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Emissions trading scheme:
An analysis of China ETS Pilots

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前言

气候变化，或称全球变暖、全球暖化 是国际社会普遍关注的全球性问题。全球气候变化的影响日议显示，各国应该携手应对气候变化，共同推进绿色、低碳发展已成为当今世界的主流。

气候变化一词在 《联合国气候变化框架公约》的使用中，气候变化是指“经过相当一段时间的观察，在自然气候变化之外由人类活动直接或间接地改变全球大气组成所导致的气候改变”。据《美国橡树岭实验室研究报告》，自 1750 年以来，全球累计排放了 1 万多亿吨二氧化碳。过去一百多年间，人类一直依赖石油煤炭等化石燃料来提供生产生活所需的能源，燃烧这些化石能源排放的二氧化碳等温室气体是使得温室效应增强、进而引发全球气候变化的主要原因。由此，大气层 就 如 同覆盖着玻璃的温室一样，可以保存一定的热量，如果没有温室效应，地球将会冷得不适合人类居住。据估计，如果没有大气层，地球表面温度会是零下 18 摄氏度。正是有了温室效应，才使地球温度维持在 15 摄氏度。温室气体效应是一种自然现象， 但是越来越多排放的后果包括极端干旱、缺水、重大火灾、海平面上升、洪水、极地冰层融化、灾难性风暴，以及生物多样性减少等。

为了减排联合国总部 图了一项计划， 这就是碳排放权交易体系（ETS）。 它是一种减排的市场机制、鼓励企业致力减排、控制污染经济工具、有助于达致 污染物减排的目标。在碳排放权交易体系中，监管机构对经济体中明确界定的部门（覆盖范围）允许排放的温室气体（GHG）上限（cap）进行定义。

碳排放许可证或配额被发放或出售（分配）给被纳入碳市场的实体。在规定的时间段结束时，每个被覆盖的实体必须交出与它们在此期间的排放量相对应的配额数量。排放量低于其持有的配额数量的实体可将多余的配额出售给碳市场的其他参与者。因此，减排成本低的实体有动力减少其碳排放，而那些面临较高减排成本的实体可以选择从市场上购买配额来实现履约。

中国目前的二氧化碳排放总量占全球的 30%，是世界上最大的排放国。于 2007 年 中国 国家发展和改革委员会 第一次发布 《中国落实国家自主贡献目标的新部署新举措》。 这本文书上 宣布 中国实施 应对 气候变化 国家的战略。截至 2020 年 把 二氧化碳数值 降低 20% 于 2005 年的数值。

截至为止，中国宣布了两个 截至 2020 年度的目标：“碳达峰”和“碳中和”目标；。通过 “碳达峰”中国承诺在 2030 年前，二氧化碳的排放 不再增长，之后逐步回落。通过“碳中和” 中国承诺在 2060 年前， 二氧化碳的排放不在排放。为了落实减排的战略 2020 年，中国宣布更新和强化国家自主贡献目标：中国二氧化碳排放力争 于 2030 年前达到峰值，努力争取 2060 年前实现碳中和；这两个目标一起 还简称“双谈”。此外，到 2030 年， 中国单位国内生产总值（GDP）二氧化碳排放 将比 2005 年下降 65％ 以上，非化石能源占一次能源消费比重将达到 25％左右。

为了准备中国碳排放权交易体系 在 2011 开始 中国政府实施中国的一些区域碳排放权交易试行， 其中包括 深圳市、天津市、北京市、 上海市、重庆市、 广东省、湖北省和 福建省。中国的碳排放交易商也正在从温室气体排放交易中获取利润。化工厂减少向大气排放污染性的温室气体，可获得碳排放信用。这种信用在国际碳排放交易市场上可以销售。

我的硕士文论 研究 对象 中国 排放放权交易的 设计、问题 和 影响。为了深入研究中国 ETS 我提供线索把覆盖范围、排放上限、排放许可证的项目。因此，我判断来源于周密的深入 调查 排放权交易的研究资料。每一个中国的碳排放权交易式的设计有一个具体效果，通过 一个系统和内在的分析方法我 研究 碳排放权交易 最重要的 设计项目: 覆盖范围、排放的温室气体上限、配额的分配。然后，我研究排放权交易的 经济和环保 背景和目前环境。我评论 中国排放权交易的未来影响和潜在效果。这论文的结论除了 表示 普遍 环境因素 的分析 以外 它还对这个论题提出一些新的见地。

INTRODUCTION

The ETS or Emission Trading Scheme is an instrument adopted by nations pledged under the Paris Agreement, with the objective to reduce as much carbon dioxide emissions as necessary, to comply to the goal of keeping the world's temperature below 2°C, preferably to 1.5°C compared to pre-industrial levels in an economic way. Since then, several ETS have been established, and as of 2022 there are 25 ETS worldwide operative representing 55% of global carbon emissions. Together with the commitments to the Paris agreement, China has also its own carbon goals: reaching peak emission by 2030 and carbon neutrality by 2060, namely known as dual goals.

The means to reach emission peaking have been unclear for many years and the road to a National ETS in China has been lengthy and full of challenges that further delayed an already complex mechanism. Since its first announcement in 2011, the National ETS formally launched ten years later in 2021 and as it just started, the national market is still in its infancy and faced with some challenges. However, in the length of these ten years, China developed different regional ETS Pilots to better understand its development and mechanism, especially in the context of the Chinese environment. The Pilots selected were implemented with the objective to develop the basis for the National ETS, learning understanding, and correcting what was necessary along the way from all these different backgrounds. Many elements of the ETS have been translated to adapt the Chinese needs.

At the basis of this study lay these two questions:

Q1: What are the learnings on ETS design through the pilots? And in light of the national one?

Q2: What are the elements in play in the context of the ETS? Has the ETS been useful to Chinese carbon goals? Are China's policies and environment mature enough to support the development of a successful ETS?

With these questions what I am aiming at is, with the first one, at a better understanding of the design mechanism that have been useful in the reduction of carbon emission in the ETS Pilots and determining which are those that can effectively assist in reducing carbon emission in the future of the National ETS by making an assessment of their impacts in the Pilots. The relevance of this study lies in the reasoning that China committing to reduce CO2 also means to potentially reduce big part of the world's carbon emission levels. It is crucial to understand what lays at the basis of a national ETS and understand the right design that can efficiently reduce carbon emissions without compromising economic growth and find a balanced way that leads to carbon peaking and subsequently to carbon neutrality. The literature in this field have discussed whether a carbon market would succeed in China, and the findings have been crucial to further assist in the development of the pilots and future National ETS. My contribution comprises of an updated comprehensive assessment of the main design features, namely coverage, cap settings, allowances and allowances allocation as they are at the base of the implementation of a carbon market and determine distinct outcomes with different choices.

Moreover, with the second question the study focuses on exploring what are the elements in the Chinese environment that influence the project: some are canonically considered in the precedent studies of the ETS, and some to a certain extent have an influence on the ETS that has not always been considered by precedent literature. As Tan et al. affirmed, although there are studies crossing decarbonization and other environmental, and economic fields, research gaps still exist when enhancing climate governance toward carbon neutrality. The contribution of my thesis in this sense lays in the expansion of this interconnection by adding to the stablished environmental and economic variables, social and climate governance variables, and moving in the context of carbon mitigation in China.

Due to the particular social structure of the country, the design of the ETS requires specific adaptations and local precautions and China distinctive socialist market economy imposes on the ETS pilots numerous complications, meaning that the design must be executed in manner to satisfy all this variables. By reframing the carbon market with Chinese characteristics and trying to understand what influenced the decision making of the designs and what results these brought, I identify the factors influencing the design process and the setting around it and outline important topics for the national ETS. This is to both highlight different aspects and studies of the pilots that have not been approached yet and to lay the foundation for a future national market-based climate policy. Ultimately, the objective is to understand

whether the ETS can be a useful climate mitigation tool for China for its carbon dual goals and the Paris agreement, as well as its implication for the future.
In doing so, the thesis is empirically founded on document analysis and expert assessments, following closely the developments of the China ETS Pilots, I display an analysis of the design features, specifically coverage, cap setting and allowance allocation, that have been implemented along the years.

The thesis is divided in 3 chapters. After the introduction will follow Chapter 1 which defines the emissions trading scheme in China supported by a historical background with timeline of ETS in China. Following right after I will illustrate China carbon initiatives, and the description of the ETS mechanism, followed by a brief overview of the regional Pilots and their contribution so far. In the last paragraphs of this chapter, I will study the issues encountered by the Pilots in these years.

In the second chapter lies the Literature Review of my thesis with relevant studies that proved to be useful in the drafting of this paper. The line of thought of the second chapter, as the first one, will initially show the literature review regarding the design feature of the Pilots, followed by the evaluations of ETS and afterword those encompassing the effects and impacts of the Pilots. At the end of each paragraph there will be a panel summarizing the literature considered in the study in order to have a clear picture of the relevant studies.

The third chapter shows the methodology adopted throughout my research, followed by the related results and by the discussion and examination of these same findings. The evaluation of the results follows the two research questions, which validity, will be verified throughout the paper. In the results and discussion paragraph I examine the relevant variables that are involved in the success of the ETS, both of the Pilots and National one, from canonic environmental and economic ones to reach the importance of the stabilization of the climate and energy framework of the country. At last, at the end of this paper I will draw the conclusion of the study by doing an outline of the final results.

CHAPTER 1 – Defining ETS in China

The concept of carbon trading is first seen in 1997 in the Kyoto Protocol[1], the progenitor of the Paris agreement[2]. Among the most common methods of climate mitigation that have been used since then, there are carbon tax, Emissions Trading Schemes (ETS), Clean Development Mechanism (CDM), and Joint Implementation (JI). As of today, the ETS is recognized as an effective mean to reduce carbon emission as well as a climate mitigation tool around the world and, since China is currently facing a series of environmental problems such as resource shortage, environmental degradation, climate change, and given China's socialist market economy and unique challenges, the launch of the China national ETS, is another trial to understand its applications and outcomes.

In this first chapter I will give an overall exhaustive presentation of the ETS developments in China as to give a proper background of the topic in discussion. I will start with the definition of ETS and Chinese carbon initiatives then move to a timeline highlighting major dates in the history of the ETS in China. I will conclude the first chapter by discussing some relevant issues related to the pilots that have been encountered along the years.

1. Historical background

The ETS, which stands for Emissions Trading Scheme, is a tool conceived with the objective to reduce the emission of greenhouse gases, in this case of carbon dioxide – CO2, into the world. It is based on the idea to implement a market for the exchange of carbon emissions certificates as main commodities and the punishment of those emitting more emissions than allowed through the mechanism. The objective is to reduce as much carbon emissions as necessary in an economic mean to comply to the goal of keeping the world's temperature well below 2°C, following the line of decisions developed the Kyoto Protocol and recently, the Paris agreement that took place in 2015 at the COP21. There are two main types of mechanism:

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[1] Kyoto Protocol: Operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries and economies in transition to limit and reduce the emissions of greenhouse gases in accordance with individual targets. It was adopted on 11 December 1997.

[2] Paris agreement: is a legally binding international treaty on climate change. It was adopted on 12 December in 2015 and entered into force on 4 November 2016 by 196 Parties in Paris. It is also referred as COP21 because it was the 21st Conference of the Parties of the UNFCCC.

“Cap-and-trade” and “Baseline-and-credit”. In the first one the government sets a cap on the emissions, then emits allowances that are given through specific criteria (which I will discuss in the next paragraphs) to participants. During the term provided the participants are allowed to produce just the amount of carbon emission equal to the allowances, and if they produce less carbon emissions than the amount given, they can exchange their excess allowances - or buy allowances to compensate their excess emissions. Creating in this way, the market for the emissions of carbon dioxide. In the “baseline-and-credit” there is not a limit of emissions but the participants that reduce their CO2 more than they are obliged to, can earn “credits” that they can sell to other participants that needs them in order to comply with other regulations they are subjected to. This market mechanism is thought to be able to reduce greenhouse gas emission in an economic way, in the sense that the objective is to reduce CO2 in a cost-effective manner, without compromising the economic growth of the country, minimizing as much as possible the costs of reducing CO2.

The Kyoto Protocol came into force in 2005 and since then carbon trading has been specifically adopted in several countries and regions wiling to combat climate change and reduce CO2. Some examples are the EU ETS, which has been running since 2005, the California Cap-and-Trade, the New Zealand ETS and many more countries. As of the start of 2022, there are 25 operational ETS’s around the world representing 55% of the global GDP. According to the 9th ICAP Status Report, these systems cover 17% of the global emission. Carbon trading has been key strategy in many developed countries to achieve their carbon targets and lastly, the final goal of different national ETS throughout the world, is to link them to create a global carbon market to keep the levels of CO2 at safety margins (based on the IPCC climate report 2015). At the same time, the linking of emission systems will promote economic efficiency, which means allowing abatement costs[3] to take place where it is cheapest to undertake. The project has relevant consequences not only in China but also in the rest of the world as globalization and chain consumption links countries all over the world in contributing to the rapid rise of CO2 levels and depletion of natural resources.

[3] Abatement costs: are the costs associated with removing environmental negative byproduct, in this case carbon emissions.

a. China carbon initiatives

China began to progressively strengthen its climate change commitments in 2007 with the development of the country's first global warming policy initiative issued by the National Development and Reform Commission (NDRC). It emphasized measures to lower greenhouse gas emissions to reach a reduction target of 20% below 2005 levels by 2020 in energy consumption per unit of GDP. In November 2009, the State Council announced two 2020 targets during the UNFCCC's 15th Conference of the Parties (COP15) in Copenhagen: reduce CO2 per unit of GDP by 40-45% relative to 2005, and to reach peak emissions at the latest by 2030. During the Asia-Pacific Economic Cooperation (APEC) in November 2014, president Xi Jinping announced that China's carbon emission would stop growing by around 2030 and that 20% of China's energy mix would make up of clean energy sources by that year. Again, in 2017 Xi reasserted that China's commitment in reducing CO2 emissions was still strong, however during the Madrid negotiation in December 2019, China joined other big carbon emitters countries such as India and Brazil in resisting more ambitious targets, insisting that developed countries had to maintain their 2015 Paris commitments before developing countries could commit to stronger, new ones. Turning back on track, in the fall of 2020, President Xi Jinping pledge before the UN General Assembly that the country would peak its carbon dioxide emissions before 2030 and aim to achieve carbon neutrality before 2060. These two goals are known as China's "dual carbon" goals. Additionally in its 14th FYP that took place in 2021 it set a reduction target of 18% for CO2 intensity and 13.5% reduction target for energy intensity from 2021 to 2025. In the last NDRC China pledged to reach 20% of non-fossil fuels in primary energy consumption by 2030. The country's first pledge in Copenhagen in 2009 committed to reducing national CO2 intensity by 40%–45% by 2020, relative to 2005 levels. Ahead of the 21st Conference of Parties (COP) in Paris in 2015, China's leaders announced intentions to reduce the CO2 intensity of China's economy by 60%–65% below 2005 levels by 2030, and to reach peak CO2 emissions at the latest by 2030. In the fall of 2020, President Xi Jinping announced before the UN General Assembly that the country would aim to achieve CO2 neutrality by 2060.

year	Carbon reduction goals and time frame
2009	Reduce CO2 intensity by 40-45% by 2020, relative to 2005 values
2014	Reduce CO2 intensity by 60-65% by 2030, relative to 2005 values
2020	Achieve CO2 neutrality by 2060
	Source: IEA

Figure 1 Carbon reduction goals and time frame

b. Timeline to a national ETS

In the following paragraph I have summarized the development of such complicated mechanism in the form of dates in a timetable, in which major policies and announcement were released in China in order to have an orderly and progressive image of its creation.

