A Work Project, presented as part of the requirements for the Award of a Master's degree in International Development and Public Policy from the Nova School of Business and Economics.

Decarbonizing Economies through Carbon Pricing –

Is there an ideal policy mix?

-

Development and relevance of a feasible emission mitigation strategy for China

Rabea Sieling

Work project carried out under the supervision of:

Professor Maria Antonieta Cunha e Sá

Mr. Álvaro Santos Pereira

03/10/2022

Abstract

Explicit and implicit carbon pricing are indispensable to reduce emissions and direct economies towards carbon neutrality. This report aimed to investigate whether there is a policy mix that is the most effective in emission reduction. A cluster analysis showed that stringent market-based instruments such as the CO2 tax are substantial for effective emission abatement. In a second step, a political feasibility analysis was conducted to investigate how China can improve their environmental policy framework further. This showed the importance of leveraging both explicit and implicit pricing when setting up successful, national carbon pricing strategies.

Acknowledgments

We would like to express our gratitude to several people whose support has been essential for the realization of this work project. We thank our supervisors Professor Antonieta Cunha e Sá and Mr. Álvaro Santos Pereira for their guidance and expertise in environmental economics. We are thankful to the Organisation for Economic Co-Operation and Development and Nova School of Business & Economics and our temporary colleagues for providing us with the opportunity to gather valuable experience in OECD's work. We especially extend our gratitude to Tobias Kruse, Ilai Levin and Bernardo Mayorga Salas from the Economics Department for their technical expertise and knowledge. Last but not least, we thank our fellow student colleagues, friends and families in their support and encouragement during this research process.

Keywords: Decarbonization, Carbon Pricing, Environmental Policy, Cluster Analysis

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

Contents

Glossary of Abbreviations

AMLO: Andrés Manuel López Obrador

BAU: Business as Usual

CAD: Canadian Dollar

CAT: Climate Action Tracker

CDM: Clean Development Mechanism

CER: Certified Emission Reductions

CO2: Carbon Dioxide

EC: European Commission

EPS: Environmental Policy Stringency Index

ETS: Emission trading system

EUR: Euro

FFS: Fossil Fuel Subsidies

FiT: Feed-in tariff

GDP: Gross domestic product

GHG: greenhouse gas

GLCC: General Climate Change Law

IEPS: Impuesto especial sobre produccion y servicios (Special Tax Law on Production and Services)

IMCC: Commission on Climate Change

INECC: National Institute of Ecology and Climate Change

LULUCF: Land use, land use change and forestry

MEE: Ministry of Ecology and Environment

NDC: Nationally Determined Contribution

NOK: Norvegian Krone

NOx: Nitrogen oxides

OBPS: Output Based pricing system

OECD: Organisation for Economic Co-operation and Development

PACE-Tool: Political Assessment of Clean air and Environmental Policies Tool

PCF: Pan Canadian Framework for clean growth and climate change

PECC: Special Programme on Climate Change

PPP: purchasing power parity

PRC: People Republic of China

R&D: Research and development

RE: Renewable energy

REA: Renewable energy auction

RET: Renewable energy technologies

RMB: Yuan

SEK: Swedish Krona

SEMARNAT: Secretaría de Medio Ambiente y Recursos Naturales (The Secretariat of Environment and Natural Resources)

SLCP: short-lived climate pollutants (SLCP)

SOx: Sulphur Oxides

STA: State Tax Administration

UN: United Nations

US: United States

USD: US Dollar

UNESCAP: The Economic and Social Commission for Asia and the Pacific

UNFCCC: United Nations Framework Convention on Climate Change

USCBC: US-China Business Council

VAT: Value added tax

Group Part

1. Introduction

Today's policymaking is driven by current and future consequences of climate change. Global greenhouse gas (GHG) emissions lead to a continuous increase of the world's temperature, resulting in extreme weather events like heatwaves, wildfires, or rising sea levels (National Geographic 2019). Recent years register records in peak temperatures, especially in the southern hemisphere, causing around 166,000 deaths between 1998-2017 (WHO 2022). In the future, climate inaction will make regions inhabitable, forcing around 216 million people to migrate within their countries by 2050 (World Bank 2022). Environmental impacts will also have substantial economic consequences and are projected to reduce the world's GDP by up to 18 percent in 2050 (WEF 2021). Weather-related shocks already caused up to 470 billion dollars in economic losses in 2017 (Kruse et al. 2022). As a result, governments are pressured to cut down greenhouse gas emissions and transition towards carbon-free economies. Global consensus on the pressing issue is captured in the Paris Agreement from 2015 where 196 parties signed an international treaty stating their commitment to reduce emissions (EC 2022). Although, historically, environmental policies were difficult to implement, global momentum on the subject and increasing public support for effective climate policies put governments in a position to advance their environmental commitments (Dechezleprêtre et al. 2022).

To offset emissions, states have a variety of policy instruments at their disposal. Those can be categorized into market-based, non-market based (command and control) and technology support instruments. Market-based instruments include carbon taxes and emission trading systems, non-market-based policies refer to performance standards, and policies such as feed-in tariff, renewable energy auctions or government expenditures for research and development classify as technology support instruments (Kruse et al. 2022). The vast variety of instruments leads to countries around the globe taking different approaches to climate mitigation policy.

In the absence of a global policy framework, some climate strategies taken by countries can cause challenges. Common problems include free-riding or carbon leakage, where firms move their production to countries with looser emission regulations (EC 2021). Moreover, given the variety of policy-approaches, the overall success in climate mitigation is dispersed and emission reduction around the globe is heterogenous (Ritchie et al. 2020). Generally, countries are lacking behind to meet the signed targets set in the Paris Agreement (Climate action tracker 2022) which creates the necessity for effective approaches to mitigate further consequences of climate change. In pursuance of transitioning to low-carbon economies, the international consensus moved towards the implementation of comprehensive policy packages, consisting of explicit and implicit carbon pricing, as well as other complementary policies (OECD 2015).

Research focusing on environmental policy usually analyses and compares the effectiveness, for instance in terms of cost, equity or marginal cost of abatement of emissions (MAC), of certain instruments like carbon taxes, trading systems or subsidies (Goulder and Parry, 2008; Stavins, 2019; Sen and Vollebergh (2018); Gugler et al. (2021)). The few studies that focus on policy effects on emission reductions, only analyze the effect of single carbon pricing instruments, mostly explicit ones. While there is a strand of research examining the effects of implicit instruments like FIT or subsidies on innovation and the uptake of renewable energy sources, research examining their effects on emission reductions does not exist to our knowledge. Also, the literature on the performance of policy mixes in terms of emission abatement is sparse. Thus, this work project in cooperation with the Organisation for Economic Co-operation and Development (OECD) aims to contribute to the literature by assessing the effectiveness of policy mixes in emission reduction across 40 countries taking into consideration both implicit and explicit pricing instruments. Moreover, country-focused analyses on the policy packages of five countries will provide an in-depth assessment of the political feasibility of different carbon pricing options depending on the national contexts. To capture the variety of policy approaches of countries across different continents, and of various development stages and size, Canada, China, Germany, South Africa and Mexico were chosen as case studies for the country-specific analysis.

Taken together, we aim to answer the following research question:

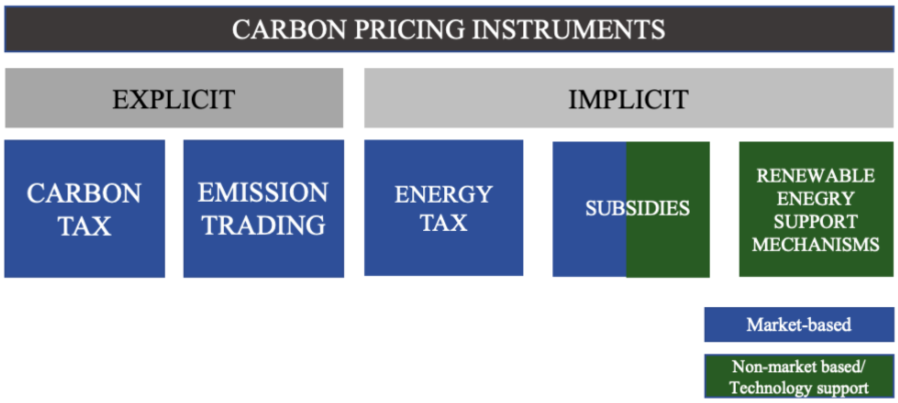
"Is there a policy-mix that is most effective in emission abatement and how can selected countries improve their environmental policy frameworks further?"

To answer this question, in Chapter 2 we begin by briefly introducing the different carbon pricing policy instruments and the economic intuition behind them. Then, an overview of the literature on the effectiveness of policy mixes to reduce emissions is presented in Chapter 3. Chapter 4 outlines the research approach taken in this report. As we define the policy mix of a country based on the OECD Environmental Policy Stringency Index (EPS) we will first explain the composition of this index. After validating the use of the EPS data set for analyzing emission intensity across countries through a bivariate regression, a hierarchical cluster analysis following the Ward's linkage method, will be calculated. With the latter, we intend to group the different countries based on their carbon pricing policy mix carbon and relate it to the associated reductions of emission intensity of the respective subset. Chapter 5 will go into the details of the described analysis and outline the results as well as their implications with regards to the research question. After discussing the "ideal" policy mix found in the cluster analysis and addressing possible limitations inherent in the research approach, the theoretical framework taken in the individual parts is outlined. A political feasibility assessment framework adapted by Peng et al. (2021) will be used for our five country-specific evaluations. The policy mix of Canada, China, Germany, South Africa and Mexico will be outlined and analyzed. Based on the findings of the cluster analysis of the common part, country-specific analyses and insights from the political feasibility framework, country-specific policy recommendations to facilitate the transition to low-carbon economies will be provided for each of the five countries.

2. Introduction to Environmental Policy Instruments

The necessary steps towards transitioning into a carbon-neutral economy, such as incentivizing agents in the markets to transition away from fossil fuels or shifting consumers behavior will require incurring significant costs (OECD 2013). Therefore, governments are facing the challenge of introducing coherent policies that minimize such costs by introducing an effective price on CO2 emissions. With such price on carbon in place, the burden of the damage can be conveyed back to the producers who are not only responsible but will also be incentivized to take measures to avoid it (World Bank 2022). The instruments currently available to policy makers today that have been developed in this pursuit are numerous and differ not only in (cost-) effectiveness but also equity, acceptability and feasibility. They can be divided into explicit, implicit and command-and-control instruments. For the purpose of this report the focus will lie on the first and second (D'Arcangelo et al. 2022, 26-38).

Figure 1. Classification of carbon pricing instruments



Source: OECD Power Point presentation given in class in T3 (OECD 2022).
Note: According to the literature review, there are many ways to classify carbon pricing instruments. In the following report we will refer to the grouping pictured above.

2.1. Explicit

According to economic theory, a well-functioning or perfect market can internalize all externalities. However, agents rarely pay the full social costs of their actions, leading to externalities in the market that must be eliminated. Carbon emissions, among other emissions are such an externality that needs to be addressed. One way to do so would be the creation of markets for the externalities, in this case carbon emissions. This is the underlying principle of the so called “marked-based instruments”, which can be divided into price-based mechanisms, such as the most-well known Carbon Tax (Dasgupta 2021). Together with the Emission-Trading-System (ETS), an instrument that has also been developed at a fast pace in the last decades, those instruments are often labeled as “explicit” Carbon Pricing Instruments, as the goal of both is to put a price on each ton of CO2 emitted. These instruments ensure efficiency in resource allocation by providing the correct incentives to all economics agents, while in some cases, they also generate government revenue (OECD 2013).

2.1.1. Carbon Tax

Policymaking in the past was shaped by limiting or banning certain undesirable actions, in the form of command-and-control regulations. In the last decades, however, the focus shifted towards market-based instruments such as carbon taxes. A carbon tax is a market-based instrument that sets a price per ton of carbon emitted (OECD 2011a). In the economic literature it is considered one of the most effective instruments to mitigate emissions and thus offset climate change consequences (Sen and Vollebergh 2018; Stavins 2019). Carbon taxes have already been implemented by many countries around the world, yet the price range varies significantly. According to World Bank Data from 2021, Sweden had the largest carbon tax rate with 137 U.S. dollars per metric ton of CO2-equivalent while other countries as Poland had a lower tax rate around only 1 U.S. Dollar (World Bank 2021).

Benefits and Challenges

The underlying reason for using carbon taxes is that without government intervention, there is no market incentive for private firms to internalize the environmental damage they cause, since negative effects of this externality is not affecting the company directly. As a result, taxes follow the objective of addressing market failures. Compared to carbon taxes, regulations may lead to higher costs. For instance, incentives for certain environmental goods or actions are employed by governments to steer the behavior of the market in a certain direction. For an efficient outcome, this requires an extensive amount of information about continuously changing technologies and market dynamics which makes the right choice difficult. Thus, regulatory instruments may result in higher costs even if other technologies are available that could potentially lead to a better outcome (OECD 2011a).

An important characteristic and benefit of the carbon tax is the fact that it raises revenue for governments which can be used for various societal purposes that may lower the social cost of the policy (Stavins 2019). Nonetheless, besides the revenue-raising effect of this instrument, there are also potential drawbacks. Goulder and Perry (2008) highlight, that the main negative effect of a carbon tax is that the costs of the environmental instrument are shifted to the consumer, resulting in higher prices for fuels or other energy-intensive goods. This "tax-interaction effect" leads to an efficiency loss which is why distributional impacts of this policy must be considered (Gouder and Parry 2008). The impacts of a carbon price on households are split into "use-side-impacts", meaning how a policy influences relative prices of goods and services, and "source-side-impacts", implying how a carbon price influences nominal wages or capital transfers. While "use-side-impacts" of a carbon tax can be seen as usually regressive (when tax revenues are not recycled), since costs are shifted to individuals as underlined prior, the "source-side-impacts" are progressive. Alterations in nominal wages or capital income through usage of tax revenue, for instance "lump-sum recycling of tax revenue" or tax cuts have progressive impacts. Since “source-side-impacts” outweighs “use-side-impacts” due to tax revenue recycling the overall impact of carbon taxes is progressive, thus beneficial (Stavins 2019).

Another advantage of carbon taxes is that they provide a continuous incentive to abate emissions and innovate from a private company perspective. Technology-based regulations which set a certain standard only incentivize economic agents to adjust behavior until the standard is met, while taxes incentivize to maximize abatement to not incur additional costs. As a result, taxes can facilitate innovation since it is in the agent’s best interest to minimize the costs of their operations. For instance, a carbon tax on fossil fuel incentivized auto-manufacturers to diversify car production towards ecological ways of transportation. Thus, more green innovation can diminish the social cost of policies addressing challenges regarding the climate change and the environment (OECD 2011a).

2.1.2. ETS

Emission Trading Systems are quantity-based mechanism to control pollution. Like the carbon tax, ETSs are part of incentive-based systems, but unlike the former instrument that focuses on price control, these instruments work through quantity control, which then indirectly has consequences for price. The distinguishing feature of emission trading systems is the transferability of permits (marketable permits) to pollute between the different individual sources. To talk more specifically about ETSs we need to differentiate them into two categories: cap-and-trade systems and baseline-and-credit systems (IEA 2020).

In cap-and-trade systems, an overall cap ("cap") on the number of emissions allowed in a given sector or area is initially chosen. Then a competent authority chooses the method of the initial allocation of permits, the sum of which must correspond to the chosen "cap". The authority can decide whether to sell the permits (auctioned permits) or to distribute them for free according to historic emissions (grandfathering approach) or even on an arbitrary basis (free initial allocation) (OECD 2013).

The concept of a baseline-and-credit system is similar, however, no cap is utilized. Instead, authority sets a standard for emissions (baseline) under a normal scenario and every firm must try to stay below this limit. If a company manages to pollute below the baseline it will earn credits. In both cases, with both permits and credits, companies that pollute less can sell the permits/credits to those that pollute more, creating an incentive to reduce emissions to the point where the abatement cost is equal to the gain from their sale (OECD 2013).

Benefits and Challenges

The cap-and-trade system bears multiple advantages. The idea of cap and trade is based on two specific points: companies will be encouraged to lower their emissions because there is a low cost to do so, while companies that have emission credits can sell them for extra profit. In addition, by having a predetermined maximum amount released, one can have a better idea of what is happening to the air quality and be able to work to reduce the maximum levels over time (Gaille 2015). The government often buys emission credits when they are available and then sells them at a higher price to businesses when they are needed. The income from these purchases helps to supplement the resources that taxpayers provide to the government (Gaille 2015). Finally, in the presence of cost uncertainty when the marginal benefit function exceeds that of the marginal cost function, then a quantity instrument is likely to be more efficient (smaller deadweight loss due to mistaken predictions of future costs). Karp and Traeger (2018) found that this is the case of pollution, and that quantity instruments are more efficient under cost uncertainty.

