, 27–55. doi:10.18278/cpj.1.1.2

Mir-Artigues, P., Del Río, P., 2014. Combining tariffs, investment subsidies and soft loans in a renewable electricity deployment policy. Energy Policy 69, 430–442. doi:10.1016/j.enpol.2014.01.040

Munnings, C., Morgenstern, R.D., Wang, Z., Liu, X., 2016. Assessing the Design of Three Carbon Trading Pilot Programs in China. Energy Policy 96, 688–699. doi:10.1016/j.enpol.2016.06.015

Nordhaus, W., 2013. The Climate Casino: Risk, Uncertainty and Economics for a Warming World. Yale University Press, New Haven, USA & London, UK.

Peters, B.G., 2017. What is So Wicked About Wicked Problems ? A Conceptual Analysis and A Research Program. Policy Soc. 4035, 1–12. doi:10.1080/14494035.2017.1361633

Price, L., Levine, M.D., Zhou, N., Fridley, D., Aden, N., Lu, H., McNeil, M., Zheng, N., Qin, Y., Yowargana, P., 2011. Assessment of China's Energy-saving and Emission-reduction Accomplishments and Opportunities during the 11th Five Year Plan. Energy Policy 39, 2165–2178. doi:10.1016/j.enpol.2011.02.006

Taeihagh, A., 2017. Network-centric Policy Design. Policy Sci. 50, 317–338. doi:10.1007/s11077-016-9270-0

Taeihagh, A., Bañares-Alcántara, R., 2014. Towards Proactive and Flexible Agent-based

Generation of Policy Packages for Active Transportation, in: Proceedings of the Annual Hawaii International Conference on System Sciences. IEEE, pp. 895–904. doi:10.1109/HICSS.2014.118

Taeihagh, A., Banares-Alcantara, R., Givoni, M., Givoni, M., 2014. A Virtual Environment for the Formulation of Policy Packages. Transp. Res. Part A Policy Pract. 60, 53–68. doi:10.1016/j.tra.2013.10.017

Taeihagh, A., Bañares-Alcántara, R., Millican, C., 2009. Development of A Novel Framework for the Design of Transport Policies to Achieve Environmental Targets. Comput. Chem. Eng. 33, 1531–1545. doi:10.1016/j.compchemeng.2009.01.010

Taeihagh, A., Givoni, M., Bañares-Alcántara, R., 2013. Which Policy First? A Network-centric Approach for the Analysis and Ranking of Policy Measures. Environ. Plan. B Plan. Des. 40, 595–616. doi:10.1068/b38058

Tan, X., Wang, X., 2017. The Market Performance of Carbon Trading in China: A Theoretical Framework of Structure-Conduct-performance. J. Clean. Prod. 159, 410–424. doi:10.1016/j.jclepro.2017.05.019

Thompson, W., Johansson, R., Meyer, S., Whistance, J., 2018. The US Biofuel Mandate as a Substitute for Carbon Cap-and-trade. Energy Policy 113, 368–375. doi:10.1016/j.enpol.2017.10.041

Wu, L., Qian, H., Li, J., 2014. Advancing the Experiment to Reality: Perspectives on Shanghai Pilot Carbon Emissions Trading Scheme. Energy Policy 75, 22–30. doi:10.1016/j.enpol.2014.04.022