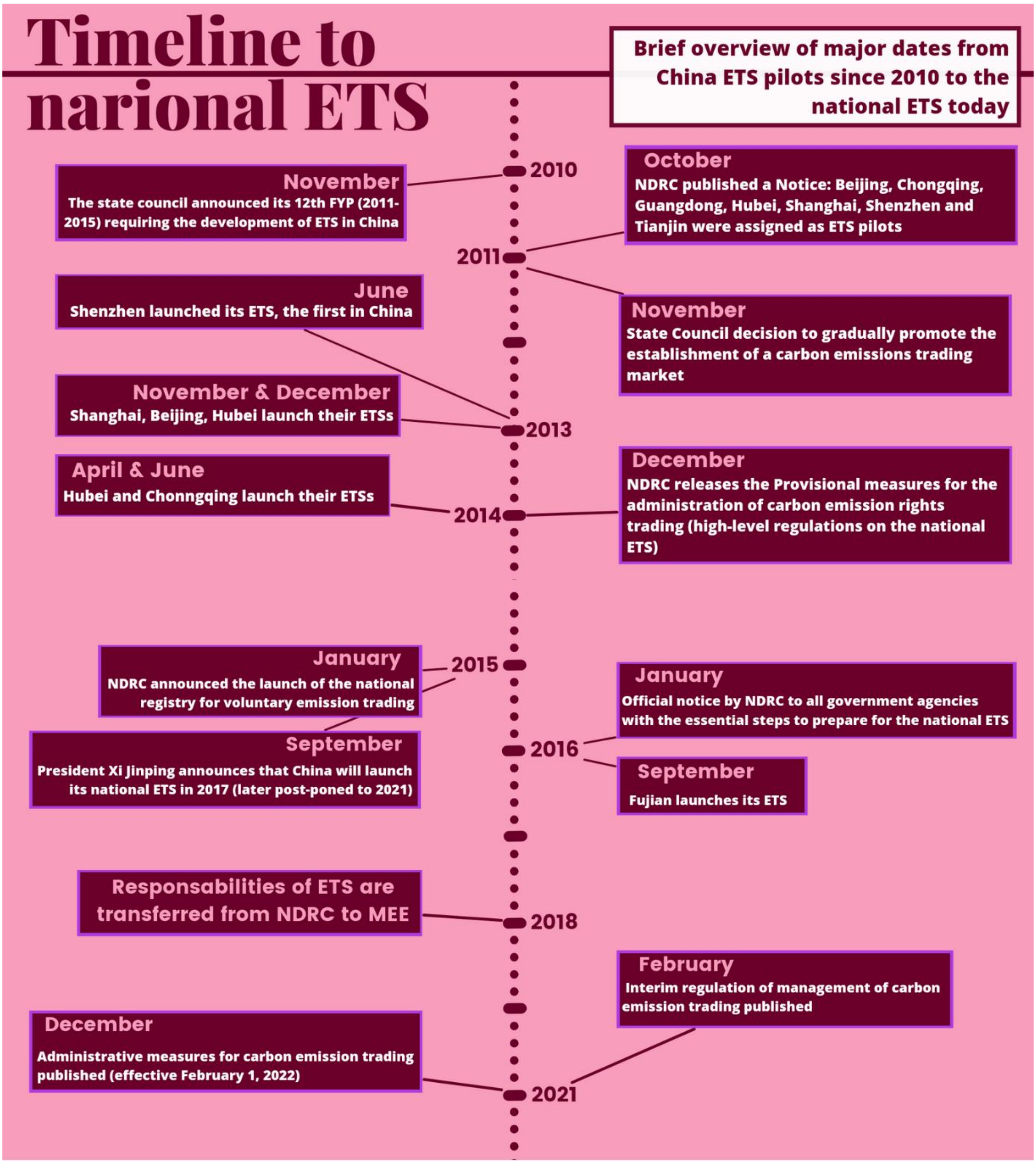

Figure 2 Timeline to a National ETS

Focusing on the ETS, China embarked into this project in November 2010, when the first announcement made by the State Council announced in its 12th Five-Year-Plan (FYP) required the development of the ETS in China. Subsequently in 2011 the NDRC – National Development and Reform Commission published a Notice assigning Beijing, Tianjin, Hubei, Chongqing, Shanghai, Guangdong and Shenzhen as ETS Pilots. In the next years the provinces, cities and regions gradually launch their local ETS'. At the same time the NDRC progressively release provisional measures and notices promoting and further developing the regulatory framework and ETS platforms such as the carbon emissions right trading and the national registry for voluntary emissions trading and in 2016, Fujian is added on the list of regional Pilots.

The China National ETS started operating in 2021, covering the power sector which equals to around 40% of China's emissions and 15% of the world industries. To date, there is still little information available but partial results show that covered overall greenhouse gas emissions of 12301 MtCO2e (Metric tons of carbon dioxide equivalent), and the extent to which emissions trading will reduce China's emissions of heat-trapping gases is still largely unclear.

An important factor is represented by the governance restructuring that took place starting in 2018 that shifted the entire climate portfolio to a new office. As a result, ETS-related responsibilities were shifted from the NDRC to the Ministry of Ecology and Environment (MEE) or Ecology and Environment Bureau (EEB) ("China to establish ministry of ecological environment," 2018). The shift was not immediate, rather it took a couple of years and as we will see later, it was effective in the pilots in different years ranging from 2018 to 2020. During 2021 the NDRC starts the preparations to launch the National ETS and publishes the framework of the national ETS. However, in May 2021 the transfer was reversed and responsibilities for the coordination of dual carbon targets were returned to the NDRC ("China puts most powerful agency," 2021). The MEE preserves the responsibilities for the carbon market. As 2022, according to the Administrative Measures (MEE, 2021a), China National ETS ought to have a multi-level governance system with unified rules for all-provinces regions. In the way that the central authority will issue the regulations and general allocation objectives and allowance allocation while the provinces have responsibilities for implementation and distribution based on the central government indications.

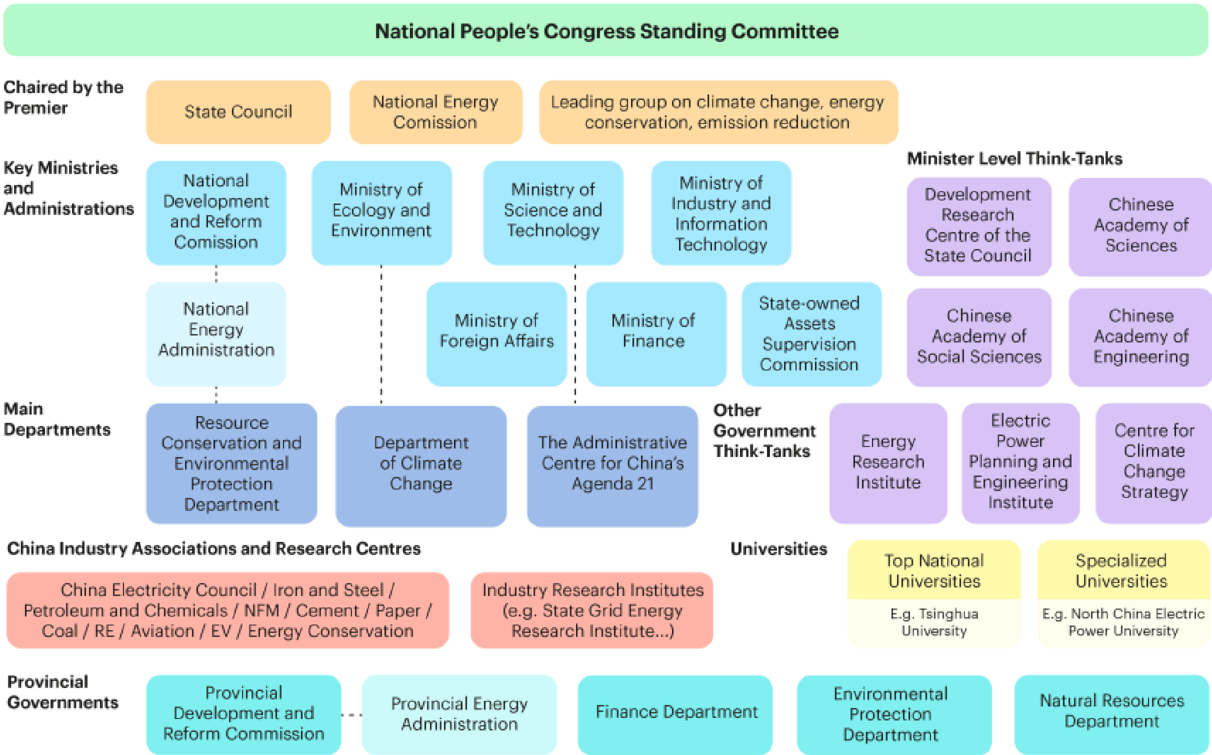

Figure 3 National People's congress Standing commitee

2. ETS Pilots overview

That very first Notice in 2011 marked the first explicit use of a market-based instrument for climate governance in China, it was chosen a cap-and-trade system and alas, the implementation proceeded slowly due to data availability challenges, government reorganization, the inherit complexity of emissions trading programs and, most recently, covid-19 pandemic. The biggest concern associated with a trading scheme discussed by many experts is whether it will effectively support economic development while reducing carbon emissions in a country with a population of over 1,412 billion people, a territory of 9.597.000 km² that includes extremely diverse development levels and GDP per capita.

Yet, in the Chinese case, the government was able to gain knowledge and experience throughout its involvement with prior experience with the Clean Development Mechanism (CDM) (an industrial energy efficiency program of the Kyoto Protocol), and early experiments with sulfur dioxide (SO2) trading in the late 90's, and adding to that, the ETS pilots. With more than ten years of experience, China surely has enough foundation to implement and operate a national ETS and thus, the national trading market was officially launched in 2021. As it just started, the market is still in its infancy and faced with some challenges (e.g., inactive trading, steep decline in carbon price, and inadequate incentive for low-carbon investment; it is not a mature carbon market and there are still not enough data at the moment to practice a proper study on the matter. Indeed, there are not many studies focusing on the actual results of the National ETS or assessing their contribution to China carbon goals based on actual available data. It is worth noting that as of 2022, the national ETS is coexisting with its pilots pioneers, as they haven't been absorbed yet and are still fully operating.

The pilots selected were not chosen by chance. The economic development of China is not at the same level throughout the whole country, as a matter of fact, along the eastern coast reside the wealthiest regions, whereas the inland, economically lag behind. The pilots are located in different areas on the Chinese territory accounting for more than 5%, this is made in order to cover as much of the complexity of the country as possible. The underdeveloped inland areas regions are represented by Hubei and Chongqing while Guangdong is the largest province with the highest GDP and population. Shenzhen is the most flourishing territory with the highest GDP per capita compared to the other six regions while Tianjin's per capita GDP is the highest among the four municipalities. The GDP and populations from all seven regions account for approximately 27.4% and 19.26% of the whole country. They cover an area populated by more than 260 million people and have widely varying economies (Jotzo, Loschel, 2014, p. 3). Beijing, Tianjin, and Shanghai had in 2015 per capita incomes above US$14,000; Guangdong US$10–12,000, while Chongqing and Hubei were in the range of US$8–10,000. It is clear the choice of these cities is to represent as much as possible the different economic development ranges existing within the country, as the main purpose of establishing the pilots by the Chinese government is to gain the needed information, knowledge, and experience to run a national ETS, its focus is to take into consideration these differences. The pilots have been independently implemented and operated by their authorities and as they vary in the different levels economic development, energy consumption structure, and due to the restructuring of key industries in the regions, as we will see later, these differences reflect also in their decisions in the design and structure of the pilots, allowance allocation, sector coverage decisions. Thus, in the next paragraphs I will briefly illustrate the overview of such differences and give a background of the pilots in order of launch before explaining in the subsequent paragraphs the specific designs for key features elements.

Pilot areas of China's ETS. Source: The data were taken from the Blue Book of Low Carbon Economy: China's Low Carbon Economic Development Report (2017) (Xue and Zhao, 2017).

Figure 4 Pilots areas of China's ETS

a. Shenzhen

The Shenzhen Pilot was the first one to launch in June 2013. As a special economic zone and part of the province of Guangdong, it is the only pilot at sub-provincial level. Despite its relatively small size, Shenzhen is one of the most active regional markets in China. It covers 635 industrial companies and 194 public buildings. The pilots are generally regulated by subnational government orders by the executive body of the government, but the Shenzhen pilots is regulated instead by a specifically dedicated ETS bill passed by its municipal legislator (the Shenzhen People's Congress), which actually provides more legal stability. Additionally, evidence of the decoupling of economic growth from carbon emissions can be seen in Shenzhen because at the end of 2020 the average carbon intensity of the covered industrial entities had dropped by 40.3% since the launch of the ETS, while the industrial value added has increased by 61.6%.

b. Shanghai

The Shanghai ETS pilot was the second Chinese region to be operative in 2013. The pilot used to cover more than half of the city's emissions, comprising industry and non-industrial sectors such as buildings, aviation, and shipping. It is the only pilot that has achieved 100% compliance rate continuously since its launch. The ETS-related responsibility in Shanghai were effectively transitioned from the NDRC to the Ecology and Environment Bureau (EEB) as a result of governance restructuring across China in 2019.

c. Beijing

The Beijing pilot started operating in 2013 and is the only other pilot (the other one is Shenzhen) with an ETS regulation passed by its regional congress, the Beijing Municipal Ecology and Environment Bureau (EEB), which became the competent authority for the ETS in 2019. The pilot covers CO2 emissions from all fixed installations within the administrative jurisdiction of its municipality, which equals approximately 24% of Beijing's total emissions from sectors such as heat, cement, petrochemicals, other industrial enterprises, manufacturers, service sector, and public transportation. In 2020 the aviation sector was added in the mandatory reporting scheme, preparing the sector to be incorporated in the carbon market but without any specific target date.

d. Guangdong

Guangdong started operating in December 2013, and successfully became the first pilot to run through the entire operational process by July 2014; including companies' emissions reporting, verification, allowances allocation and auction, and companies' compliance. It concluded eight compliance years with high compliance rates. The CO2 emissions in Guangdong mainly come from industry and manufacturing and the ETS covers cement, steel, petrochemical, paper, and domestic aviation sectors, accounting for around 40% of the province's carbon emission. The ETS-related responsibilities transitioned from the NDRC to the DEE - Department of Ecology and Environment in 2018. In December 2015, it had traded about 23.20 Mt of allowance, accounting for about 35.7% of the total trading volume of all pilot areas; and its accumulated revenue of 960 million CNY was about 43.3% of the total revenue of all pilot areas, highlighting its position as the largest carbon market in China. This pilot has been operating quite efficiently, and the covered enterprises are fairly observant as over 80% of them has achieved emissions reductions.

e. Tianjin

Tianjin launched its ETS in December 2013 and covers heat and electricity production, iron and steel, petrochemicals, chemicals, oil and gas exploration, papermaking, aviation, and building materials. The covered entities accounted for around 50-60% of the city's total emissions in 2020. The Tianjin Ecology and Environment Bureau (EEB) is responsible for the governance of the Tianjin Pilot ETS since 2019, taking over from the Development and Reform Commission. Since then, Tianjin has further enhanced the legal foundation of its ETS and continuously improved its market performance.

f. Hubei

Hubei is a major province in central China covering an area of 185,900 km2. In 2015 It contributed of 2.95 trillion yuan to the GDP, the permanent population reached 58.52 million at the end of 2015 and it is clear that the province is on the fast-growth track. Hubei ETS pilot launched in April 2014 and has since concluded seven compliance years. It is the second-largest market size in terms of trading volume after Guangdong. It covers a large range of industrial sectors and has expanded its scope several times. It covered power sector until 2019, after which transitioned to the national ETS. As of 2019, the system was covering approximately more than 373 entities and 27% of the province's CO_2 emissions.

g. Chongqing

Chongqing launched its pilot ETS in June 2014 and to date, it has concluded seven compliance years. The Ecology and Environment Bureau (EEB) of Chongqing is responsible for the ETS. It covers electrolytic aluminum, ferroalloys, calcium carbide, cement, caustic soda, and iron and steel, and other industrial sectors. The power sector was covered until 2019, after which it transitioned to the national ETS. In 2020 the 152 enterprises covered by the system accounted for 51% of the city's total carbon emissions. Among the eight Chinese pilots, the Chongqing ETS is the only one that covers non-CO_2 gases.

h. Fujian

The Fujian ETS pilot launched rather late than the others, as in the original notice for the implementation of the pilots Fujian was not present. It is the eighth pilot to be implemented during September 2016. It covers electricity grid, petrochemicals, chemicals, building materials, iron and steel, nonferrous metals, paper, aviation, and ceramics sectors. The electricity generation sector was covered until 2019, after which it was incorporated into the national ETS. It has achieved full compliance in its five compliance years. The Fujian ETS pilot has a specific focus on carbon sinks given the prominence of the forestry sector. In 2017, the Fujian government defined a plan to promote forestry offsets projects in the province. As a result, by the end of 2020 2.8 million tonnes of forestry offset credits had been traded in the Fujian ETS, with a total turnover of over 40 million CNY (6.2 million USD), overachieving the province's target of forestry offsets set in 2017.

Following this description of the ETS pilots, I will now focus on the specific designs that have been applied to the local ETS's.

3. ETS Pilots design

The great differences among the pilots such as economic development, industrial structure, energy consumption patterns, and emission intensity mentioned earlier in this chapter, have been confirmed in the great divergence in the market design of the pilots; including cap setting, sectoral coverage, allowance allocation. These ultimately reflected in the different market and emission reduction performances. There are different features that authorities have to study while designing an ETS: defining the sector from which carbon dioxide emissions will be considered; set a cap to the carbon emissions that participants are allowed to produce; the allocation of these allowances; defining the rules for offset mechanism to balance the price, the allowances, and the market, and eventually the Monitoring, Reporting, Verification system. In the following paragraphs I will explain these elements, specifically coverage, cap setting, and allowance allocation, that the pilots applied to their carbon market considering the scope of this research.

a. The mechanism

A given term is called compliance year and at the beginning of each year, the authorized offices give the amount of allowances with the maximum value of carbon emission allowed to emit. This is where the primary market takes places. Firms participating do business as usual with the addition of assessing the carbon emission deriving from their activity. Towards the end of the compliance year, there is a time set by competent offices where the participants can exchange their permits, this is also known as the secondary market and where the carbon market takes place. In this context, the carbon price is a relevant part of the exchange. This mechanism requires a high-quality system of monitoring, reporting, and verification, also known as MRV, to ensure the correct execution of the market, this however in turn raises administrative costs, and thus implicitly precludes including all gases in the schemes. Moreover, all pilots require third-party verification of the emission reports of the entities covered. Additionally, to assist participants in promoting low-carbon activities, CCER's namely China Certified emissions reduction, are carbon credits that can be traded under the ETS and in addition to these, in some pilots carbon reductions from energy-saving projects and forest sinks can also be used for offset.

b. Coverage

An important key element at the basis of the ETS is the decision of the coverage, from which industry should the emission be covered? What kind of result will lead to and why? At a certain extent the choice of coverage decides the operational efficiency and outcomes of the ETS, as selecting different sector might not generate the same results or have different implications or complications. At the same time, it comprises costs of organization and monitoring. It is vital to selects the suitable ones in order to reach a feasible construction of a carbon market that allows to learn and understand the mechanism as much as possible.

All the pilots selected sectors and thresholds based on their individual industrial structure and emission intensity. They largely choose the most emission-intensive industries such as heat and electricity production, iron and steel, nonferrous metals, petrochemicals and chemicals, pulp and paper, and glass and cement. Among the pool of sectors selected there are also some striking variations as some pilots also included transportation and aviation. As the China National ETS officially launched in 2021, around the years 2019 and 2020, some of the pilot's electric generation sector, were transferred from the pilots to the national ETS.