However, the system also has its limitations. The success of any cap-and-trade program depends on how it is designed, starting with the cap. For example, if the cap is set too high, companies can buy permits and set them aside for the future when the cap gets lower. Firms and agencies can buy credits or permits and choose not to use them, keep them indefinitely, and increase artificially the price. Such cost uncertainty (price volatility) in a cap-and-trade system can be an impediment to capital investment (Pindyck 2017) and could undermine political support for climate policy and discourage investment in new technologies, as well as research and development (Aldy and Stavins 2012). Another important factor is that for fossil-fuel intensive industries, the cost of converting to more renewable resources can be very high. Emission credits and penalties for exceeding a cap are frequently cheaper than a conversion to a new energy source. Consequently, there is no real incentive for these industries to change their practices (Kenton 2020). Finally, different nations may have different standards on what the cap should be. Some nations create more emissions than others. Some may be very lenient about emission limits and credits and others may be very strict, creating the possibility of carbon leakage (European Commission 2021).

In what concerns baseline-and-credit systems, they are still quantitative instruments but less binding than cap-and-trade since they allow the "cap" (baseline) to be exceeded at the cost of paying penalties. All the advantages and limitations mentioned above can also be applied to this instrument, except for some minor differences. While this makes it possible to decrease the problem of cap setting, it does not allow for precisely defining ex-ante the amount of emissions produced (Gaille 2015).

2.2. Implicit Carbon Pricing Instruments

Besides the explicit carbon pricing instruments there are also other instruments available to policy makers that price CO2 emissions not directly per ton of emissions produced but rather implicitly. Common implicit instruments are energy taxes, feed-in tariffs and subsidies. (D’Arcangelo et al. 2022). Taxes on energy like fuel and abatement subsidies classify as well as “market-based instruments” as they also introduce a market context. These implicit tools price not carbon emitted but rather the volume of resources used, or CO_2 emissions abated. Renewable energy support mechanisms on the other hand, are so called “technology support” instruments or “non-market-based”, utilized in practice to support the investment in new research and development, technologies, energy sources etc. (OECD 2013). Each of these instruments will be explained below.

2.2.1. Renewable Energy Support Mechanisms

Energy policies establish the objectives for a nation's future energy use. By fostering market stability and boosting investor confidence, they enable the realization of energy support. Thus, these policies have a significant impact on how energy technologies are developed in the future. Since renewable energy technologies (RET) are not as established as conventional fossil-fuel based power generation technologies, governments can make use of supportive policy instruments to boost RETs in their countries. The two main support mechanisms, which can be categorized as implicit carbon pricing, are feed-in tariffs (FiT) and renewable energy auctions (REA).

2.2.1.1. Feed-in Tariff

Feed-in tariff is an implicit carbon pricing tool for accelerating renewable energy technology investment by granting long-term contracts to renewable energy (RE) producers, with the exact provisions typically depending on the cost of generation of each technology. The policy usually guarantees RE generators specified payments per unit (e.g. Euro per kWh) over a set period of time and provides price certainty by setting that the energy produced will be bought by the supplier as a last resort (RE21 2022). The establishment of such schemes is viewed as critical for the promotion of RET development, as the installation of a RE system incurs several costs for both the owner and the grid utility, including capital and installation costs, operational and maintenance costs, and costs of interconnecting and maintaining the installation on the grid.

FiT systems are designed to aid RET's technological maturation, with the goal of reaching grid parity over a short period of time (Haas et al. 2008).

In 2021 92 countries worldwide applied the FiT scheme (REN21 2022). Each country's government appears to determine the FiT rate based on the capital, operational, and investment costs of the specific RE source (Campoccia et al. 2014), the regular cost of RE generation, plus a fixed price or auction-based price incentive usually set by legislators (Couture et al. 2010).

Feed-in tariffs are market-based instruments incentivizing the use of RET and the change of behavior within energy markets. They aim at improving energy efficiency and reducing the demand for traditional energy sources. Other broader market-based instruments include those that span energy markets, like cap-and-trade systems and carbon taxes, and are usually applied to the carbon content of energy. While those tools certainly have a place in addressing energy efficiency, they are often better at raising revenues rather than changing behavior, since energy price elasticities tend to be low (Eyre 2013). FiT limits the application of the price mechanism to the change in demand rather than the total demand. As a result, the amount of money raised for any given change in demand is significantly less, and the efficiency change to revenue transfer ratio is larger. Consequently, the political risks associated with raising large revenues on energy use are minimized (Eyre 2013).

Benefits and Challenges

The strengths of the FiT system are manifold. Firstly, a feed-in tariff offers a lot of design flexibility. Each government can set eligibility, contract duration, purchasing obligation, and capacity individually. Furthermore, the tariff level can be set based on national market conditions, with the option of promoting certain renewable energy technologies, innovations, or regional renewable energy development. Secondly, FiT increases investor confidence by providing long-term investment stability and helps manufacturers to broaden their time horizons when planning their operations, thereby promoting investments in renewable energy industries (UNESCAP 2012). Thirdly, FiT schemes are the most efficient policy for encouraging RE sources, since their mechanism's simplicity, stability, and fairness result in low administration and transaction costs, making it the most efficient policy for encouraging renewable energy sources (IPCC 2011). Finally, FiT methods that are properly implemented help society as a whole by creating jobs and lowering carbon emissions and their negative consequences. In the long run, FiTs can be viewed as a major engine of local and national economic growth and, in particular, green industry innovation.

Feed-in tariffs, however, also bear some challenges (UNESCAP 2012). To start with, finding the right tariff level is challenging: it must be established at a level that allows businesses that choose RE to compete with traditional fossil-fuel-based energy providers. Finding this level requires adaptability and a thorough understanding of the energy market's mechanics. Furthermore, capacity and cost management can prove problematic and policy makers must ensure that public resources are well handled and that they are not diverted from other, more critical development priorities. Lastly, grid access poses another key challenge. The FiT requires all renewable energy producers, including residential, commercial, and industrial customers, federal, state, and local government agencies, and non-profit organizations, to have assured, non-discriminatory grid access. This poses a problem for energy infrastructure, which may be required to connect frequently far renewable energy sources to a well-established grid that is typically concentrated in a city. The grid access guarantee may reduce the motivation for renewable energy installations to be located in the most cost-effective places (UNESCAP 2012).

2.2.1.2. Renewable Energy Auctions

Another instrument to support renewable energy technologies are renewable energy auctions (REA). In recent years, REA have become a popular policy tool, particularly in developing economies (Lucas, Ferroukhi and Hawila 2013). Several countries even have transitioned from

FiTs to auction-based systems (Kruse et al. 2022). When a country follows a REA system, "(…) the government issues a call for tenders to install a certain capacity of renewable energy-based electricity" (p. 6, Lucas et al. 2013). Project developers submit a bid with an estimated cost per unit of power at which they are willing to take up the project. The winning bidder is given a power purchasing agreement after the government assesses the bids based on price and other factors. When well-constructed, the auction scheme's built-in price competition boosts cost effectiveness and enables price discovery for electricity derived from renewable sources, preventing potential windfall gains and underpayments. While REA have attractive attributes, they only reward the winning bids and frequently favor big companies that can pay the transaction and administrative costs (Lucas et al. 2013).

The two main auction models are sealed bid auctions and iterative process auction. In the former, each bidder submits their proposal, which includes the price and estimated power output, whereby the bidders cannot view one another's proposals. In an iterative process, also known as descending clock auction, the government announces a price for a RE production project. The bidders then state how much power generation they are willing to provide for this price. The auctioneer then gradually lowers the price, which causes the bidders to lower their offered generation quantities. This cycle is repeated until the amount of new renewable energy the government wants to invest in meets the quantity generation proposed. A third auction type is a hybrid version of the two (Lucas et al. 2013).

Similarly to feed-in tariffs, REA incentivize the use of renewable energy sources. Ideally, renewable energy auctions lead to cost-efficiency, in other words, to low awarded prices. This is the case, when there is high and fair competition in the auction, speculative over/ underbidding is mitigated and the bidder risk is low (Anatolitis, Azanbayev and Fleck 2022).

Benefits and challenges

The main benefit of REAs is that they offer guaranteed purchases at fixed prices as well as guaranteed access to the grid. Moreover, when well-designed, the auction scheme's built-in price competition enhances cost effectiveness and enables price discovery for power derived from renewable sources, preventing potential windfall gains and underpayments. Inherent long-term guarantees can result in better financing options and lower prices (Lucas et al. 2013). Finally, if there is high competition in renewable energy auctions, it leads to cost efficiency and the revelation of the de facto market price of different RE technologies (Laumanns 2014). There are also certain challenges which should be kept in mind when planning the implementation of renewable energy auctions. To start with, if auctions are not regularly scheduled, they may cause discontinuations in the development of the market. Secondly, small and medium enterprises might be discouraged from participation in the auctions given the high transaction costs caused by investments in project planning, feasibility studies and risk assessment, and the associated risk of not getting returns on the money spent if they are not succeeding in the auction (Lucas et al. 2013). Thirdly, REA imply high administrative costs, potentially deterring countries from implementing this policy (Laumanns 2014).

2.2.2. Subsidies and low-carbon R&D expenditures

Subsidies are another carbon pricing tool that can be utilized to either (in)directly reduce the use of something that has a proven negative impact on the environment or to provide a relief of opportunity cost an agent is facing (Goulder and Parry 2008; Dasgupta 2021). In the context of pollution abatement, it often describes financial payments or transfers from the government targeted to reduce damaging emissions, which would classify the instrument as an explicit, market-based carbon pricing instrument. Governments for instance reward emission producers with a lump-sum transfer for every unit of emissions that they reduce below a baseline to support a certain industry, business or individual with the overarching goal of promoting an activity that the government considers beneficial not only to the economy but also to society at large (Dasgupta 2021). As every additional unit of emission produced implies a cost to the firm (in foregone subsidy opportunities) the incentives provided by subsidies can be compared to those from emission taxes (Goulder and Parry 2008).

Furthermore, subsidies can also be leveraged to incentivize the use of low-carbon technologies by governments financially supporting the research and development of renewable energy sources, energy efficiency, carbon capture and storage nuclear as well as other cross-cutting technologies and research (Kruse et al. 2022). These public expenditures on R&D are usually designed to compensate for market failures that would under normal circumstances generate insufficient investments from the private sector (C2ES 2008). Lastly subsidies can also be given to individuals (e.g. by tax relieves) to promote behavior that is beneficial for society and the environment. Financial incentives to install solar panels or buy electric vehicles are examples for such subsidies that are designed to support individuals to comply with environmental standards (Steurer 2015). These last two subsidy-instruments mentioned classify as implicit and non-market-based instruments, which the following analysis will focus on.

Benefits and Challenges

Abatement subsidies have been applied and used widely across most OECD countries in the last decades, mostly in the form of grants, tax allowances or investments that are expected to lead to environmental improvements (Perman et al. 2003). One main benefit of the tool, which in-part can explain its attractiveness and acceptance (especially across firms) is that marginal reduction costs across heterogenous firms are equalized and the form and level of reducing is up to the respective firm (Goulder and Parry 2008). However, when evaluating its cost-effectiveness, the instrument performs weaker than taxes or tradable allowances in terms of pollution abatement. As described above, subsidies and R&D support are lowering production costs which often leads to increased output. As a result, to accomplish the same target emissions reductions as under the other two policies mentioned, regulators would need to set the marginal price of emissions (the subsidy rate) higher than under the other policies, leading to too much abatement from input substitution and too little from reduced output. Poorly designed subsidies might therefore end up increasing the cost of decarbonization and result in ineffective governmental transfers (Goulder and Parry 2008). Additionally, in many countries, initiatives of the public finance directed towards emission abatement subsidies end up fostering activities that are more harmful then beneficial to ecosystems and biodiversity, through increases of production and eventually pollution. Such harmful subsidies include for instance financial support for sectors such as fossil fuels, agriculture or fisheries. Recent OECD data suggests that annually around US$500 billion per year are spent across governments on subsidies which essentially harm biodiversity and our environment (OECD 2020). Lastly, when considering also subsidies offered to individuals in forms of tax relieves, regressivity also poses a problem as the desired economic behavior that is artificially supported is mostly undertaken by those who can afford to. This is for instance the case with solar panels or electric vehicles (D'Arcangelo et al. 2022).

2.2.3. Energy Tax

Energy taxes are pricing instruments which include, among others, fuel excise taxes, electricity consumption taxes (OECD 2019) and taxes on air travel (Goulder and Parry 2008). Energy taxes are imposed on energy products for transport purposes, energy products for stationary purposes (natural gas, oil) and greenhouse gases (i.e. carbon content of fuels). A well-designed energy tax represents the most direct way to correct externality (the cost of the harm to others) provoked by specific activities or products. It directly addresses the market failure by internalizing environmental costs into the market prices. Energy taxes are a relevant source of revenue in many countries. For countries that are oil and gas producers, they can be the dominant source of government revenue. Increasing reliance on energy-related and petroleum products for taxation explains why non-oil-producing governments can be strongly affected by fluctuations in the international price of raw oil and oil products (Bacon 2004). Energy taxation revenue usually goes into the government general budget, with all other tax revenues and it is not earmarked for specific use. Nonetheless, in some countries, taxes on transportation fuels are directly associated to government expenditure for road maintenance and construction, to ensure that those who use the road system correspond to those who carry the burden of most of the costs linked to it. Different sources of energy are subject to distinct forms of taxation. Tax revenues from activities of oil and gas extraction can be highly important, especially for countries based on oil and gas production. For coal, rents are much smaller in most cases and the tax receipts from royalties are not dominant in the economy. Indeed, most of the world's large coal producers are also large economies: the relative size of the coal sector is less dominant than the oil sector in the small economies where oil is produced (Bacon 2004).

Benefits and Challenges

As established above, energy taxes can take different forms: from retail gasoline excises to wellspring royalties on crude oil. These types of taxes are broadly used as environmental policy tools in several countries. Energy taxes not only allow to address market failure, but they also represent a very effective way for governments to raise substantial revenues. Furthermore, energy taxes can be implemented to discourage certain activities and behaviors deemed socially harmful. Additionally, energy tax leave consumers and firms free to decide how to change their behavior to limit and stop socially harmful activity. For instance, countries imposing taxes on motor fuels increase the costs of driving diesel vehicles, without specifying how to reduce emissions or indicating more sustainable alternatives. In this way, while not directly identifying clean generating technologies to shift to, governments encourage citizens to evaluate a wide range of options to reduce their impact on environment. Compared to other environmental policy instruments like subsidies, energy taxes, although indirectly, provide a greater range of abatement options and greater flexibility of response (Braathen and Greene 2011). Despite presenting consistent advantages, energy taxation also bears some challenges such as unintended consequences such as businesses and residents leaving the taxed jurisdiction or adopting energy sources to circumvent the tax without reducing emissions. Energy taxes also raise questions about their distributional impact and equity. For example, imposing taxes on fossil-based energy for transportation or heating can have a severe negative impact on lower income households. However, distributional issues arising from energy taxes could be counteracted through other distributive policy measures such as a decrease in the personal income tax rate. Also, concerns in terms of competitiveness between countries imposing different energy taxes need to be closely assessed. International coordination on environmental policy is required to reduce advantages arising from relocation of taxpayers (Shahzad 2020).

2.3. Policy Mix Literature

The following literature review has the objective of giving an overview of the existing academic research on the effect of singular policies and policy packages on emission abatement and of defining this report's contribution to the body of literature.

It is well recognized that evaluating the effectiveness of carbon pricing in reducing CO2 emissions is a difficult undertaking (Sumner et al. 2011; Meckling et al. 2017). This is partially because coverage and intensity of carbon pricing policies vary among jurisdictions. Additionally, it is challenging to adequately distinguish the effects of carbon pricing from those of command-and-control climate and energy policy tools, such as regulations for the energy sector (Somanathan et al. 2014; Narassimhan et al. 2018). The emission reductions from climate change mitigation programs can be estimated using a variety of methods. Depending on whether the methodology is country-specific or used across countries and the policy scope it covers, the different options produce varying types of outcomes.

The different technological methods used to calculate the emission reductions caused by carbon pricing policies can be divided into two main categories: 1) the ex-post regression method, and 2) the ex-ante analytical method. In the first, emission reductions are attributed to already implemented policies using statistical and economic techniques. After establishing a baseline, the predicted linkages between policies and emissions can be utilized in simulations to calculate the emission reductions of policies over the long term. The second approach, which is based on economic theory (i.e., modeling the behavior of enterprises, individuals, and governments) and knowledge of countries' economic structures, can offer forward-looking insights on the effects of policies before they are enacted. Each of the two approaches can be applied either taking a country-specific or a homogeneous cross-country perspective and may be focused on the effect of singular policy instruments or policy packages.