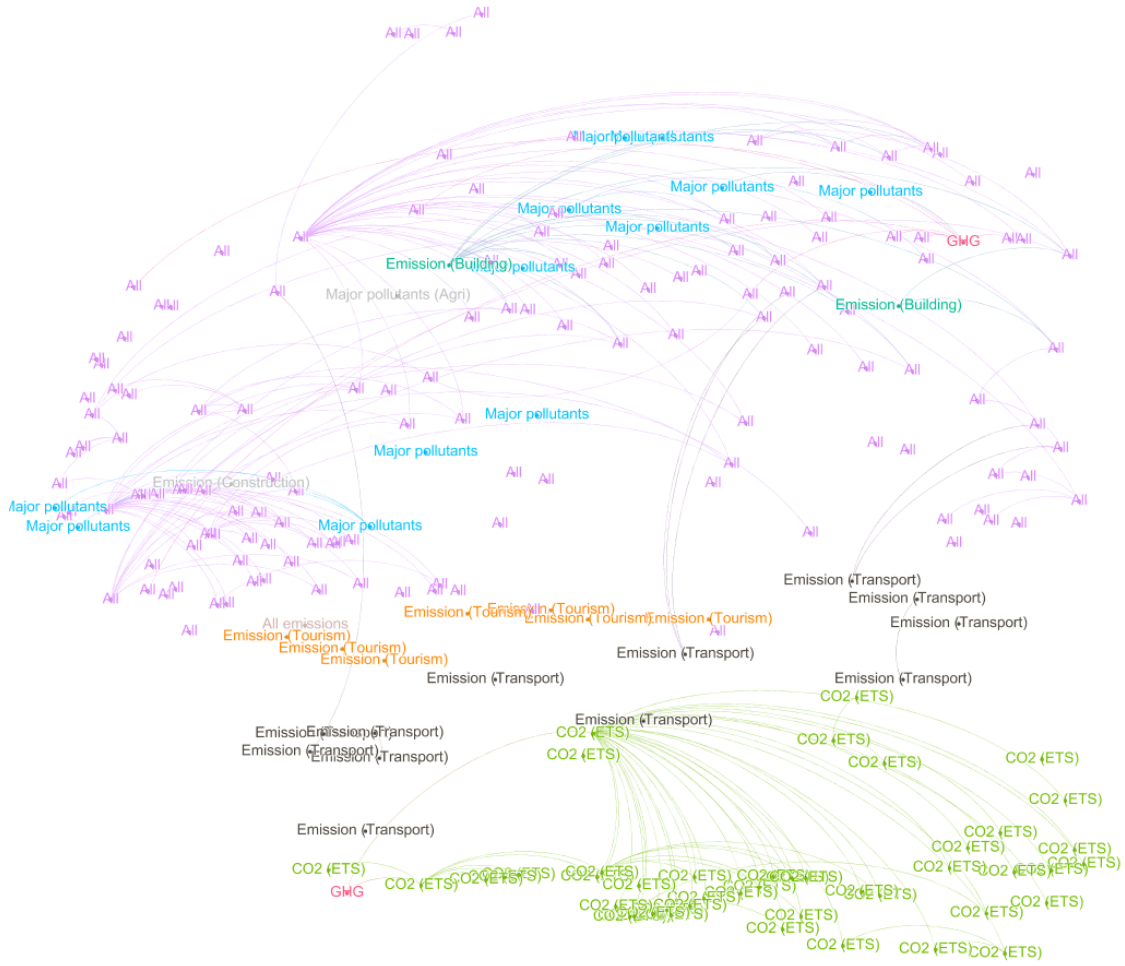
Zhang, D., Karplus, V.J., Cassisa, C., Zhang, X., 2014. Emissions trading in China: Progress and prospects. Energy Policy 75, 9–16. doi:10.1016/j.enpol.2014.01.022

Zhang, M., Liu, Y., Su, Y., 2017. Comparison of Carbon Emission Trading Schemes in the European Union and China. Climate 5, 70. doi:10.3390/cli5030070

Zhang, Z., 2015. Carbon Emissions Trading in China: the Evolution from Pilots to a Nationwide Scheme. Clim. Policy 15, 104–126. doi:10.1080/14693062.2015.1096231

Appendix

Appendix 1. Event sequence graph of Shanghai



Note: Differing from Figure 5 in the main text, this figure uses colour to differentiate policy documents aiming at reducing different emissions. Policy documents displayed from left to right indicates the temporal sequence that the policy documents are issued. That is, policy documents on the right side are the documents that are more recently released. "CO_2 (ETS)" indicates the policy document is relating to implementation of ETS to reduce CO_2 emissions. "Major pollutants" indicates the policy document is to reduce major air pollutants (such as SO_2 and NOx) and major water pollutants (such as COD and NH_4^+). "All" indicates the policy document is to reduce all emissions, including major pollutants and CO_2 emission. "Emission (Transport)" indicates the policy document is to reduce emissions in transport sector. "Emission (Construction)" indicates the policy document is to specifically reduce emissions in the construction sector. "Emission (Building)" indicates the policy document is to specifically reduce emissions in the building sector. "Emission (Tourism)" indicates the policy document is to reduce emissions in the tourism sector, including emissions of restaurants.