Emissions can be identified in direct and indirect. Direct emissions are those emissions generated by activities included within the covered sector, while indirect emissions are external but linked to the use of goods in the covered sector. The emission generated by the electricity used in the production of the goods imported into covered sectors would be an example of indirect emission. All the pilots cover both direct and indirect emissions from the electricity sector[4]. This is because indirect emissions make up the majority of the share in most of the provinces, in some cases up to 80% (Feng et al., 2013). Another important reason to take into consideration is that China's electricity price is regulated, meaning that the price signal cannot be passed to the electricity users. Thus, accounting indirect emissions helps ensuring that users will have an incentive to reduce electricity because the price they pay for electricity will include the cost of purchasing emissions permits associated with the use of that electricity.

The choice of coverage is based on the aim to cover a large share of emission while also maintaining a relatively manageable number of entities during the pilot phase of emission trading. As mentioned earlier, the long-term goal is to cover as much emission generated as possible to reduce overall emissions, but as described by Jotzo (2013), increasing coverage also increases the administrative effort for the government and the aggregate compliance cost to the industry. Moreover, differences in covered entities among the pilots adds more difficulty to the efforts to establish a uniform ETS; for this reason, the pilots in at the beginning covered only a selected range of sectors and in the same way, the national ETS launched in July 2021, only covered the power sector (which is approximately 40% of domestic CO2 emissions). However, the success of the program might be obstructed by the policy divergences stemming from the incomplete coverage, which has been deemed to be one of the largest limitations of the ETS.

c. Cap setting

In a market mechanism where there is a maximum of emissions allowed, participants purchase allowances from others if they exceed their limit and sell them if left over. Since the government gave enough freedom of choice for the design of the ETS, without a national cap, one of the first difficulties for the pilots was to set a limit that was adequate for their circumstances. Then given the different socio-economic levels of the pilots, different caps

[4] Shenzhen Development and Reform Commission, 2013; People's Government of Shanghai Municipal City, 2013; Beijing Development and Reform Commission, 2013; Zhang, 2013b

were set. There are two approaches of cap setting that the pilots could have decided on: top-down and bottom-up.

In the top-down approach, the cap is determined based on emissions targets across the whole economy or at the sector level. While in the bottom-up approach, the cap is calculated by aggregating the allowances allocated to all the market participants, that are determined through certain allocation rules.

When used, the top-down method is chosen mainly for two reasons: to serve as a reference for coordination when a bottom-up approach is used, and the need to find the "nominal cap". The pilots used different types of top-down approaches. For example, Chongqing determined its nominal cap by summing up the maximum annual emissions from all the existing production facilities in covered enterprise between 2008-2012 as a reference. Then, the annual cap for 2015 was obtained based on the decrease of 4.13% per year on the basis of the reference cap[5]. While Shenzhen sets an intensity cap rather than an absolute cap breaking down its carbon intensity (i.e., emissions per GDP) reduction target into ETS and non-ETS sectors. This intensity-based cap setting is adopted also according to the reality that each local economy will grow rapidly in the future, whereas an absolute cap would restrain their development (Kuikand Mulder, 2004; Ellerman and Wing, 2003).

d. Allowance allocation

In a cap-and-trade mechanism allowance allocation refers to the rules to assign the total amount of allowances (which equals the cap) to participants. It is important to define the mode of allocation and the methods of distribution according to the country's, in this case, China's specific situation. The two most common modes of allocation are free allocation and auction, which are also largely adopted for the Chinese pilots.

At international level hybrid modes exist and are more frequently used. Additionally, different combinations of free allocation and auction create "gradual hybrid modes" and furthermore, some sectors also use different allocation modes according to sectoral features, namely "sectoral hybrid mode".

[5] Chongqing DRC, 2014

Free allocation mode can be classified based on different standards without any specific limitations. The Chinese pilots mainly use grandfathering or benchmarking and with or without ex-post adjustments.

Grandfathering is a method based on different data timescale, meaning allowances are allocated based on average historical emissions of the covered enterprises. It is applicable to companies that are multifaceted, with various categories of technologies and a large range of products. On the one hand, due to its nature, the process of gaining information for this method is more time consuming for policymakers, but on the other hand it reduces the burden to participants, thus resulting in a limited impact on economic development.

Benchmarking in the other hand refers to free allocation based on a sector wide intensity standard, rather than enterprise-specific intensity (allowances are calculated by the production/value of a working procedure or a product, multiplied by unit emissions.)

Free allocation can also be grouped in ex ante and ex post allocation (Ellerman et al., 2007). Ex-post allocation adjustments could be for example, on the basis of production data, adjustments that are applied for those with historic intensity or benchmarking allocations when needed. Additionally, according to the different sources of data used for free allocation, there can be input-based, output-based, and emission-based methods.

The other type of allocation mode used is auction. This method is employed with different purposes and approaches. As mentioned before, auction is largely used as an addition to free allocation and the reasons are primarily two: to allocate a small portion of allowances, and to implement market intervention[6]. Market interventions are generally introduced during two scenarios: in case the allowances prices are too high, which may lead to significant negative impacts on the regional economy, and when enterprises are not willing to sell, which causes lack of market liquidity and compliance failure risk.

[6] Beijing DRC, 2013b; General Office of Shenzhen Municipal Government, 2014; General Office of Tianjin Municipal Government, 2013; Guangdong Provincial Government, 2014; Hubei DRC, 2014; Shanghai Municipal Government, 2013; Standing Committee of Beijing Municipal People's Congress, 2013

4. Issues related to China ETS Pilots

In this section of the chapter, I will discuss the environment in which the conversation of the ETS is placed in so to give a clear image of the condition of the pilots by assessing relevant issues regarding the operation of the ETS, the Chinese approach to the environment (socio-economic background to today's carbon emission) and its challenges for climate change mitigation.

The main reason to implement such a program is the need to reduce CO2 as soon as possible without compromising economic growth; many developed countries have already reached a sort of equilibrium among carbon emission and GDP, where carbon emission doesn't necessarily grow when GDP grows. To China this is also an important step to reach within its climate mitigation policies. Carbon intensity is used as a measurement to assess the situation of a country's rise of economic growth and CO2 emission. China is today the top global emitter of carbon dioxide however, this has not always been the case, but due to its intricate history, political and economic choices were the main reasons that lead China onto this path. Developing the ETS pilots was not easy task even after their launch and with the national ETS still in its infancy, their design require adjustment and improvement as challenges are identified and addressed. Many issues are still in progress as they entail national structural changes (as the reconstruction of the ministries) or lie within the economic situation of the country, or moreover are part of the social structure. The uncertainty over economic growth is an underlying part of these concerns. The pandemic has greatly demonstrated that any kind of prevision can be turn around in a matter of months with consequences lasting for years. In this context, prediction of emissions, which are also closely intertwined to economic growth and energy consumption, provides an important basis for ETS cap settings and allowance allocations (Buchner et al., 2006). Moreover, China is now experiencing an economic transformational process known as the "new normal", which is characterized by extremely rapid, but uncertain economic growth, that mixed within the contradictions of this developing country they cause even more insecurity about economic growth and energy consumption.

a. The absence of an absolute economy-wide emissions cap

As mentioned earlier in this paper, economy-wide emission control targets are another significant basis for cap settings as they give assistance in determining the caps. For example, the emission reduction target prescribed in the Kyoto Protocol have been used as a reference in the EU ETS cap settings. However, when China started the pilots, it didn't set any emission control targets nation-wide, making it more difficult to the pilots to set emission caps. This inevitably made the process of setting the caps more difficult and lengthier in time. Only recently China has established these targets, which are GDP-based intensity both at national and local level, which is also a measure recently adopted as a unified one, suggesting that the pilots still have to get used to it at that the parameters need to be adapted.

In designing the Chinese pilots, the lack of an economy-wide absolute emissions control target, great uncertainty about economic development and CO2 emissions growth, and most importantly the need for ex post adjustment of free allowance allocation, made it difficult to set a cap with a top-down approach. Hence, the pilots used the regional carbon intensity reduction targets issued by the central government to determine the regional annual emission levels at first, and then combined both top-down and bottom-up approaches for cap setting, and subsequently mainly relied on results of ex post adjustment of free allowance allocation. The caps settings are therefore characterized by flexibility or adjustment.

At the beginning of the project, only Hubei and Guangdong have published definitive caps, while a certain number of allowances have been set aside for auctioning and market intervention. Since there was the possibility that some of these reserved allowances would have not entered the market, the predetermined caps were only nominal, and the "actual cap", which are the allowances that effectively enter the market, are decided later by the bottom-up approach. Specifically, the Hubei cap setting is presented as a hybrid of the historic method and the prediction method, and it additionally allowed banking and borrowing, that refers to the use of compliance instruments from future years for current compliance, as a form a supplementary mechanism. This option enhances compliance flexibility, cost-efficiency and foster carbon price stability; however, it potentially weakens future reduction targets as it also gives an incentive to delay mitigation actions.

Most of the pilots without any definitive caps, the actual one is naturally designated as the results of bottom-up aggregation. This method makes the actual caps for the programs flexible due to two reasons. First, ex post adjustments are employed for allowance allocation for different covered entities. Second, many pilots set aside a number of allowances in case of possible market interventions, all or part of which might not be allocated later, making it more flexible.

b. Carbon leakage

One of the many risks to take into consideration when working with an ETS, that might occur during its operations is the risk of leakage. This occurs when carbon transfer between a carbon-constrained region and a non- or less-constrained one takes place. The extra carbon transfer caused by the differences between one region's constraint efforts compared to the other region's is known as leakage. The risk is that carbon emission might not actually be reduced in a given region by the carbon reduction policy implemented and the desired effects not obtained. In the case of China in the context of the carbon market, this means that a carbon transfer might occur to a region without constraint, invalidating the efforts of the carbon market as carbon-intensive industries shift to regions with less stringent constrains. For example, a firm covered by the Tianjin pilot transfers its emissions to Henan province in order to not abode to the emissions limits. This reasoning is consistent with the Pollution Heaven Hypothesis. Where a number of high-pollutant profiles might move to a less carbon emission constraint region instead of actively reduce CO2 with technological innovations or alternative solutions. Theoretically, carbon leakage is also likely to shift emissions from a non- or less-constrained region to a carbon-constrained one. This is defined as reverse carbon leakage. This direction might be considered counter-intuitive, but it is also in accordance with the factor endowment hypothesis (FEH). The reasoning behind this hypothesis is that generally a region the lead in stricter emission constraints is also more likely to be capital-dominated and hence tends to attract carbon-intensive industries. Between the pilot region and non-pilot region in China, it is still uncertain the direction that the leakage will tend to. In addition, carbon leakage issues are an important factor to look up to as the pilots in China are implemented separately and more at risk of carbon leakage.

c. Legal and regulatory framework

The national framework for the ETS is now in its early stages because when the pilots were launched at first the legal and regulatory system for a national ETS was absent. In 2013, provinces did not have legal grounds to initiate the local legislation needed to establish an emission trading scheme. A national mandate would have provided uniform guidance across provinces and ensure system-wide compatibility for future linkage. However, despite this decision, this maneuver ensured more commitment and efforts by the pilots; this also ensured that the regions developed within their specificities and differences, hence the pilots were to formulate their own mandates and legal frameworks.

A related issue comes from the situation of the final exchanges: at present their use are prohibited for the Pilots by the existing Regulation on Financial Derivatives Exchanges. Hence, carbon permit trading can only occur between one buyer and one seller or one buyer and multiple sellers and not through continuous trades among multiple buyers and multiple sellers. As much as it is a clear obstacle for an easy execution, this led to the pilots to implement their innovative instrument of financial exchanges. Of particular attention is Shenzhen, were in the face of this challenge developed the first regional green finance legislation in China, as well as the Shenzhen Economic Zone green finance regulation. The latter entered into force in March 2021, and it encourages financial institutions to participate in cross-border trading and further advance innovative carbon trading products. It additionally implemented other key policies such as gradually moving to an absolute cap and increase the proportion of allowance auctions (while decreasing free allocation); establishing a new carbon emission fund; enhancing market oversight and modifying the non-compliance punishment measures. Not only, the Shenzhen pilot is the one that present the most modernizations as it has also developed its own local offset program in order to help encourage lower carbon consumption with the Tan Pu Hui system since 2015. This is a system that incentivizes and rewards lower carbon behavior and purchases and developing a marketplace for low carbon goods and services for use by households. Shanghai on the other hand is the most effective pilot in terms of offset credit trading and for over-the-counter Shanghai Emission Allowance Forward contract allowed Shanghai to pioneer Allowance Spot Forward Trading in China. It is an innovative financial product that serves a purpose similar to carbon financial derivates, a carbon forward trading product with its own characteristics. Shanghai has brought out many others carbon finance innovations such as repurchases, carbon funds, carbon trusts, CCER pledge loans, green bonds, and carbon margin trading. The breakthroughs made by the Guangdong ETS is made by following the principle of openness and transparency: it is the first one that made public the targets for setting a cap on total allowances. The entire province has become highly aware of the importance of emissions reduction and more and more labor force is being introduced into the low-carbon service sector as a solid commitment. Moreover, by taking the lead in allowances auctions, it was able to draw new entrants into emissions regulation, creating a carbon fund with the allowances trading revenue, and constantly innovating carbon finance products. Tianjin, the last on this list, strengthened its enforcement measures: 1. companies failing to surrender enough allowances to match their emissions will face double the amount of the shortfall deducted from the next year's allocation; 2. Third-party verifiers found to not comply with regulations will be banned for three years ["Tianjin Interim Measures for the Administration of Carbon Emissions Trading", a regulatory document released every few years providing the legal basis for the regional carbon market]. On a similar line of discussion, one big issue was the overlapping of pre-existing environmental policy and responsibility for climate goals within regions. As of 2014, multiple ministries and agencies were involved in setting regulations to manage energy use, which include detailed target sets at the national and provincial levels. They also imposed specific requirements on local government and firms. These goals were however already subjected to other policies and managed by other offices.

The large number of regulations originating from different parts of the government increased the cases of inconsistency and overlap, generating confusion and reducing the intended goals of the pilots. on the same not, currently there are a wide range of sectoral measures to promote low carbon technologies and energy efficiency, as well as other national policies to manage coal and petroleum consumption, and these will inevitably interact with the national ETS, presenting the same issue. Another issue that comes from the governmental structure instead is regarding the electricity and heat generation sector. The emission coming from the electricity and heat generation sectors make up a great deal of the total emission covered by the pilots. However, these sectors are subjected to rigorous government regulation in term of pricing and output (Baron et al., 2012) that could be counteractive when dealing with the ETS. This is because the electricity and heat generation firms cannot transfer the cost arising from the emissions control to consumers nor adapt their output, ultimately putting the burden on the firms, that could suffer from allowance shortage and more costs. While talking about governmental structure, most of the sectoral emission in certain regions are dominated by a few very large enterprises that also have significant roles in local employment and taxation. Some of these are state-owned key enterprises and might sway the decision-making processes in their regions, an example is the case of Hubei, where several corporations were able to sway the decision making of employment and taxation. Another issue with state-owned enterprises is that there might be a contradiction between the market power these firms and the other participants because since they have considerable influence also on the local product market and can use that power to influence the allowance price. This is a significant issue in the perspective of the ETS as it might lead also to corruption, and compromise and hinder the process to reach climate goals.

d. China's coal dependance and future

Among the pollutant gases, carbon dioxide is the primary contributor of the raise of the global temperature. Greenhouse gases (GHG) absorb solar energy, trapping the heat into the atmosphere rather than releasing into space. Thus creates the greenhouse effect. Its action as a trapping heat gas, is not a bad thing per sé, it's a natural self-regulating mechanism. Without any greenhouse gases, the average temperature of the earth's surface would be -18 degree Celsius instead of the current average 15° Celsius, and it would be unlivable for almost all the living beings on earth. The problem comes when there is high emission of greenhouse gases in the atmosphere that overthrow the natural ecosystem, which in return, rises the temperature of the earth, which becomes unlivable, particularly for humankind. The great volume of these gases in the environment lead to consequences of which we are nowadays well aware of. Extreme weather such as drought, heat waves causing increased wildfires and heavy downpours, floods, hurricanes, monsoons, tropical cyclones, and extratropical storms are some of the consequences. CO2 emissions are now at the highest level in history and there is a strong need to find not only long-term solutions that can create resilience for the future; but as the consequences keep reversing on us as a much faster pace, the current critical condition urges humankind to find solutions that are also effective in the immediate future. China economic rise in the 2000s was met with more demand for product for consumption.

Its national gross domestic product (GDP) grew 10% on average each year for more than a decade, directly rising carbon dioxide emissions levels as well. China is today the top emitter in terms of annual emissions with a yearly increase of about 420 MtCO2 eq in 2020 and an emission of 11.47 billion tonnes in 2021. China's rapid economic growth in recent decades has been largely at the cost of excessive energy consumption, causing excess emission of CO2 and other environmental problems. Moreover, as a consequence, pollution is threatening China's natural resources which also has repercussions in people's everyday life: pollutions in water and rivers limit the drinkable water access to population and the presence of toxic gases in the air leading to premature deaths are some examples.

Another factor aggravating China's carbon emission that might be a challenging obstacle in its environmental goals is its energy mix. Emission from fossil fuels is the primary source of carbon emission in the world and China is among the most user. There are three types of fossil fuels: oil, coal, and gas, and China heavily relies on them with 82,72% of its energy mix coming from fossil fuels in 2021 (even though is slowing decreasing each year, in 2013 was 90.18% and in 2015 was 87.96%). China's rapid economic growth in the last decades has been fueled by energy supply, for this reason electricity consumption has been increasing steadily since the 1980s and specifically, from 1980 to 2014, it became 18 times the volume of economic growth. About 50% of Chinese CO2 emissions are form the industrial sector, 40% from the power sector and 8% from the transportation sector. Within the industrial sector, coal consumption is by far the leading source of heat-trapping gas emissions in 2021 with 6.57 billion tonnes, followed by oil 1.71, gas with 773.87 million tonnes, and cement 858.23 million tonnes.