The country-specific approach evaluates the emission reductions for a separate nation, often applying a methodology unique to a country, depending on data availability and the availability of country specific models. In the North American setting, Murray and Maniloff (2015) assessed the impact of the Regional Greenhouse Gas Initiative (RGGI) in the northeast of the US through the development of a statistical method of CO2 emissions in the US, finding that the RGGI decreased power sector emissions by 24 percent between 2009-2012. Schmalensee and Stavins (2017) find a less significant impact of the RGGI policy framework using a different econometric approach. In a Norway-specific ex-post study Bruvoll and Larsen (2004) decompose the observed emission changes between 1990 to 1999 and apply a general equilibrium simulation to discern the effect of different carbon pricing policies.

Focusing on the effectiveness of specific pricing instruments, numerous studies used an ex-post approach to examine the effect of the fuel tax (see for example Datta, 2010 for India, Li et al., 2014 for the US and Yan and Crookes, 2009 for China) and found significant effects in reducing emissions in both developed and developing nations. Another branch of studies focuses on the impact of established carbon taxes on emissions in various country, such as a work by Lin and Li (2011) who found a significant negative impact of carbon tax on per capita CO2 emissions using an ex-post difference-in-difference approach. Another case in point is a report by Dussaux (2020) which uses precise firm-level data specific to France to assess the effects of the French carbon tax using the ex-post regression approach.

Country-specific ex-ante studies are frequently commissioned by governmental entities. In the Netherlands, Daniëls and Koelemeijer (2016) from the Dutch Environmental Assessment Center estimate national emission reductions using a model that employs a combination of quantitatively estimated elasticities and sector-specific expert judgement. Another example is South Africa, which biennially creates a report, using a country-specific ex-ante analytical model covering all sectors, to estimate emission reduction related to the national policy mix (DFFE 2021). In the academic literature several authors take a similar approach. For example, Dissanayake et al. (2020) evaluate the future impact of introducing different possible pricing instruments, including carbon tax, fuel tax and ETS for Indonesia. Calderón et al. (2016) conducted a similar ex-ante analysis in the Colombian context, as well as Alton et al. (2014) for South Africa.

The homogenous country-approach can also be implemented by either evaluating through an ex-post regression or ex-ante analytical method. Both allow for the consistent estimation of emission reduction of single instruments or a set of policies across countries. Research by Galeotti, Salini, and Verdolini (2020) is an illustration of the ex-post regression and homogeneous country approach. The economists use cross-country regressions to evaluate and compare the effects of several environmental policy stringency (the degree to which policies put a price on environmentally harmful behavior) indicators on energy efficiency. Similarly, Brunel and Levinson (2013) proposed a stringency approach. While taking into account the sectoral structures of different OECD countries, the researchers proposed a method to ascribe reductions in emission intensities to different mitigation policies. Haites (2018) analysed the emission development under 10 carbon tax and ETS regimes across 12 jurisdictions from 1991 to 2015, finding mixed results about the effectiveness of the two instruments. Narassimhan et al. (2017) analysed carbon pricing policies across 15 regions around the globe, highlighting the potential of even modest carbon prices for emission reductions, particularly those with high policy stringency. Best and Burke (2020) analyse the impact of carbon pricing for reducing emissions across 142 countries, using different ex-post econometric modelling methods while controlling for structural factors and other impactful policies relevant for CO2 emissions.

OECD's work is an illustration of the ex-ante homogenous cross-country approach. It uses a standardized set of assumptions to analyze emission reductions of changes in climate policies across macroeconomic sectors and geographies in a Computable General Equilibrium model (Chateau, Dellink and Lanzi 2014). On an EU member state level, van Sluisveld et al. (2017) analyse and contrast the ex-ante emission reduction strategies of five member countries towards the 2050 goal of reducing emission levels by 80%-95% compared to 1990 levels.

As it becomes clear throughout the review, most studies assessing emission reductions focus on the effect of singular carbon pricing policy instruments with academic attention clearly lacking on the performance and interaction of policy mixes. Moreover, while the literature on the impact of explicit carbon pricing policies (i.e. carbon tax and ETS) is relatively advanced, implicit instruments are rarely considered. While there is extensive literature on the impact of implicit instruments such as FiT or subsidies on innovation and renewable energy adoption (see for example Baldwin et al., 2017, Carley et al. 2017) research assessing their impact on emission reductions could not be found. Against this backdrop, this paper contributes to the existing literature in three main ways. Firstly, our findings add to previous cross-country studies assessing the performance of different policy mixes, which have been scarce until this date. Secondly, by considering both implicit and explicit policy instruments, this research contributes a more inclusive approach to estimating the effect of carbon pricing on emissions. Thirdly, to our knowledge the present work will represent the first research looking at the relationship between the policy stringency of the national policy mix and emission reductions.

3. Research Approach

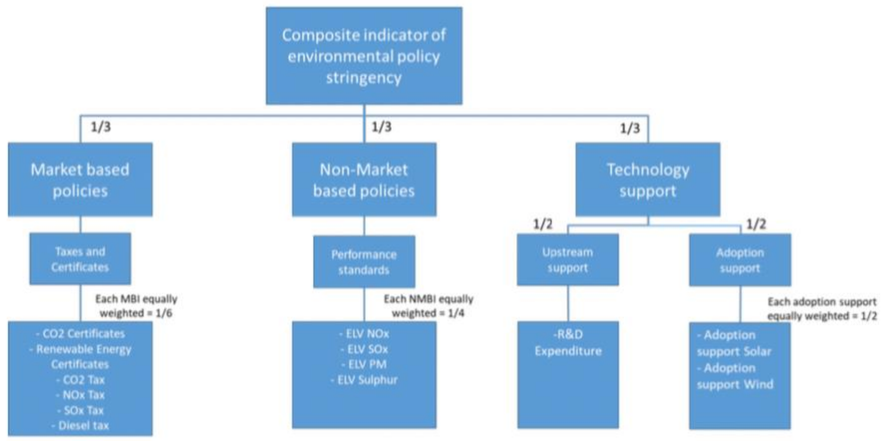
The purpose of this analysis is to determine whether there is an environmental policy mix that performs better in the abatement of emissions. To illustrate the combination of economic instruments countries used throughout time, we introduce the OECD Environmental Policy Stringency Index (EPS). Thus, the "*policy mix*" is defined as the stringency of those different instruments based on that indicator (See chapter 3.1 for more details). This research takes into account EPS data from 1990 – 2020 in 40 countries and the yearly changes of the instrument's stringencies. In order to evaluate the effect of a policy mix, we use data on the countries' emission intensity, which depicts the amount of emissions per unit of GDP. The objective of the analysis is to cluster countries with a similar policy mix and emission intensity to highlight if a certain combination of instruments delivers a better outcome. Our research approach is based on two components: the initial bivariate regression and the cluster analysis which are explained in the following chapters. However, important to note is that the methodology of this paper only allows for establishing correlations, rather than causational relationships.

3.1. EPS Index

The Environmental Policy Stringency Index (EPS) is a country-specific measure for the stringency of environmental policy (Botta and Kozluk 2014). After first being introduced in 2014 by Botta and Kozluk, the EPS has been updated to cover 40 countries with data ranging from 1990 to 2020 (Kruse et al. 2022).

The EPS21 includes 13 policy instruments, and it primarily focuses on air pollution and climate change policies (Kruse et al. 2022). In particular, it comprises three equally weighted sub-indices, grouping market-based (taxes, permits and certificates), non-market-based (performance standards) and technology support policies, respectively. The latter are subdivided into upstream (R&D support) and downstream support measures, (feed-in-tariffs and auctions), as represented in Figure 2 (Kruse et al. 2022).

Figure 2. The 2021 Environmental policy stringency index (EPS21)



Note: The figure shows the aggregation structure of the revised EPS index (referred to as "EPS21").
Source: OECD.

For the purpose of the construction of the EPS (2014) and the updated version EPS21, policy stringency is described as "a higher, explicit or implicit, cost of polluting or environmentally harmful behavior" (Botta and Kozluk 2014 pp.14). For instruments like taxes, this definition implies that higher prices per unit of pollutant correspond to higher levels of policy stringency. In the case of implicit tools, like feed in tariffs or subsidies to R&D, a higher level of stringency is given by higher subsidies. However, the stringency of the different environmental policy is expressed in a variety of units. For instance, carbon price is measured in US$ per tonne of CO2 emissions and emission threshold for NOx is measured in milligrams of pollutants per cubic meter (Kruse et al. 2022). In order to successfully provide a comprehensive aggregation of the diverse policy types into an index of policy stringency, a common scale is required.

The index is built by selecting policies for the countries under analysis and scoring their stringency on a scale from 0 to 6, where 0 represents minimum stringency (not stringent) and 6 represents the maximum level of stringency (Botta and Kozluk 2014; Kruse et al. 2022). For every policy instrument considered in the analysis, the raw data is organized from the least to the most stringent observations recorded in the 1990-2020 period (Kruse et al. 2022). The minimum score of stringency is allocated to observations with no policy in place, while the highest score of 6 is assigned to the observations surpassing the 90^{th} percentile of observations that have the policy in place. The attribution criteria for the intermediate scores (1 to 5) are obtained by dividing the difference between the 90^{th} and the 10^{th} percentiles into five parts which define the thresholds (Kruse et al. 2022).

The OECD Environmental Policy Stringency Indicator (EPS), introduced by Botta and Koźluk (2014) and updated by Kruse et al. (2022), offered a valuable contribution to this literature, by allowing for the first time the assessment of an extensive set of policies, across several countries and a wide time period. Several empirical studies extensively employ the Environmental Policy Stringency indicator to evaluate impacts of stricter environmental policies on environmental and economic outcomes and to provide related cross-country comparisons (OECD 2021; Dechezleprêtre et al. 2019). For instance, empirical analyses using EPS have shown that environmental policies have generally small impact on economic outcomes like trade, productivity, or employment, but they produce winners and losers among firms, industries, and regions. When looking at the effects of environmental policies, least productive firms from polluting sectors are negatively affected, while more productive firms and low-polluting sectors are positively affected by more stringent environmental policies (Albrizio, Koźluk and Zipperer 2017; Garsous Koźluk and Dlugosch 2020).

For the sake of this analysis, 6 out of the 13 EPS policy instruments have been selected and assessed. In particular, we will examine implicit and explicit carbon pricing tools, including CO2 tax, fuel taxes, and ETS system as market-based policies and feed-in-tariff system, auctions and R&D government expenditure, as technology support policies.

3.2. Bivariate regression

The underlying hypothesis of our analysis is that an environmental policy mix, based on the EPS index, can explain the variation in the emission intensity of a country. In order to evaluate whether this assumption holds, we run a bivariate regression with the 40 countries in the EPS index between 1990-2019 and the corresponding intensity of emissions. Assuming that this hypothesis can be answered in the affirmative, this would imply that a better policy mix with higher overall value of policy stringency, leads to better emission abatement, thus lower intensity of emissions. Consequently, this finding functions as a basis for the cluster analysis which takes into account both variables described prior.

The main rationale for choosing emission intensity per capita over other indicators for GHG pollution is the fact that it is possible to control for variables such as population, economic performance, inflation, and purchasing power within the regression. As a result, the robustness and validity of the regression are increased. The values for emission intensity are based on World Bank data and are obtained in *kg of CO2 emitted over the GDP per capita in $* (with fixed prices for the year 2017).

3.3. Cluster Analysis

After establishing the validity of using the EPS data set for analyzing emission performances across countries through the bivariate regression, a cluster analysis will be conducted. The aim of this analysis is to determine whether there is an ideal policy mix in terms of its impact on emission reduction. Through the cluster analysis, we intend to group the country set based on their policy package of explicit and implicit carbon pricing and relate it to the associated reductions of emission intensity of said group. For this purpose, only carbon pricing instruments were included in the cluster grouping (carbon tax, ETS, Diesel tax, government expenditure on R&D, FiT, REA) while excluding other complementary policies from the EPS data set. The choices for the most suitable method of cluster analysis, the type of linkage and the stopping rules were made based on a profound literature review. A hierarchical method for clustering was chosen, since research by Kettering (2006) on the prevalence of different clustering methods showed that hierarchical approaches are most frequently used among researchers. Hierarchical clustering is an algorithm which divides observations into clusters based on their similarity. In a hierarchical clustering process, each observation is first treated as a distinct cluster. Then, it repeatedly completes two actions: First, determine the two clusters that are most similar to one another, and then combine those two clusters. This iterative procedure is continued until all clusters are combined. There are different methods of hierarchical cluster analysis. Following the literature about the best hierarchical methods for cluster analysis (Mojena 1977; Milligan 1980), this work used Ward's linkage method. Hereby, the linkage function determining the distance between two clusters is computed as the increase in the "error sum of squares" (ESS) after combining two clusters into a single cluster. Ward´s method chooses the successive clustering steps in minimizing the increase in ESS at each step. To determine the number of groups the Duda-Hart stopping rule was applied (Milligan and Cooper 1985), finding that the optimal number of clusters is 10.

4. Analysis

As outlined in the research approach, the analysis to answer the research question is divided into two parts. First, we run a bivariate regression and secondly, we employ a cluster analysis to understand if an ideal environmental policy mix exists that leads to lower emission intensities. Before drawing conclusions and lessons learned from our evaluation, we present the results from our analysis and highlight several limitations inherent in the employed methodology.

4.1. Bivariate Linear Regression

To establish whether the EPS index can explain the variation in a country's emission intensity and thus function as a basis for the cluster analysis, we run a bivariate linear regression. Two data sets lay the foundation for this analysis with OECD data for EPS and World Bank figures for emission intensity. The following table depicts an overview of the variables:

Table 1. Overview over the variables in the regression

Variable	Explanation	Source
OECD Environmental Policy Stringency index (EPS)	Yearly environmental policy stringency for 13 different instruments for countries between 1990-2019.	OECD Economics Department data set. Available at request.
CO2 emissions (kg per 2017 PPP $ of GDP)	Emission intensity for 40 selected countries based on the EPS index per capita with data available between	World Bank (2022): Available online at World Bank data.

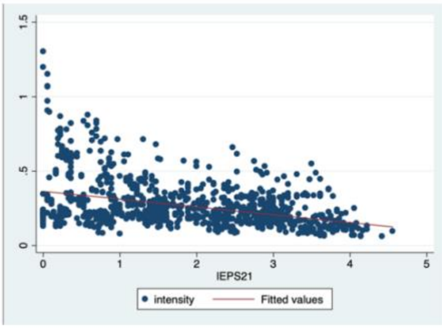
We regress the EPS of each 40 countries for every year between 1990 - 2018 with the emission intensity of each corresponding country between the years 1991 - 2019. In other words, this regression employs an artificial lag of one year between both variables. The key assumption is that implemented policies do not lead to an immediate effect which would be observable in the emission intensity of a country. We assume that emissions in a certain year are affected by policies implemented in previous years. Correspondingly, we take this into account by evaluating the effect of a policy at *year t* on the emission intensity in *year t+1*. Moreover, the null-hypothesis and alternative hypothesis are defined as following:

H_0: Variation in a country's emission intensity is not explained by the EPS index

H_1: Policy stringency based on EPS Index explains variation in a countries emission intensity

Figure 3. Results from the initial regression

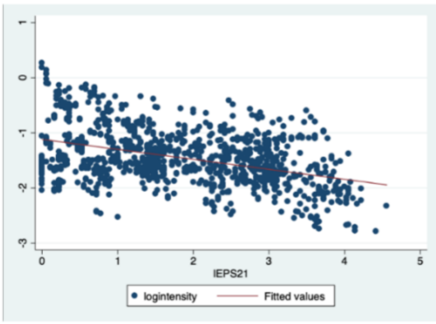
```
. reg intensity lEPS21

      Source |       SS           df       MS      Number of obs   =     1,072
-------------+----------------------------------   F(1, 1070)      =    183.84
       Model |  3.97754153         1  3.97754153   Prob > F        =    0.0000
    Residual |  23.1501336     1,070  .021635639   R-squared       =    0.1466
-------------+----------------------------------   Adj R-squared   =    0.1458
       Total |  27.1276751     1,071  .025329295   Root MSE        =    .14709

------------------------------------------------------------------------------
   intensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lEPS21 |  -.0525859   .0038783   -13.56   0.000    -.0601959   -.0449759
       _cons |   .3642789   .0082622    44.09   0.000     .3480671    .3804908
------------------------------------------------------------------------------
```



The results from the regression indicate that hypothesis H_1 can be accepted, thus the null-hypothesis is rejected. As one can derive from the figures, the correlation between the two variables depicts a negative slope (see negative coefficient). This implies that with a higher policy stringency, the emission intensity of a country decreases. Our results are statistically significant with a p-value of 0,000. In pursuance of improving the fit of the model further, we use a logarithm for the variable emission intensity as well as run a robust regression to increase the validity of our analysis. Statistical significance remains the same yet with a higher coefficient of determination R^2 of 17,38 %.