In the context of environmental protection, controlling the primary energy consumption has become a major issue of China's national energy and environment policy[7] in these years. It is important to find renewable solutions that can substitute fossil fuels and as of today, the share of primary energy from low-carbon (mainly nuclear, hydropower, solar, wind, geothermal, wave and tidal and bioenergy) sources are 17.28%.

However, contradictory to its low-carbon initiatives, in 2019 the Chinese government has approved the opening of numerous coal plants generating a soaring increment in coal as fossil

[7] State Council of China, 2013a

fuel and jeopardizing years of commitment and hard work in reducing the use of fossil fuels. The presence of these new coal plants secure that a considerable amount of carbon dioxide will be emitted in the next decades. Additionally, China is still planning to build new coal capacity for various motives such as to provide jobs, increase local economic growth, as well as satisfy heat demand.

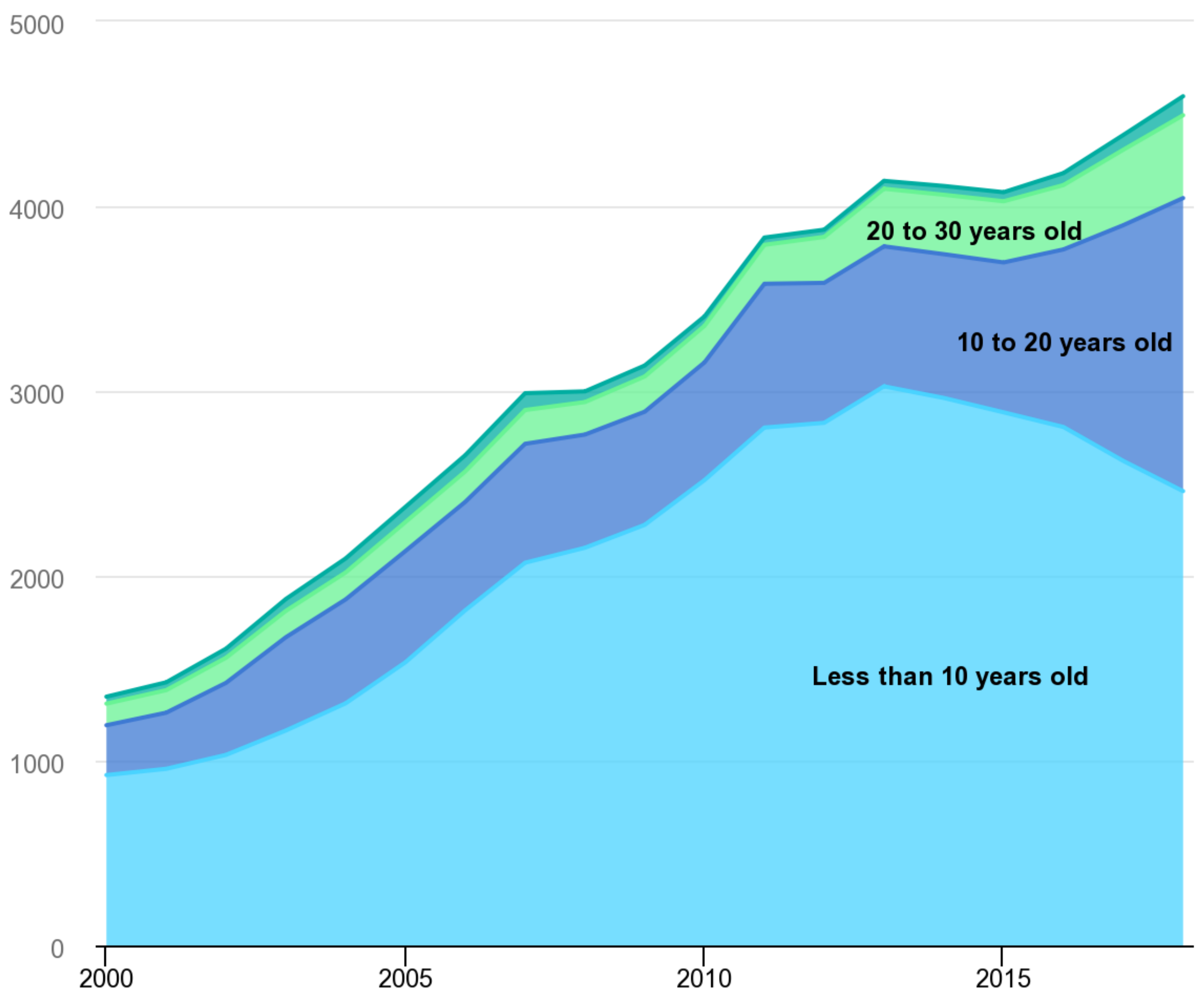

Figure 3 CO2 emissions from coal-fired power plants in China by age of plants, 2000-2018

Source: IEA

e. Decoupling carbon emission from economic growth

In a perfect world, nations would be able to grow economically and prosper whilst curbing global carbon emissions. Unfortunately, the relation between economic growth, namely GDP and CO_2 emissions is a troublesome and relevant issue that needs to be taken into consideration in a climate mitigation discourse. There is a relationship that connects economic growth and CO_2 emissions: the richer a country gets, the more carbon dioxide it emits. This is because lifestyles change and more energy are used, which usually comes from burning more fossil fuels that thus generate more carbon dioxide. However, this relationship usually breaks at higher incomes. Many developed countries have already managed to achieve economic growth while also reducing carbon emissions. CO_2 emissions decouple from GDP when it peaks and reduce over time, signaling it is no longer constrained by the economic growth of the nation. The basic idea is that in the early stages of development, a country's carbon dioxide emission is relatively low and therefore environmental qualities indicators are good; ensuing the industrialization process, initially, it damages the environment, but as per capita income increases, environmental legislations are introduced to reduce emissions and pollution (Grossman, Krueger, 1991; Shafik, Bandyopadhyay, 1992), and finally CO_2 emission dissociate from economic growth. For example, in the last thirty years UK's GDP has increased a lot, even though emission have fallen. The UK has shown evidence of absolute decoupling. From 1985 to 2016, its GDP per capita grew by 70.7% while CO_2 emission fell by 34.2%. Other countries such as France, Germany, Sweden, Finland, Denmark, Italy, and Romania also have reached emission decoupling in recent years.

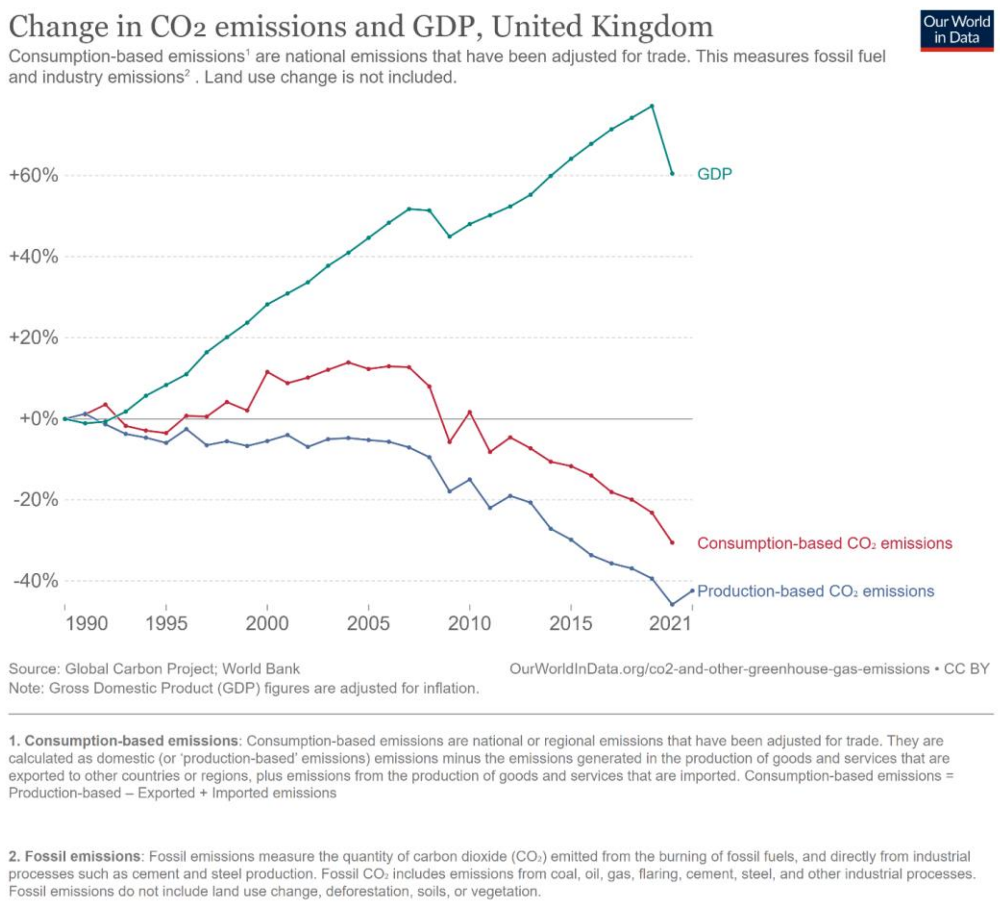

Figure 4 Change in CO2 emissions and GDP, UK

The reason that these countries could decouple emission from economic growth lie in the fact that they were able to detach the energy use from economic growth by replacing fossil fuels with low-carbon energy solutions, enabling them to produce more energy while emitting less than they used to before. In this way, the continue decline in the cost of low carbon over time makes it easier to CO2 emission to decouple effectively. In the case of China, its GDP in 1985 was 309.49 billion USD and accelerated to the point it quadrupled: in 2000 was 1.21 trillion USD and 14.68 trillion USD in 2020. This was in concomitance with its opening to the world after the 80's, and its CO2 emission started to dramatically increase as well. China carbon emissions waved relatively while increasing during the 50's until the 80's, then it increased moderately between the 80' and 2000's to increase more than 5 times in just 20 years after that. Not only, in 2006 China surpassed the United States becoming the country with the highest CO2 emission in the entire world in absolute values.

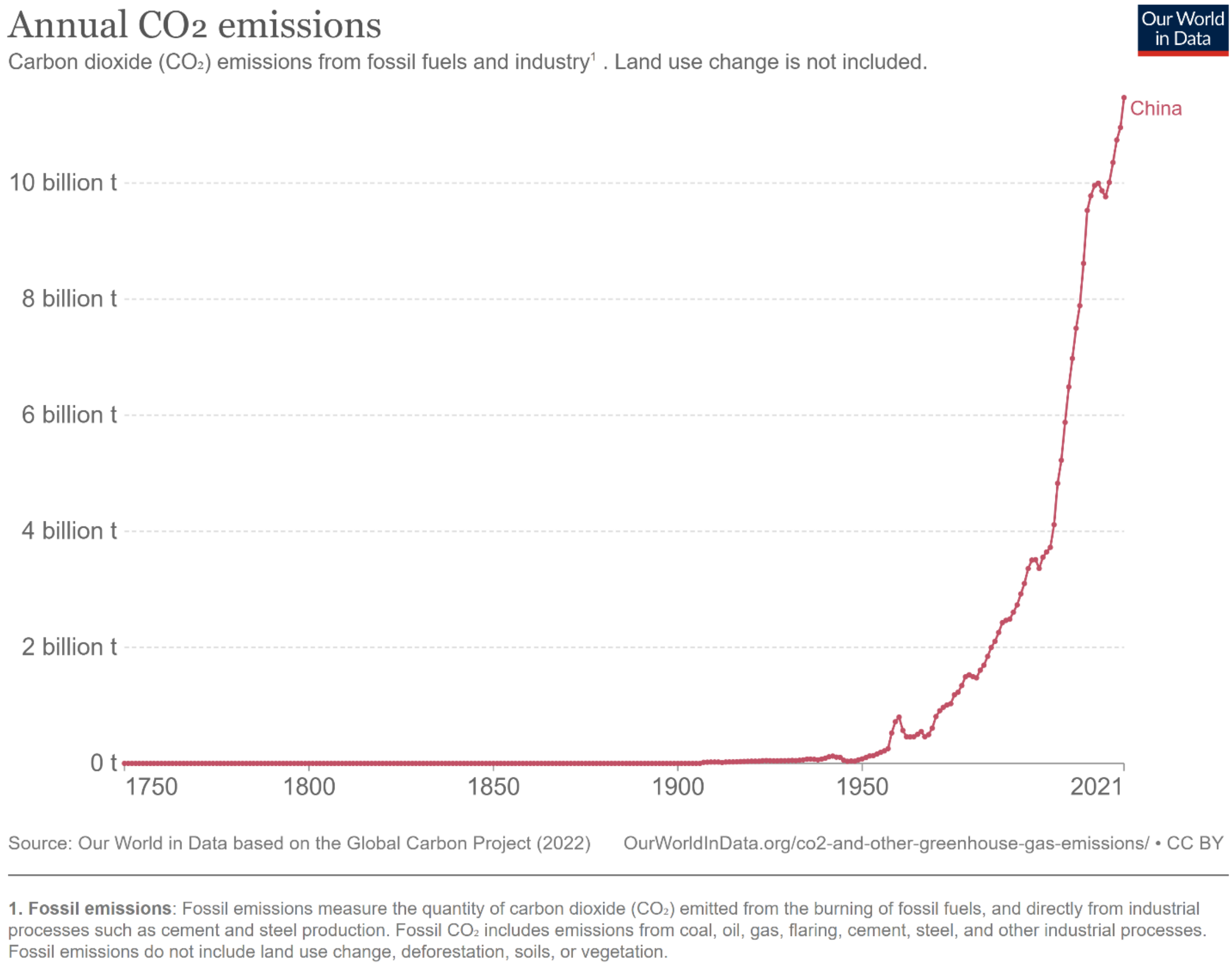

Figure 5 China annual CO2 emissions

f. Carbon intensity - the link between economic growth and CO2 emissions

The debate on an economic and environmental balance created space for "carbon intensity" as a significant variable in the conversation. Carbon intensity quantifies the amount of CO2 emitted per unit of GDP and is identified as kgCO2/GDP per year. Since these emissions depend exclusively on the carbon content of the fuel, which is generally known with a high degree of precision, CO2 emissions can be estimated with a high degree of certainty regardless of how the fuel is used. Therefore, a low carbon intensity shows low CO2 emissions relative to the size of the economy. It is important to observe that carbon intensity shows carbon emission relatively to economic growth, particularly in the case of China where its carbon intensity throughout the 50's and 80's shows a sine wave going up with two high peaks in the '60 and '80, and then a rather linear line towards the end (as shown in figure above). This is because the line is tied to Chinese Communist Party (CCP)'s decision to launch the “Great leap forward” (1958-1962), where China’s GDP and its population’s living standards failed to improve while its carbon emissions grew by 71%. This rapid increase in CO_2 emissions relative to poor GDP growth caused the dramatic spike in carbon intensity we see in the graph above. Subsequently, China’s economic downfall during the 1960-1962 period caused CO_2 emissions to fall, resulting in a decline in carbon intensity from its 1960 peak. During China’s Cultural Revolution, GDP growth rates were especially low (with less than 4% per year), however CO_2 emission continued to rise through industrial output, creating increase in carbon intensity. Following Mao’s death in 1976, China underwent a brief period of transition with strong GDP growth. It grew 30% in a few years while CO_2 emissions dropped. Living standards also greatly improved, China’s technology and industrial sector underwent rapid modernization. This led to significant improvements in energy efficiency, productivity, and a continued decline in carbon intensity. Looked at another way, carbon intensity is a measure of the relative difference between these two variables. For example, if a country’s GDP temporarily falls, it is possible to see an increase in intensity, even if CO_2 emissions remain the same. This is because GDP has dropped relative to CO_2. This clarification is made to bear in mind that the complex inter-connectivity of political stability, support, economic structure, and effective national industries implies that carbon intensity sometimes can show dramatic oscillation during periods of political turbulence. Technological transformation alone is not enough to reduce carbon intensity, political stability and reasonable policies are also crucial in accomplishing the goal of great prosperity with small environmental impact.

CHAPTER 2 - LITERATURE REVIEW

The topic of the ETS pilots have been explored throughout in this decade since it was first announced its implementation in China in 2011. The studies in this filed have been crucial to further assist in the development of the pilots and future national ETS. However, the majority of the material found on the pilots during my research mainly focus on a particular segment of the implementation of the pilots, either about the design, or the allocation, the sector coverage, either on national, sub-national or sectorial level, and their related effects or policy implication. The topic of the allowance allocation has been studied in depth, while sector coverage, cap settings, and other features are less investigated. The reason to the lack of research and materials on certain features of the ETS could be traced to the lack of availability to information data needed to assess these other features. The only pilot that made all information accessible to the public, for all the compliance years, is Guangdong, therefore, a lot of the journals and studies existing also show more deep and thorough consideration on this specific region rather than the others. Another matter discussed in many articles are issues that rise with the implementation of the ETS. Due to the particular social structure of the country, the design of the ETS requires specific adaptations and local precautions. These articles also exhibit the great uncertainty deriving from the project but still are positive to its feasibility if corrected timely. Furthermore, all of the studies reviewed for this thesis excluded Fujian in their analysis, either because the study took place before 2016 (the year the Fujian ETS Pilot was established) or because the information available was not sufficient to provide an assessment.

With my dissertation I want to build on previous research and present a more comprehensive outline of the ETS by grouping all the relevant studies from the pilots in the following paragraphs, I thus provide a literature review, deriving from the analysis of journals, articles and insights dealing with this topic.

The literature review is structured as follow: the first part focuses on the findings related to the design of the pilots, with a focus on sector coverage, cap setting, allowance allocation or their combination. Then, following the line of thought drawn in the previous chapter, I will review the articles concerning the evaluation of the Pilots and lastly those assessing the impact and effects of the Pilots. at the end of each topic feature there will be a panel summarizing the literature cited in the chapter to simplify their viewing, divided in Panel a - Design of ETS, Panel B - Evaluation of ETS and Panel C - Impacts and effects of ETS.

1. Design of ETS

The literature review in this paragraph includes the works listed in the Panel A – Design of ETS at the end of the chapter.

In terms of industry coverage, the converging idea is that more industries are covered the more stable would be the market.

In Lin and Jia early wok in 2017 they concluded that when more industries are covered, the burden in energy intensive companies lowers as well because carbon price is lowered. They conducted the study by doing a CGE model to simulate the choice of coverage industries in China's supposedly national ETS in 2017 by simulating seven different controlled scenarios, set according to major ETS markets in the world (EU ETS in its different phases I,II,III, different program in the US,UK, Australia, Japan and India) to explore the impacts and the most suitable coverage industry for China. The result of this study shows that ETS significantly reduces carbon emissions, and it will be gradually inhibited and reach its peak by 2030 and successfully achieving the NDRC emission peak goal. They find that coverage has little impact in GDP and carbon emissions, however it has on social welfare, commodity price, carbon price, export, import, and carbon rights. They find that generally, the more industries are covered, the lesser the burden on high energy consumption companies, thus they conclude by saying that in the future, the ETS should cover more industries as possible, to ensure market stability.

However, just a few years later they confute their theory by asserting that when more industries are covered, the increasing costs of coverage increase as well, which then are shifted to the other industries that are not covered. Their latest research in 2020 finds that based on the NDRC's plans and current processes of China's MRV extensive coverage is not successful and quite difficult; and conclude by proposing that only certain selected, more specifically three, industries, with effective MRV are a better choice in terms of carbon reduction and market stability.

Carbon trading generates in covered sectors greater uncertainty, notably in non-electricity sectors (specifically ferrous metal) engage in higher levels of risk taking (Li et al., 2021, “China's ETS pilots: Program design, industry risk, and long-term investment”).

As regarding for cap settings, the common idea is that without economy-wide emissions targets, it is not easy for the pilots to set cap for allowances.

In “Cap setting and allowance allocation in China’s emissions trading pilot programmes special issues and innovative solutions”, Pang and Duan, 2016, explain in detail the logic for cap settings in the pilots and denotes how in reality the majority of the pilots rely on a non-typical method for determining cap settings, namely flexible cap. They use bottom-up approach in setting the ‘actual cap’, while reserving room for ex post adjustments. The formula emphasizes how the uncertainty of emissions reductions and the costs deriving are lower with an intensity target rather than an absolute target. More specifically, from the perspective of uncertainty, a flexible cap is more suitable and practical. However, they remind that the formulation is based on the whole economy, while for now the ETS covers only parts of the economic sectors.

The article “China’s national emissions trading scheme: integrating cap, coverage and allocation” makes a review of the ETS pilots by focusing on its three main feature design, and the potential challenges in a multi-tiered ETS. Multi-tiered ETSs means that the ETS is managed by multiple tiers of governments, such as the central government and local governments in China. On the premises that a multi-tiers ETS in an emerging economy such as China, faces special economic, technical and bargaining cost issues, the analysis conveys that to fully exploit its advantages and avoiding the shortcomings, China ought to integrate different approaches for its ETS instead of a one-fits-all technique.

As regarding for coverage and allowance allocation methods the top-down approach is deemed reasonable to avoid competition distortions resulting from decentralized decision making among member states or local-level governments.

While for cap setting the bottom-up approach can provide more foundation for local and national ETS by compensating for the lack of data. Moreover, by using this approach, a fair degree of independence regarding the adjustment of coverage and allocation method can be provided to the member states or local governments to stimulate their enthusiasm.
As regarding for allowance allocation, the current materials on this topic are far more researched in the field than the others. As mentioned earlier, this is probably because there is more public information related to the allocation rather than related to others.

Pang and Duan put together a good and detailed examination of the methods used by the pilots in allocating allowances to existing installations, new installation and the reasonings for auctioning. They conclude that given Chinas' realities, allocation with ex post adjustments ought to be better accepted by enterprises and the economic authorities then a pre-determined allocation. Which however the lack of predefined emissions level (as a "cap and trade" should have by definition) will lead to social abatement costs higher than the theoretically optimal level.

In "China's national emissions trading scheme: integrating cap, coverage and allocation", Qi and Cheng make a comparative analysis of general approaches in theory and practice of the current states of the pilots in 2018. And as regarding allowance allocation they affirm that the top-down approach is good to avoid competition distortions due to the decentralized decision making among the local designers.

In "Carbon emissions trading scheme exploration in China: A multi-agent-based model" Tang et al., formulated in 2014 a multi-agent model to investigate the impacts of different CET designs in order to find the most appropriate one for China. Their proposed a bottom-up model considering all main economic agents in general equilibrium framework: the government (ETS designers and supervisors), firms in different sectors (ETS targets) and households, and further investigates their interaction under an ETS mechanism. Their simulation results show that as for allowance allocation, grandfathering method is quite moderate while benchmarking is more aggressive.

In the 2013 article "Fundamental issues and solutions in the design of China's ETS pilots: Allowance allocation, price mechanism and state-owned key enterprises", Qi and Wang conclude that for allowance allocation it is more suitable for the pilots to adopt a “gradual hybrid mode” with mainly free allocations by grandfathering at the beginning and then increase auction ratios gradually.

In Peng et al.’s work, they reiterate Pang and Duan opinion by calling the method used by the Chinese pilots “alternative” allowance allocation, and take a step further in Tang et al. estimation about the benchmarking method. Their study explores the correlation of the method of allocation chosen with the energy structure. They conduct an empirical strategy using a Difference-in-Difference-in-Difference (DDD) model by comparing outcome of concerned variables among ETS regions and non-ETS regions, among covered sectors and non-covered sectors, and eventually among pre- and post-ETS periods. And, on contrary of what Qi and Wang conclude, their findings show that the reduction of carbon emission was higher in benchmarking pilots. This was because benchmarking allowed a better adjustment of energy efficiency within the covered entities compared to grandfathering allowance allocation. Specifically, the optimization of energy structure is more likely in benchmarking-pilots compared to the grandfathering ones. For this reason, they advise the government to further develop and refine the benchmarking allocation method and gradually transform benchmarking as the dominated method for China ETS. In addition, the study finds that using benchmarking would have muted impacts on rising employment and grandfathering return on assets in enterprises.

In the study of Xiong et al. “The allowance mechanism of China’s carbon trading pilots: A comparative analysis with schemes in EU and California”, they conduct the study by comparing the Chinese pilot with the EU ETS and California Cap-and-Trade program in terms of allowance types and allowance allocation method, identifying particular issues related to the China trading pilots. The mechanism adopted by the pilots (which include allowance allocation based on historical emissions mixed with some benchmarking, free allowance allocation together with some level of auction, and predetermined quotas combined with ex-post allowance adjustments.) generate oversupply of allowances, lack of allowance credits for business that take early abatement costs, double-counting of allowances, heavy reliance on historical emissions, and lack of clarity and transparency of administrative rules governing the allowances allocation.

Summarizing, based on overall ETS and market environment the findings examine different method to employ: adopt a top-down approach (Qi, Cheng, 2018), based on grandfathering for moderate results and benchmarking for more aggressive results (Tang et al., 2014), and to implement a "gradually hybrid mode", where free allocations by grandfathering are the main choice of method at the beginning with the combination of auction, of which ratios would increase gradually over time (Qi and Wang, 2013). Based on participants acceptance Pang and Duan (2016) suggest allocation with ex post adjustments because ex ante approach hinders the development of firms. Lastly, based on carbon reduction, Peng, Qi, and Cui (2020) affirm that the benchmarking method is the one that had a higher rate of carbon reduction among the pilots, hence the government should focus on this method and refine its development and gradually apply it as the main method.

Panel A - Design of ETS		
Design topic	Authors, year of publication	Work title
Coverage	Li, QIa, Yan, Zhang, 2021	China's ETS pilots: Program design, industry risk, and long-term investment
Coverage	Lin, Jia, 2020	Why do we suggest small sectoral coverage in China's carbon trading market
Cap setting	Zhou, Jiang, Ye, Zhang, Yan, 2019	Addressing climate change through a market mechanism
Coverage, cap setting, allowance allocation	Shaozhou Qi & Si Cheng, 2018	China's national emissions trading scheme: integrating cap, coverage and allocation
Cap setting, allowance allocation	Pang, Duan, 2016	Cap setting and allowance allocation in China s emissions trading pilot programmes special issues and innovative solutions
Allowance allocation	Ling Tang, Jiaqian Wu, Lean Wu, Qin Bao, 2014	Carbon emissions trading scheme exploration in China: A multi-agent-based model
Allowance allocation	Shaozhou Qi & Banban Wang, 2013	Fundamental issues and solutions in the design of China's ETS pilots: Allowance allocation, price
Allowance allocation	Xiong, Shen, Qi, Price,Ye, 2016	The allowance mechanism of China's carbon trading pilots: A comparative analysis with schemes in EU and California

Figure 6 Panel A - Design of ETS

2. Evaluation of ETS

The literature review in this paragraph includes the works listed in the Panel B at the end of the chapter.

Carbon leakage is one secondary phenomenon deriving from the implementation of the ETS: in "Does emission trading lead to carbon leakage in China? Direction and channel identifications", Zhou et al., warn of the risk of carbon leakage by identifying the different channels in which it might present. The paper develops a DDD model to identify carbon leakage directions in emission trading pilots in China. Market participation and industrial transfer are confirmed to be the specific leakage channels in emission trading. Of the two channels, market participation is the one that determines the reverse direction. Their conclusions show that surprisingly emission trading pilots are more prone to lead to reverse carbon leakage instead of the conventional carbon leakage, as the pilots are more capital intensive. Moreover, it also led to intra-regional carbon leakage, causing the weakening of the net carbon transfer between pilot provinces. Secondly, they find that the direction of inter-regional and total carbon leakage is heavily dependent on the market participation, and as the market participation improves, the direction of inter-regional and total carbon leakage will gradually switch from reverse to forward; the switch points are at market participation levels of 5.52% and 4.26%, respectively. Their policy suggestion is to introduce real-time supporting policies related to carbon leakage, and additionally, when market participation reach the switch point, implement related policies to mitigate and prevent forward carbon leakage. And the allocated allowances ought to be of reasonable quota in order to achieve an emission mitigating effect while avoiding reverse carbon leakage.

Another take on this topic is Angelo Antoci et al.'s article "Should I stay or should I go? Carbon leakage and ETS in an evolutionary model". They conduct a simple evolutionary theoretical model to explore the possibility of delocalization effects of an ETS. The model follows the decisions of regulated organizations on whether to stay in the domestic country and keep their production there, or leave, and move production abroad in a country where an ETS is not active. Numerous simulations show that the firms' decision on whether decrease emissions or move abroad are not affected by the design feature of an ETS (such as cap setting, coverage or allowance allocation), instead are more susceptible to the policies that reduce the cost of green technologies.

In “Evaluation of effectiveness of China's carbon emissions trading scheme in carbon mitigation”, Gao et al. researched the potential effectiveness of China’s carbon trading in terms of carbon mitigation through DID and DDD models of the emission and carbon leakage of 28 industries in 30 provinces during 2005 to 2015. They found that ETS indeed contributes to emissions mitigation in region pilots. Additionally, they learned that ETS encourages the transfer of emissions from pilot areas to non-pilot areas, resulting in carbon leakage (pollution heaven effect), aggravating the imbalance of emission transfer among China’s provinces.

Zhang et al. in “Scenario-based potential effects of carbon trading in China: An integrated approach”, a difference-in-difference (DID) method is used to simulate two different scenarios that can arise in the carbon market but with different constraints. In the Scenario I, the simulation is run without any particular constraints, given that the greatest goal to achieve is to reduce carbon intensity at the given economic growth (GDP). It is discovered that carbon trading has the effect to reduce carbon intensity up to 19.79%, in terms of the Porter Hypothesis effect (that is effects on technological level and technical efficiency generated by the implementation of carbon trading). In Scenario II, while considering the factor of economic growth, with the constrain of environmental protection, the results show that carbon intensity can be reduced up to 25.24%. However, the national GDP growth would to be reduced by 2.71%.

Zhang, et al. in their 2014 “Emissions trading in China: Progress and prospects” present a comprehensive overview of the features of the seven ETS pilots. Highlighting their importance as it prevents the government to establish a “one fit for all” structure and conclude with some comments. The legislation needs stronger penalties or neither local nor national ETS designs are likely to induce changes in firm behavior. Including the authorization of carbon exchanges. Second, a transparent and independent reporting of carbon emission is crucial. The pilot ETS experiences are already generating insights into the gaps and needs of this nationwide data management process. Strengthening this capacity in support of a national ETS will likely take several more years, even with immediate and concerted effort. Lastly, they call for the coordination of the many policies (energy, climate, and broader economic and fiscal measures) that bear on the energy system.

Heggelund et al.'s article employs an analytical assessment that supports the thesis that internal learning has been proved crucial to the development of the ETS in China, arguing that having a slow and well-prepared start contributes to its potential success. Moreover, the lengthy and preparatory period enabled China to address various obstacles, providing a strong basis for success. This method pairs well as the learning process continuing as the national ETS becomes operative.

Qi et al.'s paper describes the policy designs of the Hubei Pilot, including coverage, cap, and allowance allocation and after making a comparison with the other Chinese Pilots and ETS in the EU and California, the study presents the summary of distinct features belonging to the Hubei ETS. it finds that despite its small number of covered entities, the emission generated consist of a considerable proportion of the whole pilot's emissions, making Hubei the world's third largest carbon market.

Luo et l.'s paper monitors the CO2 trajectory in China before and after the pandemic outbreak over a two-year time horizon and evaluates the emission reduction effects by ETS and its market performances. The findings provide useful insight into further mechanism design of the ETS as they show that the ETS pilot markets, which are still immature with defects, under the pandemic shocks have been performing more vulnerably in terms of liquidity and transaction continuity, therefore undermining the emission reduction effects by ETS.

Panel B - Evaluation of ETS		
Research contents	Authors, year of publication	Work title
carbon emission reduction and influences on carbon leakage	Gao, Li, Xue, Liu, 2019	Evaluation of effectiveness of China's carbon emissions trading scheme in carbon mitigation
Identification of carbon leakage directions in ETS pilots in China	Zhou, Zhang, Wang, Zhou, 2020	Does emission trading lead to carbon leakage in China? Direction and channel identifications
Simple evolutionary theoretical model to explore the possibility of delocalization effects of an ETS	Angelo Antoci, Simone Borghesi, Gianluca Iannucci, Mauro Sodin	Should I stay or should I go? Carbon leakage and ETS in an evolutionary model
Simulation of the scenario-based potential effects of carbon trading in China	Zhang, Wang, Shi, Li, Cai, 2016	Scenario-based potential effects of carbon trading in China: An integrated approach
Comprehensive overview of ETS pilots in China	Zhang, Karplus, Cassisa, Zhang, 2014	Emissions trading in China: Progress and prospects
analytical assessment of CHINA ETS Pilots	Gørild Heggelund, Iselin Stensdal , and Maosheng Duan , 2021	China's Carbon Market: Potential for Success?
Comparison among ther ETS Pilots and ETS in EU and California	Shaozhou Qi, Banban Wang, Jihong Zhang, 2014	Policy design of the Hubei ETS pilot in China
Evaluation of carbon emissions through near-real-time sector-specific region-level estimates of daily CO2 emissions	Kun Luo, Aidi Xu, Rendao Ye and Wenqian Li, 2022	Monitoring the CO2 Emission Trajectory and Reduction Effects by ETS and Its Market Performances for Pre- and Post-pandemic China

Figure 7 Panel B - Evaluation of effectiveness

3. Impacts and effects of ETS

The literature review in this paragraph includes the works listed in the Panel C – Impacts and effects of ETS, at the end of the chapter.

Numerous articles have proved ETS to have impacts on carbon emission, therefore, climate policies and their effects have been a focal research topic in the field of climate mitigation in China. There are few studies devoted at the discussion of the results rose by the operations of the pilots. Here below I present the relevant studies that had an influence in the development of this thesis.

Many studies have confirmed that a carbon market will definitely assist in the reduction of carbon emission in China. Both Zhang et al. and Tang et al.'s studies assess the positive outcome from simulations of the implementation of the ETS in carbon emission reductions. In “Scenario-based potential effects of carbon trading in China: An integrated approach”, a DID method is used to simulate two different scenarios that can arise in the carbon market but with different constraints. In the Scenario I, the simulation is run without particular constraints, given that the greatest goal to achieve is to reduce carbon intensity at the given economic growth (GDP). It is discovered that carbon trading has the effect to reduce carbon intensity up to 19.79%, with consideration of the Porter Hypothesis effect (effects on technological level and technical efficiency generated by the implementation of carbon trading).

In Scenario II, while considering the factor of economic growth, with the constrain of environmental protection, the results show that carbon intensity can be reduced up to 25.24%. However, the national GDP growth would to be reduced by 2.71% in respect of the first scenario.