Figure 4. Results from the robust logarithm regression

```
. reg logintensity lEPS21

      Source |       SS           df       MS      Number of obs   =     1,072
-------------+----------------------------------   F(1, 1070)      =    225.09
       Model |  47.1083356         1  47.1083356   Prob > F        =    0.0000
    Residual |   223.93841     1,070  .209288234   R-squared       =    0.1738
-------------+----------------------------------   Adj R-squared   =    0.1730
       Total |  271.046746     1,071  .253078194   Root MSE        =    .45748

------------------------------------------------------------------------------
logintensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lEPS21 |  -.1809718   .0120624   -15.00   0.000    -.2046405   -.1573031
       _cons |  -1.119524   .0256969   -43.57   0.000    -1.169946   -1.069102
------------------------------------------------------------------------------
```



Moreover, we test our linear model for heteroskedasticity. We employ the Breusch-Pagan and Cook-Weisberg test to evaluate the robustness of the analysis. Since the p-value of the Chi-Square test is smaller than 0.05, thus showing the presence of heteroskedasticity, we run a robust regression to provide a more accurate measure of the true standard error of the regression coefficient.

Figure 5. Robustness check for heteroskedasticity

```
. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of logintensity

         chi2(1)      =    24.02
         Prob > chi2  =   0.0000
```

Nonetheless, our model based on an OLS regression is not taking into consideration time-invariant characteristics of each country that can affect the emission intensity over years. Thus, in order to improve the robustness of our model, we run a fixed-effect and random-effect model. We use the Hausman test to understand which type is more appropriate. According to this test, we find out that the random-effect model works better, thus run a new regression based on this finding (See Appendix 1 for more detailed results).

Figure 6. Results from the random-effect model

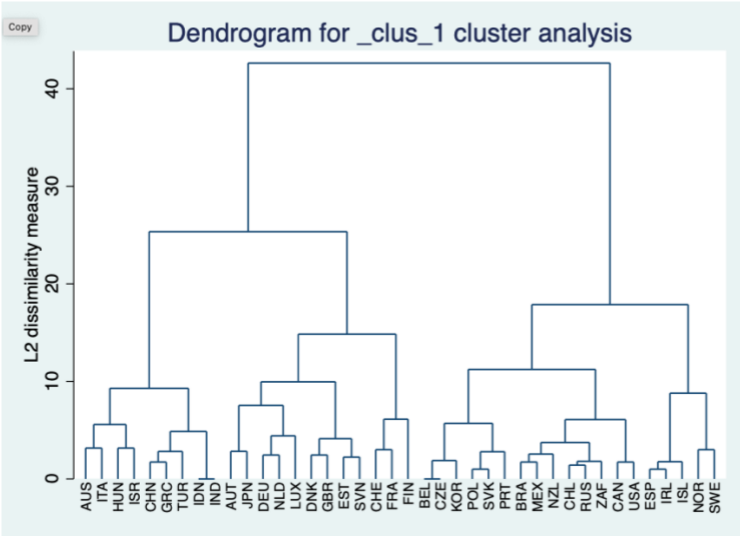
```
. xtreg logintensity lEPS21, re

Random-effects GLS regression                   Number of obs     =      1,072
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.6559                                         min =         22
     between = 0.0448                                         avg =       28.2
     overall = 0.1738                                         max =         29

                                                Wald chi2(1)      =    1969.89
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------
logintensity |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lEPS21 |  -.2107821   .0047491   -44.38   0.000    -.2200902    -.201474
       _cons |  -1.062559   .0733792   -14.48   0.000     -1.20638   -.9187387
-------------+----------------------------------------------------------------
     sigma_u |  .44862465
     sigma_e |  .13663717
         rho |  .91511211   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. estimates store random
```

Our model and robustness checks suggest that the EPS index is a valid indicator to explain certain variation in emission intensities. As a result, we can use this index in our cluster analysis to group countries with a similar environmental policy mix and corresponding emissions to evaluate an ideal combination of policies.

4.2. Cluster Analysis

As previously indicated in Chapter 3.3, to determine whether there is a country with an ideal policy mix in our sample, based on emission intensity, a cluster analysis was conducted. Through Ward's linkage method, countries were clustered based on the 2018 EPS, composed of carbon-pricing instruments only.

Figure 7. Dendrogram of the cluster analysis



In order to find the optimal number of clusters, the Duda-Hart stopping rule was applied to understand the exact number of clusters needed (Milligan and Cooper 1985).

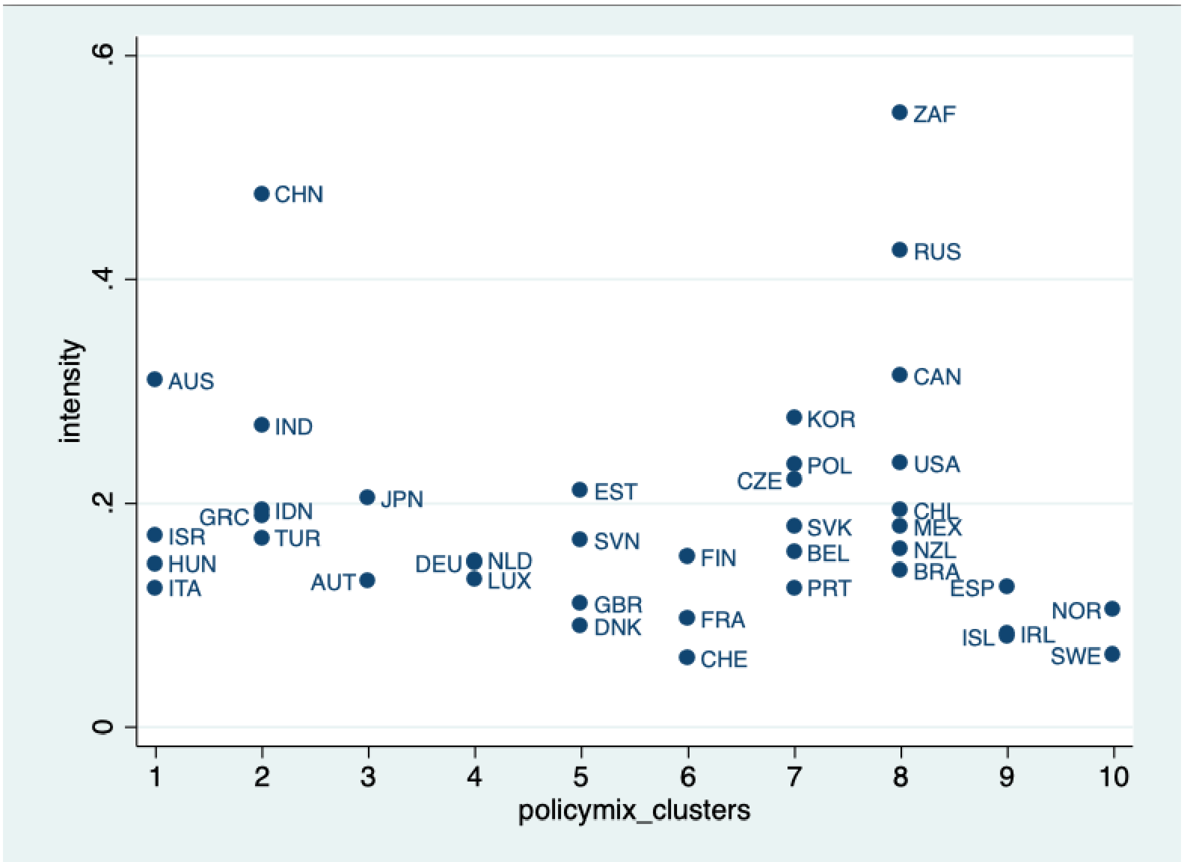
Figure 8. Results from Duda-Hart test

Number of clusters	Duda/Hart Je(2)/Je(1)	pseudo T-squared
1	0.7116	15.40
2	0.6439	10.51
3	0.5913	11.75
4	0.6181	6.18
5	0.5982	8.06
6	0.6082	4.51
7	0.5730	5.22
8	0.1958	12.32
9	0.4167	4.20
10	0.1985	4.04
11	0.5182	5.58
12	0.3556	7.25
13	0.4000	3.00
14	0.4040	4.42
15	0.2368	3.22

As can be seen, the ideal number of clusters would be 13 (number of clusters with the lowest pseudo-T-squared), but this would result in several clusters with only one individual observation (country) in them, making the analysis non-significant. The opposite problem of having different individuals in the same cluster would occur by taking too few clusters. In order to solve this problem, only numbers of clusters between 6 and 10 were considered. Within this range, the result with a lower pseudo T squared (optimal number of clusters) is

10. The result of the cluster analysis is shown through a scatter plot (Figure 1.x), which shows the 10 different groups with within them the different countries indicated by their ISO, sorted from top to bottom in descending order by emission intensity.

Figure 9. Result from the cluster analysis (scatter plot)



To show the characteristics related to each group's policy mix, the average across countries within each cluster of each instrument's EPS score was taken. The Energy Support and Wind Support instruments were grouped into one category through an arithmetic average of the two. Table 1.x shows the different groups sorted from first to last in ascending order by emission intensity. All values considered to be of low or no stringency (0-1.9) are highlighted in red, those of medium stringency (2-3.9) in yellow, and those of high or maximum stringency (4-6) in green. It is clear from the table that overall low scores of stringency lead to higher emission intensities. Moreover, it can be observed that usually a high to medium stringency in market-based instruments, most notably the CO2 tax, results in lower emission intensity.

Table 2. Policy Mix Table

Group	Countries	ETS	CO2 Tax	Diesel Tax	Low-Carbon R&D	Wind&Energy Support
10	Norway, Sweden	2	6	4	4,5	0
9	Spain, Irland, Island	2	3,33	3,33	0,67	0
6	Finland, Switzerland, France	1,67	6	4,67	5,33	4,17
4	Germany, Luxembourg, Netherlands	2	0	3,67	3,67	4,83
5	Estonia, Slovenia, United Kingdom, Denmark	2,25	2,5	4	2,25	2,38
3	Japan, Austria	1,5	0,5	3,5	4	2,75
1	Australia, Israel, Italy, Hungary	1	0	4	1	2,75
7	Korea, Polonia, Czech Republic, Slovak Republic, Belgium, Portugal	2,17	0,33	3,5	2	0,33
2	China, India, Indonesia, Greece, Turkey	0,6	0	2,2	0,4	3,8
8	Brazil, Canada, Chile, Mexico, New Zeland, Russia, South Africa, United States	0,5	0,25	1,25	1,38	0,13

4.3. Ideal Policy Mix

Based on the results of our cluster analysis, Norway and Sweden have among the lowest figures for emission intensity in 2018, demonstrating high effectiveness of their decarbonization policy mix. This result is consolidated by the Climate Change Performance Index, which ranks these two countries among best performing ones (Burk et al. 2021). Consequently, we evaluate their policy mix more closely to understand what the ideal combination of instruments can look like according to our estimations. These successful achievements are in part derived from ambitious governments' decisions to introduce carbon neutrality about a decade earlier than other developed countries (DG Trésor 2021).

Norway and Sweden are global leaders in decarbonization (IEA 2021). Nordic countries have been experiencing climate change effects first-hand, due to the polar amplification effect, recording an increase of 10°C in the average annual temperature, since pre-industrial period (DG Trésor 2021). Therefore, they have been early pioneers in the elaboration of innovative decarbonization strategies, being among the first countries to introduce carbon tax during

1990's and targeted support measures to low-income households and industry (DG Trésor 2021).

In 2019, carbon emission intensity for Sweden was 108g CO2 per euro of GDP, more than 60% below the EU average (European Parliament 2021), while Norway CO2 Emissions intensity was 11.9440 tonnes of CO2-equivalents/ output in NOK million (Statistics Norway 2021). The policies and economic tools implemented in these countries include record high carbon tax (DG Trésor 2021). However, despite being crucial to the impressive achievements of Sweden and Norway, carbon tax is not the only policy instrument in place. Accompanying support measures like targeted subsidies and income tax deductions for low-income households have been central to ensure a sustainable and just green transition (DG Trésor 2021). Moreover, renewable energy has a significant role in the climate change mitigation strategy of these countries.

Sweden

In Sweden carbon tax was introduced in 1991 at a rate of 250 SEK (25 EUR) per tonne of CO2 emitted and it has been constantly increased during the years up to 1200 SEK (129, 89 $) per tonne, in 2022 (Ministry of Finance 2022). Sweden levies among the highest CO2 tax per ton of carbon emissions (Tax foundation 2022). In the energy and power field, Sweden long term goal is a national energy system fully reliant on renewables (Bird 2017). Renewable sources like biofuels and hydropower already fulfil more than 50% of total energy consumption needs, thanks to a functioning market-based electricity certification framework implemented in 2003 and which requires energy producers to generate a portion of their energy production from renewable and clean sources (Bird 2017). A great portion of Sweden's electricity supply comes from hydro and nuclear, combined with a growing contribution from wind. Heating is supplied mainly through bioenergy-based district heating and heat pumps (IEA 2021). Additionally, effective financial incentives and subsidizing schemes are used to encourage climate-friendly investments.

Norway

Norway launched its carbon tax for the first time in 1991, and since then, it has been used as the main climate change mitigation tool (Ji 2014). Nominal Carbon tax rate in Norway is among the highest in Europe and it covers 80% of emissions on the national territory (OECD 2022). The overall country policy for emission reduction objective has a long-term perspective on carbon pricing (OECD 2022) and, indeed, Norway's national climate action plan for 2021-2030 presents great potential for increasing the carbon tax from NOK 590 (69 $) per tonne to NOK 2000 (233 $) by 2030. Besides the CO2 tax, Norway's cut-edging environmental policy strategy includes an additional energy taxation scheme targeting mineral products like oil and gas, and petroleum derived vehicle fuels to secure verified emission decrease. Furthermore, the Norwegian government has implemented, since 2008, the International Climate and forest initiative, aiming at curbing GHG emissions from deforestation and forest degradation not only within the national territory, but also globally (UN 2020). In 2021, Norway has strengthened its commitment to enhance its 2030 targets to a reduction of emissions of at least 55% below 1990 levels, rated by Climate action tracker as compatible with Paris agreement 1.5C temperature goal (Climate Action Tracker 2022).

Norway and Sweden lead the way in the reduction of CO2 emissions because they have some of the most ambitious climate change mitigation agendas (Government offices of Sweden 2022), based on substantial emission reductions goals, technology development and innovative energy infrastructures (Prime Minister's Office 2022).

5. Limitations

The analysis presented in this paper has some noteworthy limitations. To start with, this research is based on the OECD Environmental Policy Stringency Index, which bears several limitations in itself. First and foremost, many policies are outside of its coverage (Kruse 2022), including for example international agreements-based initiatives (e.g. EU ETS) and policies regulating emissions from agricultural activities (Kruse 2022). Additionally, pilot projects are not considered by the EPS index, as well as forestry related policies. Another weakness of the index is that data are only available until 2020. Although it accounts for developments related to the outbreak of Covid 19, it does not allow to define the implications of the recent war in Ukraine and consequent gas crisis. Moreover, some of the policy instruments accounted for in the EPS index have been purposefully excluded in this study, given its focus on implicit and explicit carbon pricing.

The main limitation underlying the methodology of the paper is that the analysis is only able to establish a strong correlation, but not causation between the examined variables. The first relationship between emission intensity and the EPS index shows only a correlation, despite strong statistical significance and statistical tests confirming its validity. Although some controls are already included in the "intensity" variable, many others that could influence emissions, such as geographic characteristics, level of technology, energy efficiency, are not being taken into account. This limitation recurs in the cluster analysis, which is based only on the EPS without including other control variables.

Finally, by looking at emissions in a specific year and not reductions in emissions over a period, the final analysis is static and unrepresentative of efforts to combat climate change in recent years. However, this approach is problematic because taking the difference in emissions along a period makes it difficult to isolate the effect of a single year's policy mix. In an attempt to address this problem, it was decided to take the policy mix of one year earlier than the emissions. This ensures that policies implemented in the following year will not affect environmental performance. However, even this approach has limited explanatory power since one cannot know the longer-term effects of the chosen policy mix, and one cannot isolate the effect on emissions of previous policies with a long-term effect.

6. Framework for Political Feasibility

While reducing CO2 emissions and achieving carbon neutrality in the foreseeable future is technically and economically possible, most countries are currently still failing to implement the necessary environmental policies due to political barriers (Peng et al. 2021). As Rawls described it in the early 2000, a “realistic utopia” which a net-zero economy could be described as from an environmentalist point of view, depends not only on “desirable social arrangements” but also on the “realistic achievability” of those arrangements (Rawls 2001). Accordingly, while stringent carbon pricing instruments might be desirable, the necessary social transformation to meet the decarbonization targets would require rapid economic, social, and political changes and the (realistic) achievability or political feasibility of these changes is often questionable (Patterson et al. 2018).