Following this thought, Tang et al. in “Carbon emissions trading scheme exploration in China: A multi-agent-based model” find that a emission trading scheme would effectively reduce total carbon emissions, with a decrease of economic growth over time. However, the reduction of carbon emission would be greater than decrease of GDP. Specifically, the GDP in China will decrease by approximately 1.335% and 3.492% in the 5th year and the 10th year of run, respectively.

The 2019 study of Zhou et al., “How does emission trading reduce China's carbon intensity? An exploration using a decomposition and difference-in-differences approach” explores the effects and influencing channels of emissions trading in carbon intensity reduction. The findings show that ETS reduce indeed carbon intensity. Moreover, the carbon intensity reduction was sustainable and steady thus, the implementation speed of the current pilot is efficient for reducing carbon intensity. An important element they find is that the industrial structure adjustment is the channel that influences the impact of emission trading pilots on carbon intensity, together with the optimization structure and energy intensity. As such, it is important to bring the transport industry into the covered entities and unlock the potential carbon intensity reduction of energy structure and energy intensity channels to maximize emission trading effectiveness.

In “Evaluation of effectiveness of China's carbon emissions trading scheme in carbon mitigation”, Gao, et al. researched the potential effectiveness of China’s carbon trading in terms of carbon mitigation through DID and DDD models of the emission and carbon leakage of 28 industries in 30 provinces during 2005 to 2015. They found that ETS indeed contributes to emissions mitigation in region pilots. Additionally, they learned that ETS encourages the transfer of emissions from pilot areas to non-pilot areas, resulting in carbon leakage (pollution heaven effect), aggravating the imbalance of emission transfer among China’s provinces.

In “The environmental and economic effects of the carbon emissions trading scheme in China: The role of alternative allowance allocation”, Peng et al., use a different approach to their research, instead of running possible scenarios with external factors (such as GDP and the presence or not of the ETS), they introduce internal factors to their scenarios that represent features of the ETS. Nevertheless, they conclude that emission trading scheme is a positive way to reduce CO2 emissions. They find that an emission trading scheme is successful in reducing carbon emissions specifically in the pilots that adopted the benchmarking were the one with more successful reduction in carbon intensity. Though, the reduction result also from the increase of more energy efficiency technologies.
The important study of Wen et al., 2021, “Environmental and economic performance of China’s ETS pilots: New evidence from an expanded synthetic control method”, the article investigates whether China’s ETS pilots have successfully balanced carbon emission reductions and economic growth. they use an extended synthetic control method for multiple treated units required by the difference-in-differences estimation commonly used in the field. They find that ETS helps in reducing CO2 from the period from 2001 to 2015, and as for the economic performance over this time, they find that there was a loss in value. That said, the economic loss was short term in nature and decreased over time. Additionally, they find that regions showed heterogeneous responses to the ETS pilots. These findings suggest that policy makers should consider a gradual (rather than a radical) ETS policy and make firm subsidies part of their battery of instruments in the early stage of establishing a nationwide ETS.

Dong et al.’s study employs a DID method to investigates whether the implementation of the ETS can result in the Porter effect. The findings specify that in the short term, the ETS fails in producing the Porter effects as it successfully reduces carbon emissions in the pilot areas but doesn’t increase GDP. In the long term however, it can achieve the Porter effect (Tang et al., 2014; Dong et al., 2019; Wen et al., 2021). The economic growth (GDP) that would take place in a scenario without the ETS, is higher than the ones with the implementation of the ETS. Nonetheless, the negative effects on economic variables at the beginning will deplete over time (Wen et al., 2021).

To recap, many studies have found that a carbon market will definitely assist in the reduction of carbon emission in China. The common conclusion is that the ETS can effectively reduce carbon emission and carbon intensity in China (Zhang et al., 2014, Peng et al., 2020), at the cost however of a slower economic growth (LI et al., 2021; Zhang et al.,2016; Lin at al., 2017

Zhang et al.’s research conducts a DID model to investigate the impacts of ETS policy on low-carbon development in relation to variables such as CO2 emissions, carbon intensity, energy consumption and energy intensity. The results show that to some extent the relation between carbon trading and low-carbon transformation is positive and will progressively increase overtime. Moreover, when the variables population, gross domestic product, ratio of the secondary industry, technical level, and income level are controlled, these findings are also robust.

Panel C - Impacts and effects of ETS		
Research contents	Authors, year of publication	Work title
Assess the impacts of ETS on carbon reduction in Guangdong Province	Cheng, Dai, Wang, Zhao, Toshihiko Masui, 2015	Impacts of carbon trading scheme on air pollutant emissions in Guangdong Province of China
CGE model to simulate the choice of the coverage industries in 2017	Liangpeng Wu1 · Qingyuan Zhu 2020	Impacts of the carbon emission trading system on China's carbon emission peak: a new data-driven approach
Simulate the choice of the coverage industries in China's ETS and explore the impacts of ETS and the most suitable coverage industry for China	Lin, Jia, 2017	The impact of Emission Trading Scheme (ETS) and the choice of coverage industry in ETS: A case study in China
Examines the impact of China's ETS on carbon emissions reduction and economic performance with a focus on the role of alternative allowance	Peng, Qi, Cui, 2021	The environmental and economic effects of the carbon emissions trading scheme in China: The role of alternative allowance allocation
DID model to estimate wheter the Porter effect can be achieved	Feng Dong, Yuanju Dai, Shengnan Zhang, Xiaoyun Zhang, Ruyin Long, 2019	Can a carbon emission trading scheme generate the Porter effect? Evidence from pilot areas in China
Investigates whether China's ETS pilots have successfully balanced carbon emission reductions and economic growth	Wen, Chen, Nie, 2021	Environmental and economic performance of China's ETS pilots: New evidence from an expanded synthetic control method
Research on the effect and influencing channels of emission trading carbon intensity reduction	Zhou, Zhang, Song, Wang, 2019	How does emission trading reduce China's carbon intensity? An exploration using a decomposition and difference-indifferences
Allowance allocation	Huarong Peng, Shaozhou Qi, Jingbo Cui, 2021	The environmental and economic effects of the carbon emissions trading scheme in China The role of alternative allowance allocation
DID model to estimate the net dynamics impacts of ETS	Yan Zhang, Jiekuan Zhang, 2019	Estimating the impacts of emissions trading scheme on low-carbon development

Figure 8 Panel C - Impacts and effects of ETS

CHAPTER 3 - Research method, results, and discussion

This chapter is dedicated on showing the results of my research and will follow the flow of the previous ones: in the first chapter the focus was on the different choices of implementation and subsequently on the environment surrounding the pilots, in the same way, the direction of literature review was on the features design of the ETS pilots and their outcomes and result in their environment. Therefore, this chapter will follow the same order: I will first discuss the research method adopted during my research, followed by the presentation of the results obtained followed by the discussion of said result, in manner that encompasses first the results regarding the design and then the related issues in the overall environment.

1.Research method

As mentioned earlier at the beginning of this paper, the previous research on this topic has been either focusing on specific features of ETS or on analyzing its implication and effects, especially at the beginning of the projects. My contribution in this filed is to provide a new comprehensive overview of the pilots by discussing its design and implications with attention to environmental and economic variables, in light of the national ETS; and by doing so, the research method for this study is the empirical study of the collection of data and results gathered during my research.

First and foremost, through this research my intention is to update and further develop the understanding about the design of the Pilots through empirical research on relevant literature by evaluating their implication within their objectives as well as in light of the national ETS. Moreover, I will discuss on the relationship with the overall environment that is influencing the pilots and translate the meaning of this findings for the National ETS. Hence, my purpose is not the creation and estimation of new data as many of the studies I reviewed already brought out those findings; instead, I will employ an analytical and explorative methodology and develop an analysis providing results.

The literature reviewed for this research adopted different methods to conduct their study; it ranged from DID (difference-in-differences), DDD (difference-in-difference-in-differences), and CGE (computable general equilibrium) models, to panel data, simulations, quasi-natural experiments, empirical studies to evaluation and assessments of design choices.

These methods have been used for different purposes and to obtain specific types of results, the diversity on exploration of these methods have been crucial in the elaboration of the conclusion of this study. CGE models are economic models that make use of actual economic data to estimate the reaction of the economy on changes in policies, technologies, or other external factors. This allowed scholars to explore the future impacts of the ETS on the Chinese economy. In the other hand, DID and DDD models, which are statistical techniques, by comparing the average change over time of treatment groups opposed to controlled group in natural experiments, allowed to understand the behavior of different variables applied in different ETS scenarios. The collection of panel data ultimately has been helpful in comparing and evaluating the conditions of the Pilots in the past years, while simulations have clarified possible performances coming from the pilots.

I have gathered all the relevant data throughout my research by collecting the obtained results in previous knowledge of the literature, official reports, executive summaries, and journals. Subsequently I have reorganized the data collected in a manner that orderly replied to the questions at the basis of this thesis, moreover, I have also designed the tables necessary to exemplify concepts that presented new information to the discussion.

To reply the first question "What are the learnings on ETS design through the pilots? and in light of the national one? Was dividing into small local ETS the right choice?" I have pieced together the results related to the design of the ETS Pilots, specifically of coverage, cap settings and allowance allocation coming form the significant literature described in the second chapter and discussed their implications and significance for the National ETS. The discussion observed the importance of the choice of the design and how this is crucial to determine the positive outcome of the ETS by discussing their limitations and potentials.

Afterwards, to reply to the second question at the basis of this thesis I bring together the gathered information to reply whether the Pilots have been useful to support the development of the National ETS. This discussion focuses on assessing the current state of condition where the pilots are in play, that is eventually the background of the national ETS. This portion of the discussion aims at understanding where the ETS stands within the Chinese overall environment and as well as the government. In the discussion I examine the observed heterogeneity in the different impacts and effects of the pilot in terms of the environmental and economic effects and discuss some direct implications related to the national ETS by evaluating environmental, and economic, parameters such as economic growth, greenhouse gas emission, carbon intensity, energy consumption, and annual changes in CO2.

Collecting the data necessary for this thesis was challenging as of today some information are still not revealed publicly by the Pilots. At the same time, even though the discussion about ETS started almost 10 years ago, there is still a great margin of development and perfection as the national one just launched. Nonetheless, through re-discussion of the different concepts introduced in the first chapter, that were successively reinforced in the second, and further added in this chapter results in consideration for the National ETS, the discussion enabled the formulation of the conclusion of the thesis. Therefore, in the following paragraphs I will proceed in presenting the results related to the matter and making an analytical assessment of the main design features of the ETS, namely coverage, cap setting and allowance allocation, and of the environmental and economic results, followed by the discussion that the result ensues.

2. Results and discussion

Throughout the literature review I identified the positive implications of ETS on Chinese environment. In this paragraph I will group and analyze the results of my thesis, which correspond to empirical results on economic and social factors inside the Chinese society. The tables and graphs referenced are gathered in the following paragraph.

a. "Not the more, but the right" coverage

During the pilot years, the coverage of the pilots has only expanded. The sectors covered are mainly industry, building, transport, domestic aviation, and power. Within the regional area of the pilots, they equal a wide quantity of carbon emission varying from 24% to 55% of the emission in that area. Table 1 shows the different ratio covered by the pilots, updated in 2022.

Coverage in China ETS Pilots by sectors and		
	sector	on total emissions
CHONGQING	Industry	51%
TIANJIN	Domestic aviation, Industry, Power	55%
BEIJING	Transportation , Building, Industry	24%
SHANGHAI	Transportation , Building, Industry	57%
HUBEI	Industry	27%
SHENZHEN	Transportation , Building, Industry	40%
GUANGDONG	Domestic aviation, Industry	40%
FUJIAN	Domestic aviation, industry	51%

Table 1 Pilots coverage in percentage in 2022.

The design of the pilot is a complex mechanism that needs to take into consideration many factors, including the gathering of information and coordination of activities with the same objective. Among my research, I found that when rereferring to the coverage of the sectors, it is preferable to select first those of high carbon emitting, without ignoring the others later. This ensures the coverage of large quantity of emission compared to small effort, because covering many different small sectors would imply more work and costs for coordination. Few sectors with significant impact, which can be easily managed resolve this question. During the pilot years, the coverage of the pilots has steadily expanded. The diversity in the economic effects can be detected in the different industries covered by the pilots. Even though the pilots cover relativily similar sector, the industrial outputs are significantly different (Table 1). This can also be traced with the reasoning of Boqiang and Zhijie. In fact, ccontrary to many authors that suppose that the goal is to cover many sectors as possible, they have reported how less coverage is more efficient than too much. Following the line of thought that "not the more, but the right" coverage can bring the desired results without the need to cover the total carbon emissions. They suggest covering only three easy-to-monitor enterprises are enough for emissions reduction: cement, chemical and electric power. Though, the general opinion for years has supported the concept that covering more sectors would create more stability marketwise, recently there have been more studies supporting the notion "not the more, but the right". Ultimately however, there should be a reasonable equilibrium between coverage and capability, where the covered entities are enough to reach the environmental goals but not too much to entail high costs.

However, above all these theories, there is the need to consider the phenomenon of leakage as well. Which manifests mainly due to different ETS and non-ETS areas, that can compromise the outcome of the ETS. Based on this understanding and recollecting Li et al.'s paper, the carbon market is more stable if more sectors are covered. However, the issue is true when only considering the pilots as there is the presence of non-ETS pilots within the nation. Hence, in light of a future national ETS, where overall national emission ought to be considered the issue shouldn't persist. However the problem would transfer to the national borders, where at that point leakage will manifest in China (covered by the ETS) and outside of China (countries not regulated by carbon reduction policies). This issue definitely need further studies in the future as it also comprises the regulations of other ETS around the world.

b. A flexible cap

At the beginning of the project, only Hubei and Guangdong had published definitive caps. Specifically, the Hubei cap setting is presented as a hybrid of the historic method and the prediction method, and it additionally allowed banking and borrowing as a form a supplementary mechanism. The other pilots without definitive caps, the actual caps were assigned as the results of bottom-up aggregation (Table 2). Ultimately, Chongqing set a cap of 241 in 2014, decreasing more than half of it the following year, but eventually setting the pace for a slower reduction in 2015 and following years. Tianjin set a cap a little too high too in 2014 of 324 but decreased in 2015. There are no available data for the years from 2016 to 2019, but in 2020 it reached 120. Beijing set cap relatively low since the beginning with a consistent 45 until 2015, to increase to 50 in 2016 and reduce again in 2017 to repeat again the up and down from 50 to 35 in 2020 and 2021 respectively.

Cap settings in China ETS pilots in the years in MtCO2e including reserves								
	CHONGQING	TIANJIN	BEIJING	SHANGHAI	HUBEI	SHENZHEN	GUANGDONG	FUJIAN
2013	np	np	45	~165	np	33	388	-
2014	241	324	45	~165	324	33	370	-
2015	106	281	45	~165	281	31,45	408	-
2016	100	np	50	155	253	np	386	np
2017	100	np	46	156	257	np	422	np
2018	97	np	np	158	256	np	422	np
2019	97	np	np	158	270	np	465	~220
2020	78,39	120	~50	105 *	166*	np	465	~126 *
2021	np	np	~35 *	np	np	np	265 *	np

np= cap not published by the pilot

* the drop is mainly due to the transfer in the power sector in national ETS

~ the cap is estimated by experts

source: ICAP (2022), Zheng et al.(2014), Council (2011)

Table 2 Cap settings in China ETS pilots in the years in MtCO2e including reserves.

As regarding for the cap setting, the studies show how the flexibility cap that was adopted by the pilots allowed them to be more elastic. The flexible method makes use of the ex-post-adjustment allowing more margin of improvement. This option enhances compliance flexibility, cost-efficiency, and foster carbon price stability; however, it potentially weakens future reduction targets as it also gives an incentive to delay mitigation actions.

For the other pilots without definitive caps, the actual caps were naturally designated as the results of bottom-up aggregation. This method makes the actual caps for the programs flexible due to two reasons. First, ex post adjustments are employed for allowance allocation for different covered entities. Second, many pilots set aside several allowances in case of possible market interventions, all or part of which might not be allocated later, making it more flexible.

Summarizing, a definitive cap with borrowing risks of weaken mitigation actions and carbon reduction goals while a bottom-up with ex-post-adjustments is more flexible and convenient when there is little indication from authorities.

b. A hybrid allocation method can be the key to allowance allocation

Free allowance allocation method used by the pilots		
	method	application
Without ex-post-adjustments	Emission-based grandfathering	Beijing: industrial sector (power and heat generation sector excluded) and service sector Shanghai: industrial sector (electricity and heat generation sector excluded) and large public buildings Tianjin: all industries excluding electricity and heat generation sector Guangdong: co-generation unit in the power sector, short processes in the iron and steel sector, and mining in the cement sector (2013, 2014) Hubei: all sectors excluding the power sector and preallocated allowances for the power sector
	Historical production based benchmarking	Guangdong: pure power generation units in the power sector, long processes in the iron and steel sector, and clinker production and grinding in the cement sector (2013)
With ex post adjustment	Current production and historical intensity-based grandfathering	Beijing: electricity and heat generation sector, based on baseline years (3 years prior) Tianjin: electricity and heat generation sector Shenzhen: manufacturing sectors, ports, airports, subways, public buses, and other non-transport sector Shanghai: with ex-post adjustments to some industrial sectors, aviation, ports, shipping, and water suppliers, generally based on the previous three years' data.
	Current production based benchmarking	Shanghai: electricity and heat generation sector, aviation, airport, port and other sectors Hubei: adjusted allowances of the power sector Guangdong: pure power generation units in the power sector, long processes in the iron and steel sector, and clinker production and grinding in the cement sector (2014) Shenzhen: Water, power, and gas sectors
	Current emission-based updating	Chongqing: all sectors
Source: Pang, Duan, "Cap setting and allowance allocation in China's ETS pilots",2016; ICAP, 2019		

Table 3 Free Allowance allocation methods used by the pilots.

	Grandfathering	Benchmarking	Hybrid method
Encourage emission reduction	No	Yes	Partly
Consider the financing difficulties	Yes	No	Partly
Method consistency of new entrants	No	No	No
Requirement for data	Simple	Complex	Complex
Complexity	Simple	Complex for setting Simple for allocation	A little complex
Suitable application phase	Suitable for the early stage	Suitable for applying after the ETS has run for some time	Suitable for applying after the ETS has run for some time

Table 4 Comparison of free allocation modes

Modes	Auction	Free allocation	Gradual hybrid	Sectoral hybrid
Advantages	Internalization No formula in advance Avoid "windfall profits" Finance for clean technology	Enhance attractiveness to companies in the early stage Resolve carbon leakage issue	Compromise	Different treatment based on different sectoral features
Disadvantages	Heavy burden for enterprises	Need calculation formula in advance Coordinate interest claims Over issue of allowances	The similar disadvantage to the free allocation mode in the early stage	The similar disadvantage to the free allocation mode in the early stage

Table 5 Comparison of allocation modes used by the pilots.

Shenzhen assigned allocations by benchmarking applied to water, power, and gas sectors based on sectoral historical emissions intensity. While grandparenting is applied to manufacturing sectors, ports, airports, subways, public buses, and other non-transport sector based on the entity's historical emissions intensity. Additionally, 3% of the allowances can be reserved for auctions however so far Shenzhen has only held one auction.

Beijing distributes free allocations through grandparenting based on historical emissions or emissions intensity in the baseline years (the three years prior). While benchmarking is used for new entrants with expanded capacity in the power sector (until 2020), heat production, cement and data centers. Beijing could save 5% of allowances for auctions, however, to date no auctions have been held.

Shanghai distributes via free allocation based on sector-specific benchmarks (for the electricity and heat producers, and electricity grid sector). Grandparenting based on historic emissions intensity for some industrial sectors, aviation, ports, shipping, and water suppliers, generally based on the previous three years' data. Grandparenting based on historic emissions for airports, buildings, commercial sector, and some industrial sectors with complex products or a considerable change in emission boundary, generally based on the previous three years' data. Ex-post allocation adjustments are applied for historic intensity or benchmarking allocations. As regarding for auctioning, ad hoc auctions have been held since 2014 in each of the following years: 2014, 2016, 2018, and 2019. After 2019, two auctions have been held each year.

Guangdong was the first one to introduce auctioning as an allocation method among the pilots, and since 2013 it has held quarterly auctions until 2016; 2017 auctions have been held on an ad hoc basis. No auctions took place in calendar years 2018, 2019 and 2021. Free allocation is made through grandparenting based on historical emissions (applied to some processes in the cement and steel industries and the whole petrochemical industry) or emissions intensity (applied to some products in the cement industry, captive power plants in the steel industry, special paper and paper product manufacturers, enterprises with pulp manufacturing, and other aviation enterprises), or benchmarking (applied to industrial processes in the aviation, cement, paper, and steel sectors). Ex-post adjustments based on real production data of the respective compliance year are also applied for those sectors that use benchmarks and emissions intensity methods.

For Tianjin free allocations are assigned through grandparenting based on total emissions (for iron and steel, petrochemicals, chemicals, exploration for oil and gas, and aviation) or on emissions intensity (for heat and electricity production, papermaking, and building materials). Benchmarking applies for new entrants. Pre-allocation allowance amount is 50% of the previous year's emissions. Ex-post allocation adjustments based on actual production level are applied to determine the final allocation, especially for those sectors that use benchmarks and emissions intensity. To date, auctions have been held on an ad hoc basis, since 2019, it has held two auctions in each compliance year.

Hubei distributes free allocations through benchmarking for power (until 2019) and cement industries. While through grandparenting based on historical emissions for heat production and supply, pulp and paper, glass and other building materials, water supply, and automobile and equipment manufacturing. Also, grandparenting based on the previous three years' historic emissions for all other sectors. Ex-post allocation adjustments are applied, for benchmarks and emissions intensity's sectors. To date, auctions have been held on an ad hoc basis and took place in 2014, 2019, 2020 and 2021. Recent years have seen two auctions per year.

Chongqing allocates free allocations via grandparenting based on historical emissions (highest number in period 2008-2012). Auctioning was introduced in 2021 without a fixed schedule and two auctions have been held so far.

Fujian's allowances are mainly distributed for free using benchmarking (the electricity (until 2019), cement, aluminum, plate glass, chemical and aviation sectors) or grandparenting (The other sectors are allocated allowances based on historical carbon intensity). Up to 10% of the total cap is reserved for market intervention.

The pilots used combinations of mainly free allocation plus auction as allocation method however the different combinations among grandfathering and benchmarking were the decision that made the difference (Table 3). These two methods together with the hybrid one, all present different advantages and disadvantages (Table 4). Benchmarking encourages emission reduction while grandfathering takes into consideration the financing difficulties. All of the three methods however are not consistent of new entrants. The requirement for data is simple for the grandfathering while half complex for benchmarking and a little complex for the hybrid method. Nonetheless, they are all valid methods that are suitable in different phases of the ETS. Grandfathering is suitable for the early stages opposed to the other two that are more suitable after the ETS has run for some time.

As seen in Table 5 auction mode advantages include being an internal operation, and the absence of a formula needed, and it avoids "windfall profits" which are profit made by accumulating a lot of allowances. However, the burden falls on the enterprises as they are the one estimating the number of allowances needed on top of auctioning for them. The free allocation mode enhances the attractiveness of the carbon market to companies in the early stages and potentially resolve carbon leakages but needs the effort of calculating in advance the formula and might present over issue of allowances. At last the gradual hybrid and sectoral hybrid comprise, the first as a compromise of the different issues resented in the first two modes, while also having similar disadvantaged to free allocation in the early stages.
The studies furthermore show that certain practices, especially the banking and borrowing of allowance allocation might reduce the push of firms towards alternative use of technology for clean energy, allowing them to wait on the kept allowances. The hybrid formula used in the pilots during these compliance years developed specifically by the Chinese ETS pilots allowed them to be more prepared in case of new entrants in the market or for market interventions. However, the discussion is centered more on which free allocation is the most effective method to apply, and there are several research on this specific carbon trading

feature. Pang et al. demonstrated well how allocation with benchmarking is more suitable for carbon reduction. Because it allows a better adjustment of energy efficiency within the covered entities, while grandfathering is less flexible and doesn't leave room for corrections. However, benchmarking requires complex classification and preparation of data beforehand and, on the other side, auctioning is best fitting for market interventions rather than as the main method of allocation. The latter would leave a heavy burden for the firms in calculating how many to buy and risks in leaving disparities among distribution.

The gradual hybrid mode seems the most suitable way of practice for China, both for the pilots (how it has been) as well as for the national ETS, as its flexibility allows for more adjustment during the course of growth letting development and corrections to take place. The optimal combination from the studies suggests a combination of free allocation and auction (as the pilots are already doing) but using grandfathering at the beginning and slowly collecting the data necessary to shift to benchmarking, which is a more effective method in reducing carbon emission and can be adjusted to the different needs of the local areas.

d. Decoupling and carbon intensity reduction

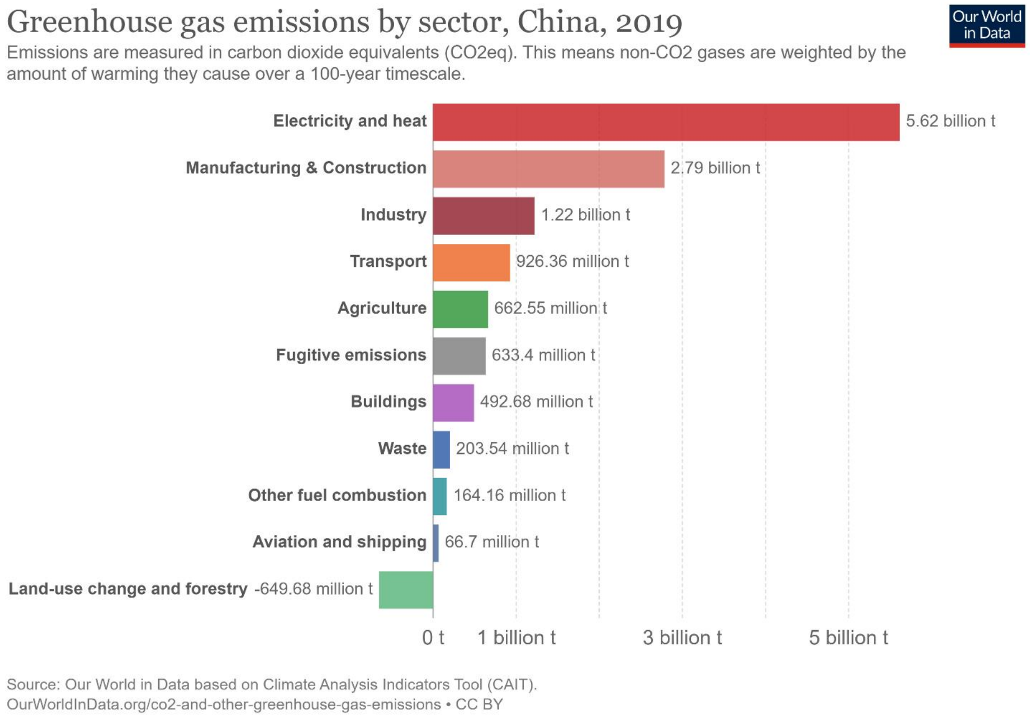

Table 6 Greenhouse gas emissions by sector China, 2019

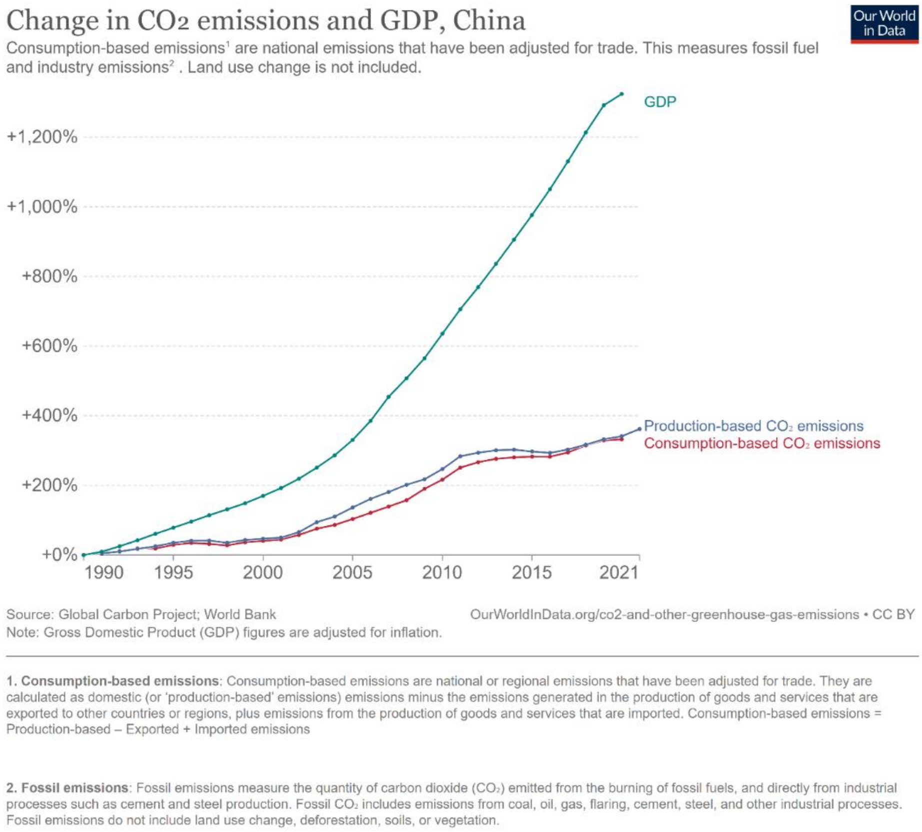

Table 7 Change in CO2 emissions and GDP, China

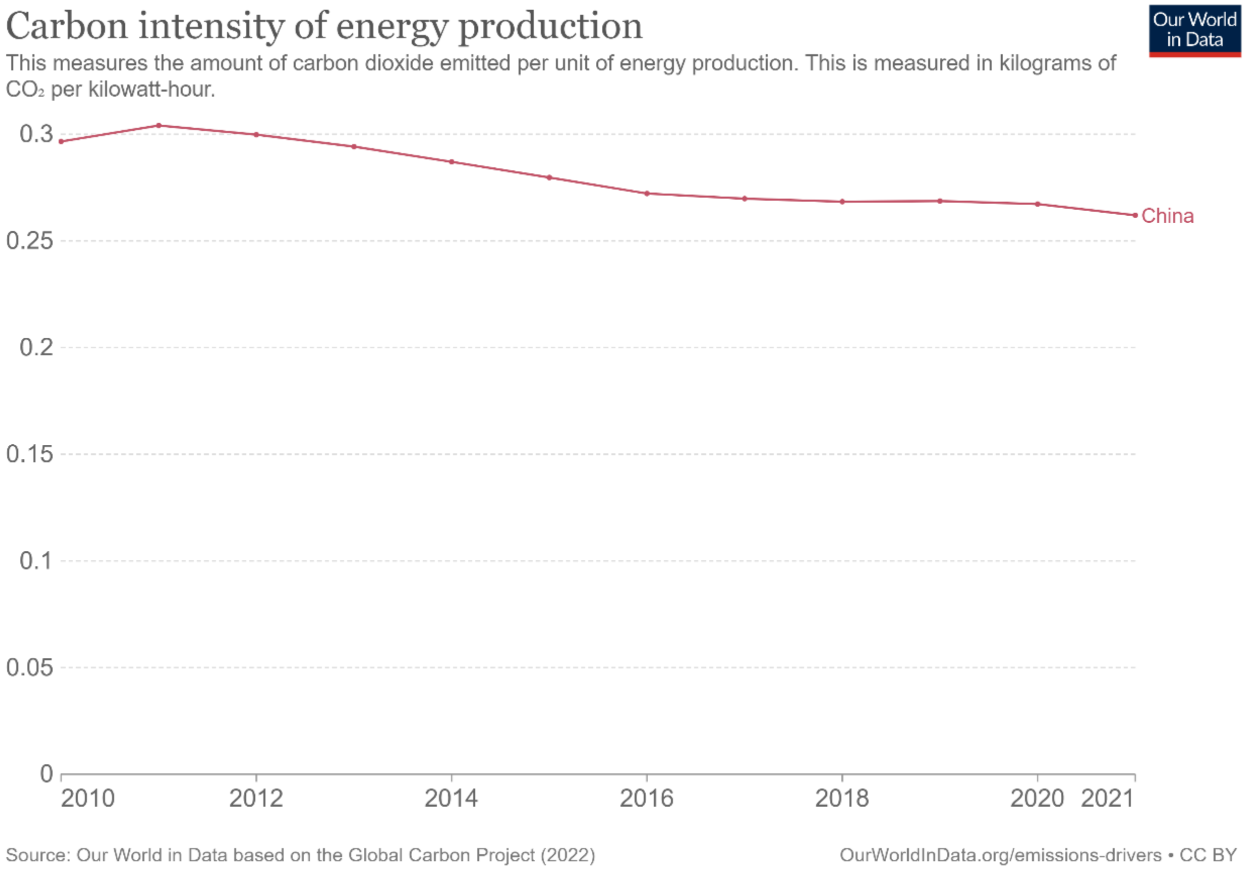

Table 8 Carbon intensity of energy production, China

The total global greenhouse gas emission growth in China in 2019 was at a rate of 1.1% (52.4 gigatonnes of CO2e), a continuation of the average annual growth rate of 1.1% since 2012. Though, it is still the lower growth rate seen since 2000 (with an average of 2.6%) 74% of which are carbon dioxide. The greenhouse gas emissions by sector in China in the same year show most of the emissions comes from the electricity and heat sectors, with the biggest value of 5.62 billion tonnes (Table 6). Manufacturing and construction sector is the second most emitting with 2.79 billion tonnes, little more than half of the first category. The industry sector is the third sector that goes above 1 billion tonnes with 1.22 billion tonnes. Transport, agriculture, buildings, aviation and shipping are respectively 926.36, 662.55, 492.68, and 66.7 million tonnes. The only sector that has actual negative values is land-usage and forestry with -649.68 million tonnes. In 2019 was reported that China contributed to 28% of the total global carbon emissions. China's annual GDP since 2012 reported to be at least 7.3%. In juxtaposition to its carbon emission, that had an average annual increase of 8.0 % between

2001 and 2011, then of 1.1%, 0.2% and 0.0% respectively in 2014, 2015 and 2016; and resumed to grow from 2017 with 1.9% and 2018 with 2.3%.