Political feasibility in this context describes the collective belief within a society and government about the extent and speed of carbon abatement initiatives that are considered to be desirable and realistic. The feasibility of different carbon pricing instruments can vary over time and is influenced by the characteristics of each country, such as wealth, the industry and geography. Additionally, technical and economic feasibility and policy innovation shape political feasibility and most importantly, the support (or opposition) of influential members of society such as politicians, private sector agents or the media (Patterson 2018). Policymakers should consider political feasibility when proposing policies, as policies with a lack of political support are generally more difficult to implement. (Peng et al. 2021). When a policy faces strong opposition from the public, from interest groups or when institutional capacity is low, governments are unlikely to implement initiatives successfully, even when the policy has substantial technical or economic potential (Patterson et al. 2018). Similarly, policies tend to be implemented faster when they are politically feasible and cause less disruption to the domestic political environment (Peng et al. 2021).

6.1. The Political Assessment of Clean and Environmental Policies Tool

To reach the climate targets set internationally, for instance in the Paris agreement, a policy mix with stringent instruments is needed. However, political feasibility must be considered in order to introduce these kinds of instruments successfully, to protect the more vulnerable members of society from the consequences of climate change and to move towards an equal net-0 society and economy (Kruse et al. 2022). Nonetheless, the dimension is often not represented in the most used decision-support tools, which usually focus on factors such as costs or emission abatement rates. After identifying the most ideal policy mix in the previous chapter, in the following the political feasibility of implementing the respective policy instruments in different environments will be analyzed. For that, a decision-support tool targeted at measuring feasibility along different dimensions was developed, based on the Political Assessment of Clean air and Environmental Policies (PACE-Tool) (Peng et al. 2021). Utilizing the tool, a political-feasibility score is assigned for each policy on the basis of seven key metrics that are most relevant according to political economy literature. The seven metrics can be divided into Public Opinion, Market Structure and Government Capacity. These three different economic considerations have found relevant for the following reasons:

1. Public opinion: as identified before, in order to implement a policy successfully, the support of the public is necessary. In the tool, the metric considered to measure public

opinion is the direct cost to the public that the respective policy would cause (Benes et al. 2015)

2. Market structure: the more compatible the proposed policy is with the current market structure, the easier its implementation will be. Therefore, the tool measures the expected benefits and costs for the market, the degree of market concentration, and the presence of organized interests (Busby and Shidore 2017; Mitchell 2008)
3. Government capacity: a stronger capacity of the respective governmental is also an important determinant for implementation outcomes; to determine the score, three different metrics are considered, measuring government concentrations, institutional capacity and government willingness (Galston 2009; Benes et al 2015)

Dependent on the country's performance across each metric and how favorable each dimension is for political feasibility considerations, a score from -1, 0 or 1 is assigned. The scoring and interpretation logic in detail can be found in the appendix (see annex 1-2). After obtaining a score for each policy initiative, the results can be compared in order to determine the highest scoring initiative(s) that appear to entail the highest political feasibility and therefore the highest chances of a successful and timely implementation (Peng et al 2021). In order to generate scores that can be easily compared and to avoid negative scores, the final scores where adjusted by adding 6. The insights will then be utilized to inform the policy recommendations for the respective country.

Individual Part

7. Country Analysis: China – Rabea Sieling

Development and relevance of a feasible emission mitigation strategy for China

7.1 Introduction

No matter how much effort states around the world will continue to put into implementing ideal and stringent policy mixes, if China, the leading polluter who is currently accountable for almost one third of global annual emissions (Stalley 2022), fails to deliver its fair share, chances of reaching the 1.5°C (or even the below 2°C) target will be close to zero (Climate Action Tracker 2022). For that reason, it is of utmost importance to analyze the current pollution drivers and political environment of the OECD key partner China and to examine how the policy mix in place could realistically be enhanced.

Chinas development journey over the last forty years[1] can be described as a success story in many regards. In the last four decades, more than 800 million people of the rural population were lifted out of poverty (The World Bank 2022), GDP continuously increased by an annual average of 9.6% and China transformed itself from a developing country to a middle-income one (Lu et al. 2019, 1-2). Despite the surge in wealth and economic prosperity, social inequality and income disparities continue to exist between regions and rural-urban populations. Additionally, Chinas economic progress has been coupled with environmental degradation (Lu et al. 20191-2). The increase in productivity and production of the industrial sector and the electricity required for it was generated mostly by coal (Kahn 2016), making Chinas coal consumption the highest in the world (Stalley 2022). Accordingly, carbon dioxide emissions

[1] China began to open and reform its economy in 1978 by passing economic reforms such as the introduction of the market system and trade liberalization (Lau 2008)

rose rapidly to an extent that led China in 2019 to surpass the emissions of all OECD countries combined (Larsen et al 2021). However, when evaluating the biggest polluters of the 21st century, it is often not considered that since 1750, when looking at emissions cumulatively, OECD countries have produced approximately four times more CO2 emissions than China.

In the 21st century worsening air pollution began to cause serious health problems (Kahn 2016) and is currently causing more than one million premature deaths yearly (Hong et al. 2019). In response, the Chinese government began to participate actively in developing green technologies, especially in the renewable energy sector. This industry was seen as both an attractive way to reduce harmful emissions in the long-run and an industry with significant growth potential to secure its future energy supply needed for production and economic growth (USCBC 2013). After heavily subsidizing the expansion and research of renewable energy heavily in the following years (see section 2.3.2.2), China became the largest investor in renewables as well as the biggest buyer of raw materials needed for their expansion, such as cobalt mines in Africa (Stalley 2022). This allowed China to enter and dominate new export markets of products like green technologies, electric busses, solar panel etc. demanded globally for the transition to lower-carbon economies (Kahn 2016).

Nonetheless, today it is still uncertain, if China will be able to increase its renewable energy supply fast enough and lower prices low enough to meet the energy demand growth and replace fossil fuels in time to meet the 1.5°C target. Yet, this is of great relevance for China, as the country is predicted to be one of the countries that will be suffering most from effects of climate warming, such as severe heat weaves, flooding, decreased food security (Hong et al 2019).

The aim of this report is therefore to define a politically feasible emission mitigation strategy that can support China in this endeavor. Based on a profound analysis of government documents, academic research and climate reports, Chinas climate strategy, targets and current policy mix are outlined. Derived from the analysis, different policy options are identified and assessed using the political feasibility model. Finally, these results are leveraged to give informed, and implementable sustainable public policy recommendations.

7.2 The Chinese Environmental Policy Framework

7.2.1 The Chinese Environmental Strategy

In recent years, China has had a strong track record of participating in international conferences and emphasizing the importance of addressing climate change. However, its climate change policy since 1990 has evolved considerably and undergone multiple shifts (Lai 2021). When analyzing Chinas policies during these three important decades, one can identify multiple periods with different degrees of ambition and progressiveness.

During the first period from 1990-2005, when emissions in China were quickly increasing, Chinese climate policies were either still nonexistent or reluctant and the Chinese government saw the responsibility for climate action rather lying with the developed countries. Its own domestic economic development was prioritized and with it the belief that all countries have "*common but differentiated responsibilities*" as formalized in the United Nations Framework Convention on Climate Change (UNFCCC 1992, 4). Accordingly, China stated that it would not commit to any targets or initiatives until a "*medium level of development*" would be reached (Lai 2021). This "*free-rider*" mindset however slowly began to shift in the early 2000s, when China started to become an active participant in climate conferences and formulated its first energy consumption target in 2006, which marked the beginning of a more progressive period. At that time, Chinese emissions rose by more than 15% annually and the country surpassed the former biggest polluters, the US and India, attracting negative global attention (Lai 2021). In 2009 then, under considerable pressure from the public, China announced its first-ever public carbon target at the occasion of the Copenhagen Conference[2] and pledged in front of the UN to "*lower carbon intensity by 40-45% from 2005 levels by 2020*" (Moore 2009). Additionally, its long-standing hesitance to an internationally binding commitment began to vanish in the following years.

However, when Xi Jinping was elected in 2012, he did not want to be perceived as too accommodating to Western demands and China started to revert to a more nationalist, resistant standing (Lai 2022). But when Beijing was witnessing a record-breaking smog in 2013 with thousands of people hospitalized (Liu 2021), international pressure on China grew (Kahn 2016) and the Chinese climate policy reached a turning point: in November 2014, China and the US jointly announced more stringent climate targets and China declared its ambitions to let its carbon emissions peak around 2030 and if possible, even earlier. This joint agreement is still perceived as the groundwork for the Paris Agreement negotiated a year after, in which China also participated (U.S Department of State 2014). Up to date, the Chinese government has been resilient in its support for the agreement, even when the US, the second biggest polluter withdrew from it in 2017 (Friedman 2021).

Nonetheless, in line with its overall ambivalent climate strategy, China has not stood out for ambitious target setting in the past. In fact, most of the targets set in the last decades have been very low and were overachieved in many cases (Stalley 2022). In line with that, analysts have raised concerns that China's commitment to the progressive climate course could be harmed by cutting spending on renewable energy sources and reverting to coal. This has been triggered especially because of recent global developments, such as the COVID-19 pandemic,

[2] The Copenhagen Climate Change Conference took place in 2009 and more than 115 world leaders attended. Its key achievement was an agreement to limit the global temperature increase to 2 degrees Celsius above pre-industrial levels (subject to a review in 2015) (UNFCC 2009)

during which coal output ended up rising to 4.13 billion tons in 2021 (up 5.7% from 2020) due to energy shortages- China's highest total ever (Maizland 2021).

7.2.2 Climate Targets

In November 2021, China surprised the public when it unexpectedly updated its Nationally Determined Contributions (NDCs). The main elements of these updated NDCs are 1) a fixed commitment to reach the carbon emissions peak before 2030 (vs. the previous "around 2030"), 2) pledges to lower carbon intensity by more than 65% (vs. "by 60-65%" in 2005), increase non-fossil fuel share up to 25% (vs. 20% in previous targets), increase forest stock volume by 6 billion cubic meters in 2030 from the 2005 level cubic meters (1.5 billion more than previously) , to increase the renewable wind and solar energy to 1200 GW and 3) to become carbon neutral before 2060 (You 2021).

Despite these more ambitious targets that replaced the previous, softer targets, it is projected that China will, without significant stricter abatement policies, easily overachieve the targets (Climate Action Tracker 2022). Experts estimate that becoming carbon neutral by 2060 is feasible for China if the government commits to its targets. Nonetheless, that would not imply that China will fulfill the emission-reduction requirements for the 1.5C goal (Duan 2021). The climate action tracker (CAT) therefore continues to rate Chinas NDC targets as "*highly insufficient*" to fulfill its pledges to the international community (Climate Action Tracker 2022).

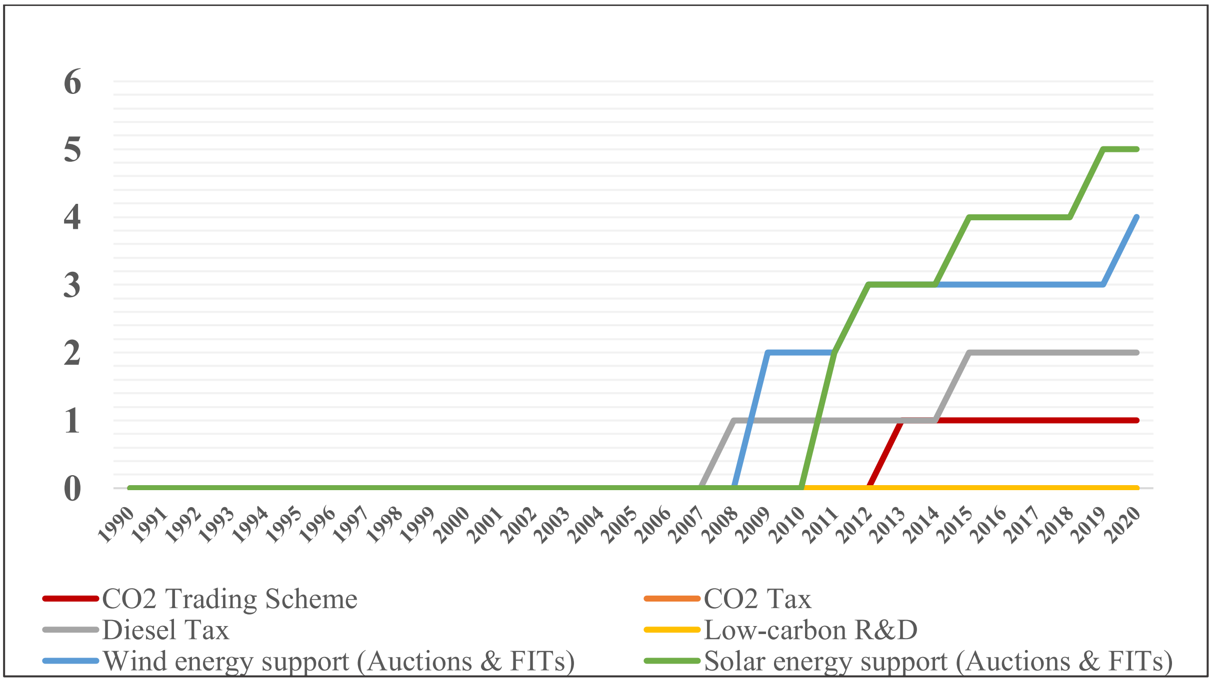
7.3 The Chinese Policy Mix

When it comes to fighting climate change especially in the last decade, the narrative that China is doing little to implement climate policies is misleading – as mentioned above, the problem is rather the lack of ambition when it comes to setting targets (Stalley 2022). As indicated by the "highly insufficient" rating of Chinas Climate Targets by the CAT, in order to decarbonize its economy and meet the Paris Agreement, China would need to improve its targets and adjust its climate policies and actions accordingly (Climate Action Tracker). In the following, the five previously introduced explicit and implicit instruments and their (if applicable) usage in China's current policy mix will be analyzed. To quantify China's Policy Mix and its stringency for the respective instruments, the Environmental Policy Stringency (EPS) score China received for each instrument will be used (see Figure 1).

7.3.1 Climate Policy Stringency in China

Across the countries considered in the EPS index, policy stringency has increased significantly within the assessed time frame (Kruse et al 2022). This is also the case for China: when considering absolute values of the OECD EPS21 score, China increased its policy stringency between 2000 and 2020 by +2.9, the second largest growth.

Figure 1 – Economic Policy Stringency Index China (1990-2020)



Source: Kruse et al. 2022

Looking at the development of the stringency level across the five instruments utilized for the purpose of this work project, the developments are in line with the political strategic shifts and periods described in section 2.1. From 1990 until 2005, the Chinese policy was characterized by denial and hesitation and no noteworthy policies were in place nor launched. This changed around the year 2008/09, in line with the events of the Copenhagen Business Conference when the Diesel Tax and FiTs were introduced first. Solar and wind FiTs were the most stringent policy in China in the following years with a +2 score. After initiating the "*soft*" ETS (CO2 Trading Scheme) in 2012 (see section 2.3.2.1) it remained with the same stringency level (1). The Diesel Tax and Solar FiTs became more stringent after the turning point in 2013, exactly on time for the Chinese American joint declaration and Paris Agreement. After the Paris Agreement was signed, the Chinese then continued with its policy stringency level until in 2018/19, when the "ecological civilization"[3] pledge led the FiTs to become even more stringent. The changes after 2020 are not considered in the data of the EPS but briefly touched upon in the following sections.

7.3.2 Chinese Carbon Pricing Instruments

7.3.2.1Explicit Carbon Pricing

Carbon Tax: To date, China has not introduced a domestic carbon tax (Carpenter 2021). Although taxing carbon emissions is advocated by many research studies according to which taxes can encourage a significant cleaner energy system, the Chinese government is still relying on other instruments (Wei, Ayub and Dagar 2022). Accordingly, the EPS score has remained at 0 from 1990 to 2020 (see orange line Figure 1) (Kruse et al 2022).

---

[3] A set of values and development concepts announced and enshrined in the Constitution of the People's Republic of China (PRC) in 2018. It can be understood as a philosophy, vision, and compass for a green and prosperous future (Hanson 2019)

Emission Trading System: In 2011, as a response to the Copenhagen Conference in 2009 (see section 2.1), China announced the establishment of an emission trading system in seven municipalities[4] to reach the 2020 carbon reduction target. The program officially launched in January 2012, the covered industries and companies accounting for 25% of China‘s annual GDP. More than 40 million metric tons (Mt) of CO2 were traded at a combined value of approximately 195 million USD (Parenteau and Cao 2016). In the EPS data this first step on China's road to gradually develop a carbon trading market, is assigned a stringency value of 1 which continued throughout the period of the "soft ETS" until 2020 (see red line Figure 1) (Kruse et al 2022). In 2017, China's Ministry of Ecology and Environment (MEE) announced a nationwide carbon trading scheme which officially started operating in 2021 (Luyue 2022). Under the ETS, the MEE is restricting the total emissions of the coal and gas power plants across the country. Currently, allowances are capped at 20% above the number of allowances allocated initially but if needed, firms can purchase additional allowances or sell redundant ones at an exchange in Shanghai. The price for allowances is around 65 RMB (approximately 10.22 USD) per ton (Carpenter 2021). As the expanded ETS only started operating in 2021, it is not reflected in the EPS Score (yet).

7.3.2.2 Implicit Carbon Pricing

Diesel Tax: As in most countries, fuel excise tax, the so called" Refined *Oil Excise Tax"* is the only tax on energy use currently in place in China (OECD 2019). The tax was first adopted in 2008 (STA 2021) and applies to gasoline, diesel, and other oils at rates from 1.52 EUR per liter and 1.2 EUR per liter for fuel oil (OECD 2021). In line with Chinas shift in strategy in

[4] The seven pilot programs were Beijing, Chongqing, Guangdong, Hubei, Shanghai, Shenzhento, and Tianjin (Parenteau and Cao 2016)

2014, the excise tax was also increased to guide consumers towards saving energy and lowering CO2 emissions (Zhao et al 2018). Accordingly, the EPS increased from 1 to 2 at that period (Kruse et al 2022). Important to note about the Chinese energy tax in-place is, that it is not applied to aviation kerosene, nor the fuels used to generate electricity. Moreover, the revenues are earmarked for investments in the transport sector (OECD 2021).

Feed-in Tariff: Due to consequent policy incentives and investments in the Chinese wind and solar capacity, China is the global leader in this market (Lin 2022). To expand their renewable sectors, the Chinese government relied mostly on non-competitive allocation of feed-in tariffs (FiT) (Roberts 2020). Launched in 2009 for wind (light blue line) and 2011 for solar (green line), the Chinese FiT schemes offered firms support payments per kilowatt of electricity produced, targeting a higher output, profit, and lower market price for consumers (Yang 2021). Accordingly, over the ten-year period following the introduction, costs for solar energy fell by 81% and for on- and offshore wind energy by more than 45% (Roberts 2020), renewable energy capacity increased approximately four times and the total share of solar and wind energy in China's power generation increased from 2.6% to almost 12% (Jaghory 2022). As reflected in the constantly increasing EPS scores for solar and wind, China's stringency with the FiT schemes increased permanently, resulting in increasing costs for the government from approximately 14 billion Yuan in 2014 to almost 230 billion Yuan in 2019 (Roberts 2020). To lower costs, the government shifted to an auction approach which implied a national bidding process which selected the most competitive projects in 2019 (Roberts 2020). In 2020, it was announced that the climate strategy would move away from the direct handouts or cost-intensive subsidies associated with the FiT system, and accordingly, offshore wind feed-in tariffs ended in 2021 and solar and onshore wind projects were haltered (not reflected in EPS data) (Lin 2022; Jagory 2022).

Subsidies: In recent years, the Chinese strategy to encouraging green development has relied mostly on the tax system to discourage the consumption of polluting commodities (for instance, an increased tax for high emission vehicles). Therefore, the EPS index has been at 0 for during the EPS timeframe. However, in 2021, the government also announced the allocation of a fund for supporting green and low-carbon development of 350 billion Yuan (Huld 2022). The stringency index is therefore expected to rise in the future.

7.3.3 Final Remarks

Looking at the current Chinese climate policy mix today and its development in the last three decades, we conclude that China has focused on implicit (mostly non-market-based) instruments. This was beneficial for the economy, making the Chinese the world leading producer of renewable energy today and lowering costs for clean energy considerably. When looking at the main findings of the bivariate and cluster analysis in section 3.1-3.2 in the common part, economies with stringent market-based policies are more successful in lowering emissions intensity. Yet, China has been lacking those in the past. The updated ETS will be a first step towards that approach, however more initiatives must follow in order to meet the Paris agreement and outperform its own, rather unambitious climate targets.

7.4 Political Feasibility Analysis

As mentioned above, Chinas current policy mix is not in line with what the results of the common analysis identified as the "*ideal policy mix*". However, it is questionable if the policy mix from Cluster 10, which contains developed and wealthy Scandinavian countries is feasible to be implemented in China, given its economic and political environment. Nonetheless, in order to move towards the most successful policy mix, the following section will analyze four different policy options for China and their respective feasibility: Introduction of a Carbon Tax (EX-CT), expansion of the ETS to subsectors (EX-ETS), increase of the "*Refined Oil Excise Tax"*(IM-ET) and finally, phasing out of coal subsidies (IM-CO). For the analysis, the "Political Assessment of Clean and Environmental Policies"-Tool introduced in the common report (see chapter 6) will be used to measure the feasibility and to suggest a priority list for China.

7.4.1 Derived Policy Options

From the ideal policy mix identified in chapter 4 (common report) and informed by the specific current circumstances of the Chinese economy and climate change policy, four policy options were selected. This selection is considered to best support China best on its path towards net-zero while meeting its own and international climate targets. Stringent marked-based explicit carbon pricing instruments seem to be an essential part of a successful climate policy. Therefore, the first two options to probe are the introduction of a carbon tax in China (EX-CT) as well as an expansion of the ETS in place (EX-ETS). As laid out, China currently does not levy any carbon tax, even though this has been advocated (Carpenter 2021). For instance, it was calculated that a 5 RMB (USD 0.72) per ton tax on carbon could already reduce emissions by 4.1% and therefore even a low tax could promote a considerably cleaner energy system (Wie, Ayub and Dagar 2022). and enhance climate efforts from companies (Liu, Suk and Yamamoto 2014).

While the ETS has been rolled out nationwide just recently and expected to be „*all but toothless*"(Carpenter 2021), it is far smaller in scope than initially envisioned when it was first proposed in 2015 covering around 40% of emissions of China (Luyue 2022). By expanding the ETS to more subsectors, such as chemicals, steel, cement, among others, more emissions would be covered. For instance, just by including the cement industry, approximately 8% more of China's emissions could be covered under the ETS (Ritchie and Roser 2022).

Moreover, as FiTs on wind and solar have been reduced or phased out (Jaghory 2022) more initiatives to transition the energy sector towards renewables should be deployed. One crucial step towards carbon intensity reduction is to reduce coal consumption and end coal altogether by 2060, especially as coal was responsible for 70% of CO2 emissions in China in 2020 (Ritchie and Roser 2022) and as output rose by almost 6% in 2021 to a record-high of 4.13 billion tons, making it more difficult to achieve the NDCs (Climate Action Tracker 2022). Therefore, the third recommended option to analyze is to commit to phasing out coal subsidies (IM-CO) as soon as possible. Simultaneously, to foster the transition, increasing the fuel consumption tax further (IM-ET) will be considered as a fourth and final policy option. Although gasoline demand elasticity in China does not appear to be high according to studies, sufficiently large adjustments could guide consumers towards reducing fuel consumption and CO2 emissions nonetheless (Zhao et al 2018). Additionally, China's current consumption tax is, compared to other countries, rather low. Consumption taxes in Germany for instance account for more than half of the price, and also in Japan, Australia, and Norway taxes are more than 25% of the price (Zhao et al 2018). In combination with ear-marked tax revenues for transportation and electric vehicles, this approach could for instance work towards cleaner air in overpopulated metropolitan areas.

7.4.2 The Feasibility Framework

After elaborating on the policy options for China, the feasibility of each option was assessed along three different dimensions, according to the political feasibility framework developed by Peng et al. 2021. The three dimensions, public opinion, market structure and government capacity were measured by a total of 13 sub-metrics (see chapter 6 in the common report) and the final assessment and scoring of the four options is summarized in Table 1 below. Each score was assigned based on information and data gathered from scientific research, indices, governmental communication, newspaper etc. and a justification for each score is attached in the Annex (Annex 2).

Table 1 - The Political Assessment of Clean and Environmental Policies Tool

Policy	Feasibility Measures							Aggregate score (rescaled from 1-13)
	Public Opinion	**Market**			**Government**			
	Popular Opposition	Market benefits/cost	Market concentration	Organized Interests	Government concentration	Institutional Capacity	Government Willigness	
EX-CT	Weak oppsition (+1)	Market cost (-1)	Not concentrated (-1)	Not represented (+1)	Concentrated (+1)	High Capacity (+1)	Low willigness (-1)	7
EX-ETS	Weak oppsition (+1)	Market cost (-1)	Not concentrated (-1)	Not represented (+1)	Concentrated (+1)	High Capacity (+1)	High willigness (+1)	9
IM-CO	Strong opposition (-1)	Market cost (-1)	Not concentrated (-1)	Represented (-1)	Concentrated (+1)	High Capacity (+1)	Ambivalent	4
IM-ET	Weak oppsition (+1)	0	Concentrated (+1)	Represented (-1)	Concentrated (+1)	High Capacity (+1)	Low willigness (-1)	8

Source: Peng et al. 2021
Darker shades of yellow indicate a higher political feasibility score

One of the main findings of the analysis is that overall, China's government is quite concentrated, and its institutions are characterized by a high institutional capacity. Accordingly, one can assume that due to its (institutional) set up, the government would be able to introduce even controversial policies. As the consequences of climate change are predicted to be severe for China and are already tangible, such as the poor air condition in cities, the majority of the population also appears to be in favor of most policies, even if they would directly bear the costs associated with the implemented policies. Especially as China's citizens become wealthier, their willingness to avoid pollution increases. However, as China can be regarded as authoritarian, this should be considered less than for instance in western democracies where state capacity is more limited, and power dispersed (Stasavage 2020). Additionally, it is questionable whether the poorer rural population would agree on this.

Another interesting sub-metric in the case of China is the government willingness (to implement the respective policies). Although China emphasized its commitment to stringent climate policies multiple times and there has been a remarkable shift in its positioning in the mid 2010s, the Chinese actions are currently still mixed (e.g., revamping of coal in recent years) and not sufficiently consistent. Finally, one must consider that, according to the analysis, all the policies will pose, in part, severe costs to industries and markets and could therefore collide with China's economic growth ambitions. Generally, based on the analysis the Carbon Tax (EX-CT) and Coal subsidy fade out (IM-CO) seem to be least feasible, which can be traced back especially to economic considerations, while the expansion of the ETS and higher excise tax on fossil fuels tend to be more feasible.

7.5 Proposed Emission Mitigation Roadmap

In what follows, insights from the political feasibility and document analysis will be leveraged to give short- to long-term recommendations for China's decarbonization efforts going forward.

7.5.1 Short-term recommendations

In the short term, China needs to assure that the country is committed to the initiatives and targets in place and set themselves up for effective emission mitigation in the future.

A: More ambitious Target Setting: As elaborated throughout the analysis, China has been increasingly ambitious with its (NDC) target setting but is still lacking ambitious enough targets that would allow them to meet the 1.5° target (Wie, Ayub and Dagar 2022). Therefore, to identify the necessary timeline and steps and to set and commit to ambitious targets to fulfill the Paris Agreement should be the first step and enable China to develop an effective action plan. (Climate Action Tracker 2022)

B: No additional policies benefiting coal: The current coal production and consumption is still preventing China to lower emissions sufficiently and too many of China's subsidies and policies benefitting coal are still in place. In the short-term the least that China must commit to is restraining from introducing additional subsidies or tax breaks, as it has in recent years (Riordan and Li 2022). The coal dependency is posing the biggest threat to Chinas net-zero target and the energy transition key to reduce emissions.

C: Assure growth of renewable sector without FiTs in place: As renewables are supposed to replace coal and fossil fuels as soon as possible, the supply of affordable wind and solar energy must be secured. As support schemes for renewables are decreasing or ending, the industries' growth without government support must be monitored (Lin 2022). If necessary, less costly intense initiatives such as cheap loan offerings for the deployment should be considered.

7.5.2 Medium to long-term recommendations

D: Expand market-based carbon pricing initiatives: As the analysis has found, Chinas strategy to focus on non-marked based instruments, in particular renewables and their deployment, will be insufficient to reduce the necessary amount of emissions. Therefore, market-based carbon pricing initiatives need to be prioritized. This appears to be most feasible for an expansion of the ETS in place (EX-ETS) and increase the "*Refined Oil Excise Tax*" (IM-ET).

E: Introduce distributional programs: While the majority of the Chinese appear to be in favor of more stringent carbon pricing tools (Kruse et al. 2022), it is undeniable that the poorer population will have to face higher costs for energy (at least in the mid-term) and will be affected most by increased price for gasoline or goods under the expanded ETS. Considering that this part of the population will also be most affected by the consequences of rising temperatures, refraining from initiatives even if they are regressive would be counterproductive (Kahn 2016). Instead, the government should account for these issues by to investing in distributional programs, for instance, tax breaks or lump sum transfers.

F: International Cooperation: As the leading emitter, China should in any case continue to be part of the global discussion and initiatives regarding climate change and advocate for an aligned strategy on initiatives, to reduce economic damage caused by initiatives such as the European ETS. To do so, the Chinese must prove their commitment and collaborate with the western world, rather than against it (Skarbek 2022). If implemented successfully, these diverse measures could for instance increase government willingness (see recommendations A, B, C, F), and minimize market costs (see recommendation C), therefore increasing the political feasibility score by at least two points per policy. Currently, the most significant barrier to implement stringent marked-based carbon pricing policies are the associated costs and the Chinese fear of a declining economy. To counteract this, the most important goal is to lay the foundations for affordable clean energy as quickly as possible.

7.6 Conclusion

The goal of analyzing the Chinese climate policy further was to develop a set of feasible, evidence-based recommendations for China in order to move as much as possible towards the "*ideal policy mix*" identified in the common part. As learned from the document analysis, Chinas climate strategy has been inconsistent in the past, but the government has in recent years, because of national environmental circumstances, been forced to improve its policy mix. The emphasis so far has been on complementary, non-marked based FiTs which, as this report indicates will not be sufficient in the long run to decarbonize the economy. However, these initiatives will play a crucial role in making clean energy more profitable and affordable then coal or fossil fuels.

As the political feasibility analysis has shown, the main barrier to implement stringent policies appears not to be the public opposition but rather the fear of economic decline. This highlights once again the need for cheap clean energy. To work toward that goal, while assuring emission abatement progress in the meantime, six recommendations were developed. These aim to balance the regressivity of the policies recommended while enhancing the policy mix in place.

Nonetheless, when evaluating the findings of this report, two limitations need to be considered: One is the scoring of the feasibility analysis, which can be subject to subjectivity. Additionally, due to time and space constraints, only a limited number of policies, those directed at carbon pricing, were considered. These policies are mostly targeted toward domestic consumption and taxation, disregarding foreign investments and imports. Therefore, this work does not claim to be able to provide detailed, instrument-specific recommendations for implementation. Instead, it should be viewed as a synthesized and contextualized overview of the complex situation and challenges China is facing, laying down potential ideas for a mitigation roadmap, which should be further researched.

Group Part

8 Final Remarks and Conclusion

The objective of this work was to answer the research question whether an ideal policy mix that is most effective in the abatement of emissions exists. Moreover, five in-depth country-specific analyses were conducted to understand how selected countries could realistically improve their respective environmental policy mixes further.

Based on our assumptions and hypothesis in the bivariate regression and cluster analysis, it is possible to answer the first part of the research question in the affirmative. Our findings suggest that when different clusters of countries with similar environmental policy stringencies and corresponding emission intensities are developed, it is evident that, generally, states with overall high stringencies in their policy mix showcase lower intensities of emissions. Analyzing the best-performing clusters (10, 9 and 6), we show that a common characteristic are high stringency values for market-based instruments such as carbon- and diesel tax. Although Group 9 (Spain, Ireland, Island) depict slightly lower values, clusters 10 (Norway, Sweden) and 6 (Finland, Switzerland, France) both indicate a strong focus on explicit instruments such as the CO2 tax, leading them to lower emission intensities in comparison to other country groups. In particular, Sweden and Norway have strongly relied on high rates for their carbon taxes, while committing to have their energy systems almost exclusively based on renewables. Thus, in line with the majority of economic studies on explicit carbon pricing instruments, we draw the conclusion that **market-based policy tools are of utmost importance in any policy mix and can substantially bring countries closer to reach their climate objectives.** With this finding, our working project contributes to the body of research on environmental policy mixes by evaluating the emission abatement effect a broader spectrum of carbon pricing policies, rather than just focusing on one instrument.

Nonetheless, when interpreting the findings of our analysis, several limitations must be considered. First and foremost, one must note that the bivariate regression does not prove causality between the EPS index and emission intensity, yet only shows a strong, statistically significant correlation. The results should therefore be utilized as a basis for additional research on this subject to confirm the findings. In addition, the ideal policy mix our results have identified is in place in two highly developed countries - Norway and Sweden. However, applying this policy mix in other contexts may not lead to similar emission reduction, because Norway and Sweden are characterized by very high levels of economic and social development, as well as very strong democratic institutions. Replication of the Scandinavian policy approaches in other countries, without accounting for country-specific characteristics, may lead to different results, thus bearing the potential for misinterpretation. Additionally, one must acknowledge the ongoing dispute between the developing and developed countries regarding the responsibilities of emission mitigation given the historic pollution behavior of the industrialized states during their economic growth in the last centuries. Lastly, the report on hand is exclusively examining the effectiveness of carbon pricing instruments. In practice however, countries can choose from a more diverse set of instruments and must consider other harmful GHG emissions such as Methane in their policy making as well.