Even though there has not been dramatic change in total carbon emissions, we can see how carbon intensity decreased overtime (Table 8). Carbon intensity started reducing in 2011 (the ETS was first announced in this year) and slowly decreasing. In 2013 its value was of 0.29, decreasing of 0.01 each year in 2014 and 2015, to then remaining stable at 0.27 from 2016 to 2020. In 2021 it was 0.26. Additionally, during the compliance years since 2013, the total carbon emission in China have not decreased, however it is growing at a slower pace. Nevertheless, the carbon intensity has been decreasing quite steadily since 2011, with a reducing rate of -0.04 per unit of energy production (kilograms of CO2 per kilowatt-hour) and relative change of 14%.

f. China is struggling to reach its goals

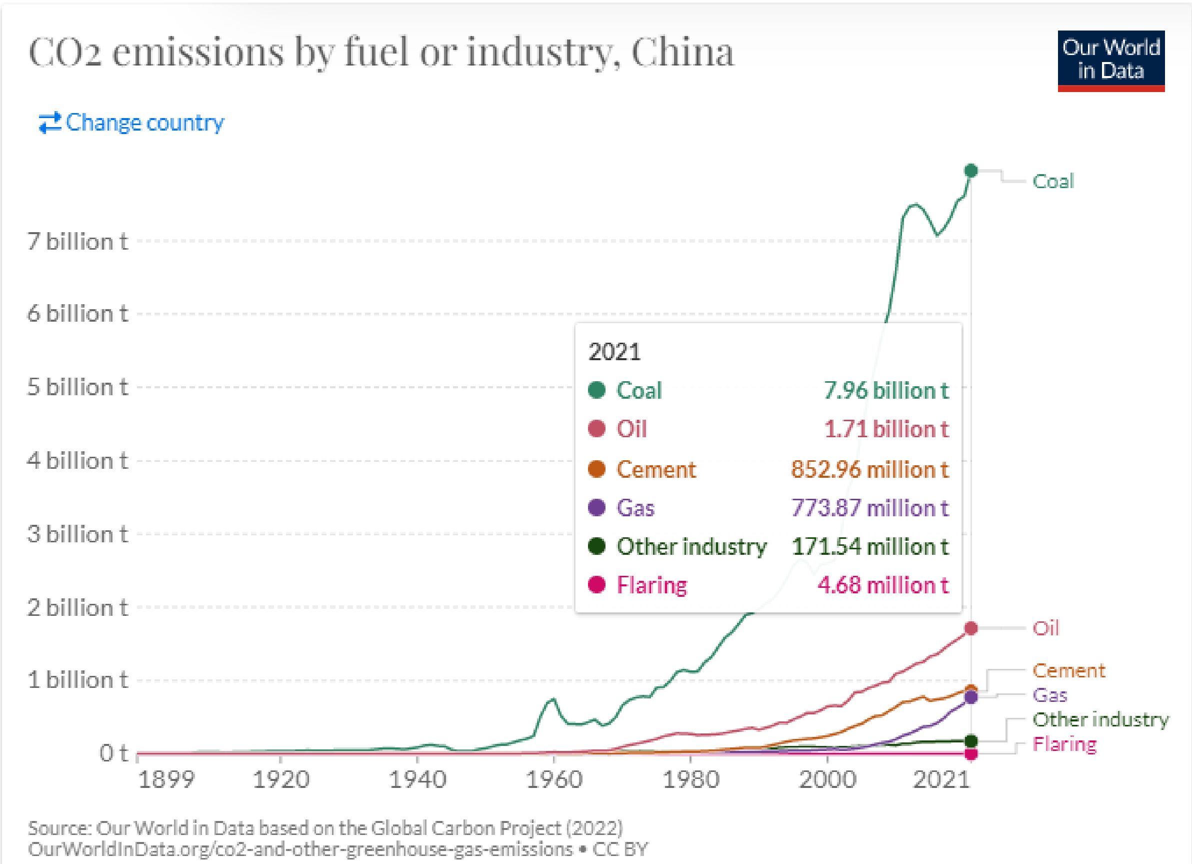

Table 9 CO2 emissions by fuel or industry, China

Coal remains the primary source of carbon emisisons and in the last years it has not given sign to reduce (Table 9). In 2021, coal burning in china reched 7.96 billion tonnes; followed far well below the chart by oil cement amd gas with respectufuly 1.71 billion t, 852.96 million t, and 773.87 million.
The environmental impacts reported in the pilots show how their establishment have produced consistent results with previous simulation studies in decreasing carbon emissions and with trends that show a positive outcome in the long term.

The industrial output in the pilots had some negative repercussion that are indicated to alleviate in the long term, hence this shouldn't hold a great concern on national GDP at the moment and, in the same way carbon emission, affected by the ETS pilots, has shown positive results to decrease even more over time as well.

Summarizing, the results in the numerous studies all come to an agreement that, in the long-term, related to the activities of the ETS, it can effectively reduce CO2 by each passing year and that economic growth will be affected at the beginning and reduce its loss over time. Moreover, following the environmental goals economic growth and carbon emission will be not connected anymore from 2030, and in 2060 reaching the point where there will be no more carbon emissions.

Nevertheless, in these years, when considering the overall national carbon intensity and CO2 emissions, their reduction rate has been extremely slow and minimal. This was due to the several carbon mines approved in 2019 that increased the overall carbon emissions (Table 9). Chinese industry is still highly dependent on coal-generated electricity, so the ETS alone cannot be considered the only way to reduce carbon emissions to reach national environmental goals but rather there is a need of the combination of different several elements in order to reduce carbon emissions efficiently. Among this, China needs to invest in more renewable energy in order to deplete coal plants as well. However, as mentioned in the first chapter carbon intensity is a reflection of not merely the relation of two variables but by many factors other factors that influence the economy and social condition of the country. Furthermore, in 2021, the power crisis already in place since 2019 was exacerbated by the division of political power and responsibility between the central and provincial governments and subsequently, in 2022 the war in Ukraine and the demand with the undulating covid restrictions added further pressure; all these factors combined had a substantial impact on carbon intensity. Eventually, China returned to the reliance on coal, that explains the soaring difference in the emission of coal-generated energy and other sources. However, the consequence of this step back is that, with the targets of the 14th FYP getting closer in 2025, and losing years in decarbonization efforts, China has less than a decade left to reach its 2030 goals (a reduction target of 18% in CO2 intensity and 13.5% reduction target for energy intensity from 2021 to 2025.). Furthermore there is the strong need to manage existing coal plants to reduce emissions as a key clean energy transition. Emissions could be reduced by managing plants better and working to retrofitting plants and retire inefficient plants.

g. Change in CO2 emission caused by ETS

Change in CO_2 emissions and industrial output value caused by ETS.
Source: Estimated with SCM by the author.

	2011	2012	2013	2014	2015	Add up
	CO_2 emission reduction (10000t)					
Beijing	−3200.02	−3733.47	−5561.44	−4960.63	−5022.02	−22477.57
Tianjin	−657.23	−1247.12	−1448.04	−2453.16	−3167.55	−8973.08
Shanghai	−29.53	−750.65	−3590.84	−2594.88	−2558.48	−9524.38
Chongqing	−255.45	−3425.92	−2925.83	−6798.64	−9090.22	−22496.06
Guangdong	−916.76	−2959.22	−9454.04	−8936.51	−9422.92	−31689.46
Hubei	−3065.75	−4502.80	−3316.47	−6193.45	−4332.70	−21411.17
Add up	−8124.73	−16619.18	−26296.64	−31937.27	−33593.89	−116571.72
	Industrial output value (100 million RMB)					
Beijing	−204.92	−314.85	2059.94	2441.82	2299.69	6281.69
Tianjin	441.46	732.92	2678.23	3307.75	3779.54	10939.90
Shanghai	238.93	−2298.88	−1161.46	−1856.59	−1934.75	−7012.76
Chongqing	313.19	−216.33	605.48	2095.25	3299.31	6096.89
Guangdong	−3074.64	−15619.29	−18399.45	−17906.34	−19166.85	−74166.57
Hubei	−141.38	871.95	705.38	472.69	−136.63	1772.00
Add up	−2427.36	−16844.48	−13511.88	−11445.42	−11859.70	−56088.84

Table 10 Change in CO2 emissions and industrial output value caused by ETS

The study of Wen et al. produced the following results in analysing carbon reduction during the ETS using industrial output (an important tool for forecasting future GDP and economic performance) and CO2 emission reduction as unit of measure. Thanks to the implementation of the ETS, from 2011 to 2015 CO2 emissions declined by aproximately 1,165.72 Mt. this result equals 12.78% of the total carbon emission in the pilot regions in study. At the same time the value of industrial output fallen by about RMB 5,608.88 billion, though the loss reduced gradually overtime. The different outcomes of the pilots was reflected in the impacts on the output. Especially, the losses were condensed in the Guangdong and Shanghai Pilots (respectively of RMB 7,416.66 billion, 4.64% of the region's total output and RMB701.28 billion, 4.08%). On the contrary, Tianjin is the only pilot with a cumulative industrial output of 10,939.90 from 2011 to 2015, and positive reduction of carbon emission at the same time. Beijin, Tianjin, saw a decline in industrial output in the fisrt two years of the ETS, while Chongqing only in 2012, and then a small increasing trend from the third year. There is a comprehensive reduction of carbon emisison from 2012 to 2015, in the six pilots considered by the study of 116571.72 (Co2 in 10,000 t) and an industrial outcome of minus 56'088.84 (100 million RMB)

h. Firms' participation and regulatory framework

As the literature reviewed mainly observed economic and environmental variables and executed experiments based on data, the component of firms' participation was overlooked in the process but nevertheless the heat generation is among the sectors that emits the most in the whole country so its regulation, even if not directly tied to the ETS policies is critical component worth including in the discussion.

The regulation of the electricity and heat generation sector is strictly tied to the structure of the country and mainly used to regulate the prices of said sectors. However, it is an issue that can reverse on firms' participation were referring to the ETS. This is because the firms in these sectors cannot transfer the cost arising from the emissions control to the consumers nor adapt their output, leaving a burden on these same firms that ultimately could suffer from allowance shortage and more costs. This condition puts more obstacles on the firms that might not see the advantages in adapting to this project, prompting in less genuine commitment with the ETS that can ultimately weaken the potential benefit of the ETS.

Corporate influence is another element that can come into play when taking into consideration firms. Large corporates can play significant roles in advocating for local employment and taxation. This is a serious issue that can lead to corruption and the counter effect of the ETS. It is important that in the national ETS this issue is resolved effectively but it may not seem easy as this lays also in the social structure of China.

In 2013 a regulatory framework for ETS' was still not present, therefore, when it began, and new regulations and frameworks were set up, this led to two set of issues: uncertainty in the process and overlapping of responsibilities.

The first issue can be resolved by time, as developments, corrections and improvements of regulations and framework can continuously take place. The Chinese government could have taken directly from other country's framework and regulations and applied them to the Chinese ETS and speeding the whole process of establishing an ETS, but the absence of one already prepared framework allowed the pilots to grow within their specificities (especially as regarding for financial products).

The second issue deriving from the creation of something completely new, is the overlapping of responsibilities and existing climate policies. New offices were being set up with task already assigned to old ones: multiple ministries and agencies were involved in setting regulations to manage energy use, which included detailed targets sets at the national and provincial levels. The national government restructuring that took place in 2019, addressed the issue and directed the responsibility to one ministry: the Ministry of Ecology and Environment of People's Republic of China (also abbreviates as MEE or EB for local offices, e.g.: Beijing Environmental Bureau) with distribution of minor responsibilities to the regions of the pilots. With the National ETS the existence of the MEE should alleviate the bureaucratic burden initially taken by the pilots, yet the scale of the national one could comprise as a challenge and additionally, new issue will arise as the convergence of all the covered entities in un carbon market.

As mentioned briefly earlier, the absence of a regulatory framework allowed the Chinese pilots to grow within their specific characteristics. A strong example are the financial products in the different pilots, that contribute in different ways to the smooth operation of the carbon market. This behavior from the pilots is one of the important positive outcomes derived from the main decision of selecting pilots with different situations, without previous framework to stand on.

To reach its environmental goals China needs to tackle carbon commitments with stronger actions if it wants to reach its carbon goals and recovery from these years of carbon loss, however, there still margin for the dual carbon goals, always given if it puts on more stronger efforts.

Moreover, the reframing of the governmental structure has been a challenging issue for the smooth operation of the ETS, as it arose delays since the staff of the local authorities were not familiar with the ETS and lacked relevant capacity. Now, with the climate portfolio divided in different agencies some of the coordination challenges might arise. Additionally, the energy policy remains with the NDRC and the National Energy Administration (NEA), therefore the need for close coordination among these agencies and the MEE in order to develop robust and unified frameworks ensues. If the MEE would have remained both charged of the climate change and environmental issues, it would have contributed to stricter enforcement of climate policies in general as well as enable close follow up on implementation. Moreover, the consolidation of environmental responsibilities in one ministry would have aligned various environmental strategies and policies, including the carbon market.

CONCLUSION

As carbon trading is rising as a climate mitigation method throughout the world, and China National ETS just launched in 2021, it is important to understand its application in different context to evaluate its success and, specifically in this case, the Chinese social structure and economy give a great opportunity to better understand its result. China is the most carbon emitter country in the world and the success of the ETS in this country can signal a groundbreaking discovery of the future of environmental policies in the world. To conclude this study will follow the formulation obtained by the discussion of the results find along my research which have strong policy implications.

A carbon market in China has the potential to reduce carbon emissions in the long-term, with some limitations in economic growth in the short-term, and this is consistent with the overall literature on the topic that the ETS. As regarding for design features, throughout the result collected I can positively affirm that the success of the positive outcome of the carbon trade in China is also based on the decision making on the design of the carbon market. Specifically, as regarding for the coverage of sectors in the Pilots, the findings show innovative results. The coverage under an ETS is conventionally though to be best if it covered more emissions as possible, including more sector along the process, in order to have more control on the emissions emitted and hence being able to reduce them. However, in these last years a new trend of though is emerging as Lin et al., and Boqiang et al., find that covering just the right sectors can trigger the positive result of the ETS, specifically just three easy to monitor sectors (cement, chemical and electric power). These new findings show that perhaps “not the more, but the right” coverage is what the carbon market needs. Ultimately, there should be a reasonable equilibrium between coverage and capability, where the covered entities are enough to reach the environmental goals but not too much to entail operational costs. However, there should be more studies in the future that can validate this new line of thought, and on the National ETS as well to identify the right coverage.

Another issue to take into consideration while talking about coverage is the risk of carbon leakage and reverse carbon leakage. As Zhou et al. found, reverse leakage and leakage are determined by market participation and industrial transfer. To address correctly this issue there is the need to further understand the channels that affect these spillover and strengthen the regulations targeting specifically the prevention on carbon leakage by introducing real-time supporting policies. Additionally allowances allocated ought to be of reasonable quota in order to achieve an emission mitigating effect while avoiding reverse carbon leakage.

As regarding for cap settings, the pilots have already found a reasonable solution by themselves by adopting a flexible cap that allowed them to adjust along the years in order to give the right amount of allowances.

As regarding for the cap setting, the studies show how the flexibility cap that was adopted by the pilots allowed them to be more elastic. The flexible method makes sure that the Pilots can adjust along the years to a better fitting cap, this option enhances compliance flexibility, cost-efficiency, and foster carbon price stability; however, it potentially weakens future reduction targets as it also gives an incentive to delay mitigation actions. For this reason, in light of the National ETS the MEE and the NDCR should collaborate and assure with other complementary policies in order to incentivize carbon reduction target.
For allowances allocation instead, we have seen how the Pilots are already adopting a combination of free allowances and auctions with different purposes, that was suitable for their specific situations, this approach also allowed them to be more prepared in case of new entrants in the market or for market interventions. Throughout the findings and discussion of these, the learnings obtained by the pilots that should be implemented for the national ETS is to take a step further and adopt the grandfathering mode at the beginning of the ETS and successful switch to benchmarking after the ETS has been running for some time, as it is a more aggressive as a carbon reduction mode of free allocation.

Shifting the focus on economic and environmental variables, the results show how China is not showing sign of decoupling carbon emission and economic growth at the moment (Table 7). However, there is little time until China carbon peak goal set time of 2030. Carbon intensity is one of the most important channels measuring a country’s carbon emissions and China has shown a steady direction in reducing it however at an extremely low path. This indicates that the carbon reduction in the country is not moving at a pace fast enough to generate sufficient change in carbon intensity. Moreover, electricity and heat is among the sector that generates the most carbon emissions in China. The crucial issue that ties all these factors together is surge in the coal consumption in China that has aggravated its capacity in generating CO2 in the coming future locking great amounts of coal-fired emissions in the country, jeopardizing the work that has been done so far towards a carbon free path and adding more workload in the commitments to the steps needed to reach carbon goals.

Despite carbon intensity and related variables rates looking gloom, the actual effects of the ETS registered since 2011 are consistent with the common opinion that the carbon market has good potential in the landscape of decarbonization of China. At the same time the carbon market cannot be the solely mean of carbon reduction, especially now, since it's still in its infancy but also in the future. China's carbon goals are to be obtained with the tight partnership of related ministries that have the responsibilities of the carbon market, electricity and heat sector and overall carbon goals of the country. The NDRC and MEE need to cooperate in order to draft consistent regulations and policies and avoid overlapping. Moreover, the sole targeting the reduction of carbon emission is not sufficient to support climate goals, in order to reach carbon peak and carbon neutrality China should incorporate other changes in related areas such as the regulation of coal plants, the redefinition of sources of energy mix, incentivizing clean energy as well as low-carbon technologies.

Another crucial factor to take into consideration is firm's participation as well. There is the need to sensibilize participants of the importance of environmental matters and the decarbonization of the country in order to enable advancement.

To finally conclude the thesis, different features designs determine different outcomes, and to reach its carbon goal China also needs to understand what design for the National ETS is the right fit for the country. At the same time, focusing on one decarbonization instrument is not enough to reach carbon peak and carbon neutrality, therefore I developed this study to contribute to this subject matter and discussed the findings.

In the next years, the field of carbon trading in China need to be further studied to provide more insightful results aside from environmental and economic effects. Most importantly there is the need to further transparency in the processes and availability of the information of the ETS in order to facilitate design, research and development. Indexes such as carbon reduction, economic growth and carbon intensity are useful factors to understand its impacts, but insightful studies applied to the different mechanism can show the different actions that need to be carried aside from the main channels of carbon reduction. Additionally, the effects and impacts of the National ETS should be analyzed frequently to better understand the course of journey that China need to take in order to reach carbon neutrality.

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