We complement our theoretical results from the cluster analysis by introducing political economy considerations based on Peng et al. which are crucial when implementing policy instruments. **We highlight that, although focusing on market-based instruments can lead to high abatement of emissions as our theoretical findings suggest, in practice, country specificity must be taken into consideration.** Each of the five country-analysis revealed distinct challenges and differences in the political feasibilities of policies which must be addressed with custom and specified solutions to bring these economies closer to climate neutrality instead of a “one-size-fits all” approach.

Evidence from **Canada** shows that a more centralized approach in environmental policies is fundamental to reduce emissions more effectively. The example of **China** proved once more that leveraging almost exclusively non-marked based policies, no matter how stringent, cannot lead to the amount of emission abatement needed to meet the 1.5° target. The analysis of **Germany** showed how fossil fuel subsidies in the energy sector hinder a rapid low-carbon transition and that reallocation of capital to environmentally friendly technologies and industry-practices is crucial. In **Mexico**, the political feasibility of carbon pricing was found to be generally low, which is why the implementation of complementary measures such as support schemes were recommended. In **South Africa**, the analysis showed that low energy efficiency, coal subsidies, and poor coordination between institutions are the root causes of its high emission intensity and proposed "quality" FDI as a possible solution for the green transition.

Similar to the interpretations from the cluster analysis, the political feasibility tool selected for formulating the country-specific policy options and recommendations also presents some limitations. The numerical scale from -1 to 1 does not capture the slight variety of circumstances that may affect certain outcomes in the countries under review. Additionally, the implementation of the tool through the scoring process might be subject to biases which this study is not controlling for. Future research could examine political feasibility of different emission reduction policy options, by formulating evaluations and scoring based on a more varied numerical scale, accounting for the several shades of political and social scenarios in the countries analyzed.

Finally, we emphasize the **importance of addressing distributional aspects** when implementing environmental instruments. Complementary policies that support, for instance, low-income households in the transition to low-carbon economies are non-negligible to reach climate objectives and avoid anti-climate movements as seen in France with the "yellow vest" demonstrations. Policies must be designed with complementary measures that make the green transition fair and feasible in order to ensure public support for climate related activities.

9 References

9.1 References Common Part

Albrizio, Silvia, Tomasz Kozluk, and Vera Zipperer. 2017. "Environmental Policies And Productivity Growth: Evidence Across Industries And Firms". Journal Of Environmental Economics And Management 81: 209-226. doi:10.1016/j.jeem.2016.06.002

Aldy, E. Joseph, Robert N. Stavins. 2012. “The Promise and Problems of Pricing Carbon: Theory and Experience”. Journal of Environment & Development 21, 2: 152–180. DOI: 10.1177/1070496512442508

Alton, Theresa, Channing Arndt, Rob Davies, Faaiqa Hartley, Konstantin Makrelov, James Thurlow, and Dumebi Ubogu. 2014. “Introducing Carbon Taxes in South Africa.” Applied Energy 116 (March): 344–54. https://doi.org/10.1016/j.apenergy.2013.11.034.

Anatolitis, Vasilios, Alina Azanbayev, and Ann-Katrin Fleck. 2022. “How to Design Efficient Renewable Energy Auctions? Empirical Insights from Europe.” Energy Policy 166 (July): 112982. https://doi.org/10.1016/j.enpol.2022.112982.

Bacon, Robert. 2004. "Taxation Of Energy". Encyclopedia Of Energy, Elsevier, 13-25. doi:10.1016/B0-12-176480-X/00161-3.

Baldwin, Elizabeth, Sanya Carley, Jennifer N. Brass, and Lauren M. MacLean. 2016. “Global Renewable Electricity Policy: A Comparative Policy Analysis of Countries by Income Status.” Journal of Comparative Policy Analysis: Research and Practice 19 (3): 277–98. https://doi.org/10.1080/13876988.2016.1166866.

Benes, Keith. Cheon, Andrew. Urpelainen, Johannes. Yang, Joonseok. 2015. “Low oil prices: An opporunity for fuel subsidy reform.” Center on Global Energy. Policy Working Paper. 5-17. https://www.energypolicy.columbia.edu/sites/default/files/Fuel%20Sub sidy%20Reform_October%202015.pdf

Best, Rohan, and Paul J. Burke. 2020. “Energy Mix Persistence and the Effect of Carbon Pricing.” Australian Journal of Agricultural and Resource Economics 64 (3): 555–74. https://doi.org/10.1111/1467-8489.12370.

Bird, Timothy. 2017. "Nordic Action Climate Change”. Nordic Council of Ministers. https://norden.diva-portal.org/smash/get/diva2:1148260/FULLTEXT01.pdf.

Braathen, Nils Axel, and James Greene. 2011. "Environmental Taxation: A Guide For Policy Makers". Oecd.Org. September 2011. https://www.oecd.org/env/tools-evaluation/48164926.pdf.

Bray, Sean. 2022. “Carbon Taxes in Europe”. Tax Foundation. June 14, 2022. https://taxfoundation.org/carbon-taxes-in-europe-2022

Brunel, Claire, and Arik Levinson. 2013. Measuring Environmental Regulatory

Bruvoll, Annegrete, and Larsen Bodil M. 2004. “Greenhouse gas emissions in Norway: do carbon taxes work?”

Busby, Joshu.W., Shidore, Sarang. 2017. “When decarbonization meets development: the sectoral feasibility of greenhouse gas mitigation in India.” Energy Research & Social Science 23, 60–73. DOI: 10.1016/j.erss.2016.11.011.

C2ES. 2008. “Technology Policies to Address Climate Change.” Center for climate and energy solutions. November 2008. https://www.c2es.org/document/technology-policies-to-address-climate-change/

Calderón, Silvia, Andrés Camilo Alvarez, Ana María Loboguerrero, Santiago Arango, Katherine Calvin, Tom Kober, Kathryn Daenzer, and Karen Fisher-Vanden. 2016. "Achieving CO2 Reductions In Colombia: Effects Of Carbon Taxes And Abatement Targets". Energy Economics 56: 575-586. https://doi.org/10.1016/j.eneco.2015.05.010

Campoccia, Angelo, Laurent Dusonchet, Enrico Telaretti, and Gaetano Zizzo. 2014. "An Analysis Of Feed’In Tariffs For Solar PV In Six Representative Countries Of The European Union". Solar Energy 107: 530-542. https://doi.org/10.1016/j.solener.2014.05.047.

Carley, Sanya, Elizabeth Baldwin, Lauren M. MacLean, and Jennifer N. Brass. 2016. "Global Expansion Of Renewable Energy Generation: An Analysis Of Policy Instruments". Environmental And Resource Economics 68 (2): 397-440. doi:10.1007/s10640-016-0025-3.

Chancel, Lucas, Thomas Piketty, Emmanuel Saez, and Gabriel Zucman. 2022. "World Inequality Report 2022". World Inequality Lab. https://wir2022.wid.world/www-site/uploads/2021/12/Summary_WorldInequalityReport2022_English.pdf.

Château, Jean, Rob Dellink, and Elisa Lanzi. 2014. "An Overview Of The OECD ENV-Linkages Model". OECD Environment Working Papers. Paris: OECD. https://doi.org/10.1787/5jz2qck2b2vd-en

Climate Action Tracker. 2022. "Norway". Climateactiontracker.Org. Accessed September 6, 2022. https://climateactiontracker.org/countries/norway/.

Climate Action Tracker. 2022. Countries. Accessed September 1, 2022. https://climateactiontracker.org/countries

Couture, Toby, Karlynn Cory, Claire Kreycik, and Emily Williams. 2010. "A Policymaker’S Guide To Feed- In Tariff Policy Design". Golden: NREL-National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy10osti/44849.pdf

D’Arcangelo, Filippo. Levin, Ilai, Pagani, Alessia, Pisu, Mauro, Johansson Åsa. 2022. “A framework to decarbonize the economy.” OECD Economic Policy Papers, No. 31: OECD Publishing. https://doi.org/10.1787/4e4d973d-en

Daniëls, Bert and Robert Koelemeijer. 2016. “Kostenefficiëntie van beleidsmaatregelen ter vermindering van broeikasgasemissies.” Amsterdam: Planbureau voor de Leefomgeving. https://www.pbl.nl/sites/default/files/downloads/pbl-2016-kostenefficientie-van-beleidsmaatregelen-ter-vermindering-van-broeikasgasemissies_1748.pdf

Dasgupta, Partha. 2021. The Economics of Biodiversity: The Dasgupta Review. HM Treasury. London

Datta, Ashokankur. 2010. "The Incidence Of Fuel Taxation In India". Energy Economics 32: 26-33. https://doi.org/10.1016/j.eneco.2009.10.007.

Dechezleprêtre, Antoine, Adrien Fabre, Tobias Kruse, Bluebery Planterose, Ana Sanchez Chico, and Stefanie Stantcheva. 2022. "Fighting Climate Change: International Attitudes Toward Climate Policies". OECD Economics Department Working Papers, no. 1714. https://doi.org/10.1787/3406f29a-en

DFFE. "South Africa’S 4Th Biennial Update Report To The United Nations Framework Convention On Climate Change.". Reprint, Capetown: Department of Forestry, Fisheries and the Environment, 2021. https://unfccc.int/documents/307104

Direction Générale Du Trésor. 2021. "Climate Strategies In The Nordic Countries". Ministre de l'Économie et des Finances. May 20, 2021. https://www.tresor.economie.gouv.fr/Articles/2021/05/20/climate-strategies-in-the-nordic-countries

Dissanayake, Sumali, Renuka Mahadevan, and John Asafu-Adjaye. "Evaluating The Efficiency Of Carbon Emissions Policies In A Large Emitting Developing Country". Energy Policy 136 (2020): 111080. https://doi.org/10.1016/j.enpol.2019.111080.

European Commission. 2021. “Carbon Border Adjustment Mechanism: Questions and Answers”. Accessed September 7, 2022. https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661

European Commission. 2021. “Carbon Border Adjustment Mechanism: Questions and Answers”. Accessed September 7, 2022. https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661

European Commission. 2021. “Carbon Leakage.” Accessed September 4, 2022. https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/free-allocation/carbon-leakage_en#:~:text=Carbon%20leakage%20refers%20to%20the,increase%20in%20their%20total%20emissions

European Commission. 2021. “European Quality of Government Index 2021.” Accessed August 29, 2022. https://ec.europa.eu/regional_policy/en/information/maps/quality_of_governance/

European Commission. 2022. “Paris agreement.” Accessed September 4, 2022. https://ec.europa.eu/clima/eu-action/international-action-climate-change/climate-negotiations/paris-agreement_en#global-climate-action-agenda

Eyre, Nick. "Energy Saving In Energy Market Reform—The Feed-In Tariffs Option". Energy Policy 52 (2013): 190-198. https://doi.org/10.1016/j.enpol.2012.07.042.

Gaille, Brandon. 2015. “12 Cap and Trade Pros and Cons”. Brandongaille.com. Accessed September 7, 2022. https://brandongaille.com/12-cap-and-trade-pros-and-cons/

Galeotti, Marzio, Silvia Salini, and Elena Verdolini. "Measuring Environmental Policy Stringency: Approaches, Validity, And Impact On Environmental Innovation And Energy Efficiency". Energy Policy 136 (2020): 111052. https://doi.org/10.1016/j.enpol.2019.111052.

Galston, William A.. (2009). “Political Feasibility: Interests and Power.” The Oxford handbook of public policy. 543-556. https://doi.org/10.1093/oxfordhb/978019954845 3.003.0026

Garsous, Gregoire, Tomasz Kozluk, and Dennis Dlugosch. 2020. "Do Energy Prices Drive Outward FDI? Evidence From A Sample Of Listed Firms". The Energy Journal 41 (3). doi:10.5547/01956574.41.3.ggar.

Goulder, Lawrence H, and Ian W. H. Perry. 2008. "Instrument Choice In Environmental Policy.". Web.Stanford.Edu. 2 (2). https://web.stanford.edu/~goulder/Papers/Published%20Papers/Instr%20Choice%20in%20Envir%20Policy%20(with%20Parry).pdf

Gugler, Klaus, Adhurim Haxhimusab, Mario Liebensteinerc. 2021. “Effectiveness of climate policies: Carbon pricing vs. subsidizing renewables”. Journal of Environmental Economics and Management. Volume 106, March 2021, 102405. https://doi.org/10.1016/j.jeem.2020.102405

Haas, Reinhard, Niels I. Meyer, Anne Held, Dominique Finon, Arturo Lorenzoni, Ryan Wiser, and Ken-Ichiro Nishio. 2008. "Promoting Electricity From Renewable Energy Sources – Lessons Learned From The EU, United States, And Japan". Competitive Electricity Markets: 419-468. https://doi.org/10.1016/B978-008047172-3.50016-7.

Haites, Erik. 2018. "Carbon Taxes And Greenhouse Gas Emissions Trading Systems: What Have We Learned?". Climate Policy 18 (8): 955-966. https://doi.org/10.1080/14693062.2018.1492897.

IEA. 2020. “Implementing Effective Emissions Trading Systems” Accessed September 7, 2022. https://www.iea.org/reports/implementing-effective-emissions-trading-systems

IEA. 2021. "Sweden - Countries & Regions - IEA". Accessed September 6, 2022. https://www.iea.org/countries/sweden.

IEA. 2021. “Phasing Out Unabated Coal: Current Status and Three Case Studies.” IEA. October 2021. https://www.iea.org/reports/phasing-out-unabated-coal-current-status-and-three-case-studies

IPCC. 2011. "Special Report On Renewable Energy Sources And Climate Change Mitigation". Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/03/SRREN_FD_SPM_final-1.pdf.

Ji, Amanda. 2014. "The Carbon Tax In Norway". Blogs.Ubc.Ca. March 12, 2014, https://blogs.ubc.ca/amandaji/2014/03/12/the-carbon-tax-in-norway/.

Karp, S. Larry, and Traeger P. Christian. 2018. “Taxes Versus Quantities Reassessed”. CESifo Working Paper No. 7331. http://dx.doi.org/10.2139/ssrn.3338660

Kenton, Will. 2020. “Cap and Trade”. Investopedia.com. Accessed September 7, 2022. https://www.investopedia.com/terms/c/cap-and-trade.asp

Kozluk, Tomasz, and Enrico Botta. 2014. "Measuring Environmental Policy Stringency In OECD Countries". OECD Economics Department Working Papers. doi:10.1787/5jxrjnc45gvg-en.

Kruse, Tobias, Antoine Dechezleprêtre, Rudy Saffar, and Leo Robert. 2022. "Measuring Environmental Policy Stringency In OECD Countries: An Update Of The OECD Composite EPS Indicator". OECD Economics Department Working Papers, 1703. doi:10.1787/18151973.

Laumanns, Ulrik. 2022. "Renewable Energy Tendering Schemes - Energypedia". Energypedia. Accessed September 6, 2022. https://energypedia.info/wiki/Renewable_Energy_Tendering_Schemes.

Lin, Boqiang, and Xuehui Li. 2011. "The Effect Of Carbon Tax On Per Capita CO2 Emissions". Energy Policy 39 (9): 5137-5146. https://doi.org/10.1016/j.enpol.2011.05.050.

Lucas, Hugo, Rabia Ferroukhi, and Diala Hawila. 2022. "Renewable Energy Auctions In Developing Countries". Abu Dhabi: IRENA. https://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/IRENA%20Renewable%20Energy%20Auctions%20in%20Developing%20Countries.pdf.

Meckling, Jonas, Thomas Sterner, and Gernot Wagner. 2017. "Policy Sequencing Toward Decarbonization". Nature Energy 2 (12): 918-922. https://doi.org/10.1038/s41560-017-0025-8.

Milligan, Glenn W. 1980. "An Examination Of The Effect Of Six Types Of Error Perturbation On Fifteen Clustering Algorithms". Psychometrika 45, 3: 325-342. DOI:10.1007/bf02293907.

Milligan, Glenn W., and Martha C. Cooper. 1985. "An Examination Of Procedures For Determining The Number Of Clusters In A Data Set". Psychometrika 50, 2: 159-179. DOI:10.1007/bf02294245.

Ministry of Finance. 2022. “Sweden’s carbon tax”. Government Offices of Sweden. Accessed September 6, 2022. https://www.government.se/government-policy/swedens-carbon-tax/swedens-carbon-tax/

Mojena, R. 1977. "Hierarchical Grouping Methods And Stopping Rules: An Evaluation". The Computer Journal 20, 4: 359-363. DOI:10.1093/comjnl/20.4.359.

Murray, Brian C., and Peter T. Maniloff. 2015. "Why Have Greenhouse Emissions In RGGI States Declined? An Econometric Attribution To Economic, Energy Market, And Policy Factors". Energy Economics 51: 581-589. https://doi.org/10.1016/j.eneco.2015.07.013.

Narassimhan, Easwaran, Kelly S. Gallagher, Stefan Koester, and Julio Rivera Alejo. 2018. "Carbon Pricing In Practice: A Review Of Existing Emissions Trading Systems". Climate Policy 18 (8): 967-991. https://doi.org/10.1080/14693062.2018.1467827.

Narassimhan, Easwaran, Kelly S. Gallagher, Stefan Koester, and Julio Rivera Alejo. 2018. "Carbon Pricing In Practice: A Review Of Existing Emissions Trading Systems". Climate Policy 18 (8): 967-991. https://doi.org/10.1080/14693062.2018.1467827.

OECD. 2011. “Environmental Taxation. A Guide for Policy Makers.” Paris: OECD Publishing. https://www.oecd.org/env/tools-evaluation/48164926.pdf

OECD. 2013. “Climate and Carbon. Aligning Prices and Policies.” OECD Environment Policy Paper. 1: https://www.oecd-ilibrary.org/docserver/5k3z11hjg6r7-en.pdf?expires=1662582568&id=id&accname=guest&checksum=9FF0F81747CD22031E7F5524275BFEF0

OECD. 2013. “Effective Carbon Prices”. OECD Publishing. https://doi.org/10.1787/9789264196964-en

OECD. 2015. “Aligning policies for a transition to a low-carbon economy.” Paris: OECD Publishing. https://www.oecd.org/environment/Aligning-Policies-for-a-Low-carbon-Economy.pdf

OECD. 2019. "Taxing energy use 2019 – Country Note Mexico." Accessed September 4, 2022. https://www.oecd.org/tax/tax-policy/taxing-energy-use-mexico.pdf

OECD. 2019. “Taxing Energy Use 2019: Country Note – China.” Accessed September 7, 2022. https://www.oecd.org/tax/tax-policy/taxing-energy-use-china.pdf

OECD. 2020. “A Comprehensive Overview of Global Biodiversity Finance.” OECD Publishing. Accessed September 7, 2022.

OECD. 2021. “Carbon Pricing in Times of COVID-19: What Has Changed in G20 Economies?”. OECD. Accessed September 9, 2022. https://www.oecd.org/tax/tax-policy/carbon-pricing-in-times-of-covid-19-what-has-changed-in-g20-economies.htm?_ga=2.248339599.963935040.1662719432-696168448.1657140075

OECD. 2021. “Update on recent progress in reform of inefficient fossil-fuel subsidies that encourage wasteful consumption 2021.” Paris: OECD Publishing. https://www.oecd.org/fossil-fuels/publicationsandfurtherreading/OECD-IEA-G20-Fossil-Fuel-Subsidies-Reform-Update-2021.pdf

OECD. 2022. “OECD Environmental Performance Reviews: Norway 2022”. OECD Environmental Performance Reviews. April 22, 2022. https://doi.org/10.1787/59e71c13-en.

Patterson, James. Thaler, Thomas. Hoffmann, Matthew. Hughes, Sara. Oels, Angela. Chu, Eric. Mert, Aysem. Huitema, Dave et al. 2018. “Political feasibility of 1.5°C societal transformations: the role of social justice.”. Current Opinion in Environmental Sustainability. April 2019, Vol.31, 1-9, https://doi.org/10.1016/j.cosust.2017.11.002

Peng, Wei, Sung Eun Kim, Pallav Purohit, Johannes Urpelainen, and Fabian Wagner. 2021. "Incorporating Political Feasibility Concerns Into The Assessment Of India’S Clean-Air Policies.". One Earth. August 20, 2021. https://www.cell.com/one-earth/pdf/S2590-3322(21)00405-X.pdf

Perman, Roger. Ma, Yue. McGilvray, James. Common, Michael. 2003. Natural Resource and Environmental Economics. London. Pearson

Pindyck, Robert S. 2017. “The Use and Misuse of Models for Climate Policy.” Review of Environmental Economics and Policy 11, 1: 100–114. http://dx.doi.org/10.1093/REEP/REW012

Prime Minister’s Office. 2022. "Norway And Sweden Agree To Intensify Cooperation On Carbon Capture And Storage". Government Offices of Sweden. April 7, 2022. https://www.government.se/articles/2022/04/norway-and-sweden-agree-to-intensify-cooperation-on-carbon-capture-and-storage/.

Rawls, John., Kelly Erin. 2001. “Justice as Fairness. A Restatement.” Cambridge. Harvard University Press.

REN21. 2022. "Renewables 2021: Global Status Report". https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf

Ritchie, Hannah, Max Roser and Pablo Rosado. 2020. “CO_2 and Greenhouse Gas Emissions”. Accessed September 1, 2022. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Schmalensee, Richard, and Robert N. Stavins. 2017. "Lessons Learned From Three Decades Of Experience With Cap And Trade". Review Of Environmental Economics And Policy 11 (1): 59-79. https://doi.org/10.1093/reep/rew017.

Sen, Suphi and Herman Vollebergh. 2018. “The Effectiveness of Taxing the Carbon Content of Energy Consumption.” Journal of Environmental Economics and Management 92: 74–99. https://doi.org/10.1016/j.jeem.2018.08.017

Shahzad, Umer. 2020. "Environmental Taxes, Energy Consumption, And Environmental Quality: Theoretical Survey With Policy Implications". Environmental Science And Pollution Research 27 (20): 24848-24862. doi:10.1007/s11356-020-08349-4.

Simões, Henrique Morgado. 2021. “Climate action in Sweden: Latest State of play.” European Parliament. Accessed September 6, 2022. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698764/EPRS_BRI(2021)698764_EN.pdf

Somanathan, Eswaran, Thomas Sterner, Tashi Sugiyama, Donald Chimanikire, Navroz K. Dubash, Joseph K. Essandoh-Yeddu, et al. 2014. "Chapter 15 - National and sub-national policies and institutions." In Climate Change 2014: Mitigation of Climate Change, edited by IPCC Working Group III Contribution to AR5. Cambridge University Press. http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter15.pdf

Stavins, Robert. 2019. “The Future of US Carbon-Pricing Policy.” Environmental and Energy Policy and the Economy, 1 (May): 8-64, https://doi.org/10.3386/w25912

Steurer, Anton. 2015. “Environmental subsidies and similar transfers Guidelines” Eurostat. 5-8. https://doi.org/10.2785/907129

Sumner, Jenny, Lori Bird, and Hillary Dobos. 2011. "Carbon Taxes: A Review Of Experience And Policy Design Considerations". Climate Policy 11 (2): 922-943. https://doi.org/10.3763/cpol.2010.0093.

UNESCAP. 2012. "Low carbon green growth roadmap for Asia and the Pacific. Fact sheet feed-in tariff." Accessed August 21, 2022. https://www.unescap.org/sites/default/files/26.%20FS-Feed-In-Tariff.pdf

United Nations. 2022. “Ecological Tax Reform.” Accessed September 1, 2022. https://sustainabledevelopment.un.org/index.php?page=view&type=99&nr=92&menu=1449#:~:text=Ecological%20Tax%20Reform%20%2D%20Between%201999,gas%20in%20small%20foreseeable%20stages.&text=Ecological%20Tax%20Reform-,Between%201999%20and%202003%20the%20ecological%20tax%20reform%20raised%20taxes,gas%20in%20small%20foreseeable%20stages.

van Sluisveld, Mariësse A.E., Andries F. Hof, Detlef P. van Vuuren, Pieter Boot, Patrick Criqui, Felix C. Matthes, Jos Notenboom, Sigurd L. Pedersen, Benjamin Pfluger, and Jim Watson. 2017. "Low-Carbon Strategies Towards 2050: Comparing Ex-Ante Policy Evaluation Studies And National Planning Processes In Europe". Environmental Science &Amp; Policy 78: 89-96. https://doi.org/10.1016/j.envsci.2017.08.022.

World Bank. 2021. “The Year in Climate in 5 Numbers.” Accessed August 2, 2022. https://www.worldbank.org/en/news/feature/2021/12/16/2021-the-year-in-climate-in-5-numbers

World Bank. 2022. “Carbon Pricing Dashboard. What is Carbon Pricing?” Accessed August 5, 2022. https://carbonpricingdashboard.worldbank.org/what-carbon-pricing

World Bank. 2022. “Carbon Pricing Dashboard. What is Carbon Pricing?” Accessed August 5, 2022. https://carbonpricingdashboard.worldbank.org/what-carbon-pricing

World Bank. 2022. “Government Effectiveness.” Accessed September 6, 2022. https://govdata360.worldbank.org/indicators/h1c9d2797country=BRA&indicator=388&viz=line_chart&years=1996,2020

World Bank. 2022. “Government Effectiveness.” Accessed September 6, 2022. https://govdata360.worldbank.org/indicators/h1c9d2797country=BRA&indicator=388&viz=line_chart&years=1996,2020

World Economic Forum. 2021. “This is how climate change could impact the global economy.” Accessed August 2, 2022. https://www.weforum.org/agenda/2021/06/impact-climate-change-global-gdp/

World Health Organization. 2022. “Heatwaves.” Accessed August 2, 2022. https://www.who.int/health-topics/heatwaves#tab=tab_2

Yan, Xiaoyu, and Roy J. Crookes. 2009. "Reduction Potentials Of Energy Demand And GHG Emissions In China's Road Transport Sector". Energy Policy 37 (2): 658-668. https://doi.org/10.1016/j.enpol.2008.10.008.

9.2 References Individual Part

Carpenter. Scott. 2021. “Toothless Initially, China’s New Carbon Market Could Be Fearsome.” Forbes. Accessed September 6, 2022. https://www.forbes.com/sites/scottcarpenter/2021/03/02/toothless-at-first-chinas-carbon-market-could-be-fearsome/?sh=6676b8e72af1

Climate Action Tracker. 2022. “China”. Accessed September 6, 2022. https://climateactiontracker.org/countries/china/

Duan. Hongbo. Zhou, Sheng. Jiang, Kejun. Bertram, Christoph. Harmsen, Mathijs. Kriegler, Elmar. Van Vuuren, Detflef P. et al. 2021. “Assessing China’s efforts to pursue the 1.5°C warming limit.” Science. 372(6540): 378-385. DOI:10.1126/science.aba876

Friedman, Lisa. 2021. “U.S. Quits Paris Climate Agreement: Questions and Answers.” The New York Times. Accessed September 8, 2022. https://www.nytimes.com/2020/11/04/climate/paris-climate-agreement-trump.html

Hong, Chaopeng, Zhang, Qiang, Zhang, Yang, Davis, Steven J., Tong, Dan, Zheng, Yixuan, Liu, Zhu, Guan, Dabo, He, Kebin, Schellnhuber, Hans Joachim. 2019. "Impacts of climate change on future air quality and human health in China" Proceedings of the National Academy of Sciences (PNAS). 116 (August): 17193-17200. doi:10.1073/pnas.1812881116

Huld. Arendse. 2022. "China Lays Fiscal Policy Foundation for Reaching Carbon Targets." China Briefing. Accessed September 8, 2022. https://www.china-briefing.com/news/chinas-environmental-policy-new-fiscal-support-for-green-development/

Jaghory, Dillon. 2022. "Chinese Cleantech: 2022 Marks Year of Transition for Wind and Solar Policy." Global X. Accessed September 8, 2022. https://www.globalxetfs.com/chinese-cleantech-2022-marks-year-of-transition-for-wind-and-solar-policy/

Kahn, Matthew E. 2016. "For China, climate change is no hoax- it's a business and political opportunity." The Conversation. Accessed September 6, 2022. https://theconversation.com/for-china-climate-change-is-no-hoax-its-a-business-and-political-opportunity-69191

Lai, Hongyi. 2021. "The evolution of China's climate change policy: international and domestic political economy and a strategy for working with China." The British Academy, 9(10):69-98. https://doi.org/10.5871/jba/009s10.069

Larsen, Kate, Pitt, Hannah, grant, Mikhail, Houser, Trevor. 2021. „China's Greenhouse Gas Emissions Exceeded the Developed World for the First Time in 2019." Rhodium Group. Accessed September 7, 2022. https://rhg.com/research/chinas-emissions-surpass-developed-countries/

Lau, Lawrence J. 2008. "Thirty Years of Chinese Economic Reform: Reasons for Its Success and Future Directions." In: Papadimitriou, C., Zhang, S. „Internet and Network Economics." WINE 2008. Vol 5385. Springer, Berlin. https://doi.org/10.1007/978-3-540-92185-1_2

Lin. Max Tingyao. 2022. "China continues strong renewables policy support after record PV, offshore wind power expansion in 2021." HIS Markit. Accessed September 7, 2022. https://cleanenergynews.ihsmarkit.com/research-analysis/china-continues-strong-renewables-policy-support-after-record-.html

Liu, Xianbing. Suk, Sunhee. Yamamoto, Ryuichi. 2014. " The Feasibility of Pricing of Carbon Emissions in Three Northeast Asian Countries: Japan, China and the Republic of Korea." Policy Brief. 29 (April). https://www.iges.or.jp/en/publication_documents/pub/policy /en/4145/PB_29_E_0403.pdf

Lu, Yonglong, Zhang, Yuequing, Cao, Xianghui, Wang, Chenchen, Wang, Yichao, Zhang, Meng, Ferrier, Robert C, et al. 2019. "Forty years of reform and opening up: China's progress toward a sustainable path." Science Advances 5(8) (August): 1-10. doi:10.1126/sciadv.aau9413.

Luyue, Tan. 2022. "The first year of China's national carbon market, reviewed." China Dialogue. Accessed September 7, 2022. https://chinadialogue.net/en/climate/the-first-year-of-chinas-national-carbon-market-reviewed/

Maizland, Lindsay. 2021. "China's Fight Against Climate Change and Environmental Degradation." Council on Foreign Relations. Accessed September 7, 2022. https://www.cfr.org/backgrounder/china-climate-change-policies-environmental-degradation

Moore, Malcom. 2009. “China announces carbon target for Copenhagen.” The Telegraph. Accessed September 7, 2022. https://www.telegraph.co.uk/news/earth/copenhagen-climate-change-confe/6662299/China-announces-carbon-target-for-Copenhagen.html

OECD. 2019. “Taxing Energy Use 2019: Country Note – China.” OECD Publications. Accessed September 7, 2022. https://www.oecd.org/tax/tax-policy/taxing-energy-use-china.pdf

OECD. 2021. “Carbon pricing in times of COVID-19: What has changed in G20 economies? Background Notes”. OECD Publications. Accessed September 3, 2022. https://www.oecd.org /tax/tax-policy/carbon-pricing-background-notes.pdf

Parenteau, Patrick. Cao, Mingde. 2016. “Carbon Trading in China: Progress and Challenges.” Environmental Law Institute. Washington, DC. Accessed September 3, 2022 https://www.vermontlaw.edu/sites/default/files/Assets/elc/Parenteau.March2016.pdf

Richie, Hannah. Roser, Max. 2022. “China: Country Profile.” Our world in Data. Accessed September 7, 2022. https://ourworldindata.org/co2/country/china

Riordan, Primrose. Li, Gloria. 2022. “China boosts coal usage as extreme heat triggers power shortages.” Financial Times. September 7, 2022. https://www.ft.com/content/fc316e81-b584-485e-b349-e313098ac3a7

Roberts. Don. 2020. “Feed-in tariffs for renewable power and the role of auctions: the Chinese & global experience.” China Economic Journal. 13 (May) 152-168. https://www.tandfonline.com/doi/abs/10.1080/17538963.2020.1752494?needAccess=true&journalCode=rcej20

Skarbek. Anna. 2022. “Tackling climate change requires university, government and industry collaboration – here’s how.” The Times – Higher education. September 7, 2022. https://www.timeshighereducation.com/campus/tackling-climate-change-requires-university-government-and-industry-collaboration-heres-how

STA. 2021. “Tax System”. Accessed September 7, 2022. http://www.chinatax.gov.cn/eng/c101270/c101271/c5157953/content.html

Stalley, Philip. 2022. “China’s climate change record: Beijing tends to meet its targets, but sets the bar too low“. The Conversation. Accessed September 7, 2022. https://theconversation.com/chinas-climate-change-record-beijing-tends-to-meet-its-targets-but-sets-the-bar-too-low-172138

Stasavage, David. 2020. „Democracy, Autocracy, and Emergency Threats: Lessons for COVID-19 From the Last Thousand Years.“ International Organization, 74(S1), E1-E17. doi:10.1017/S0020818320000338

The World Bank. 2022. „The World Bank in China. Overview.” Accessed September 7, 2022. https://www.worldbank.org/en/country/china/overview

UNFCC 2009. “Copenhagen Climate Change Conference - December 2009“ Accessed September 5, 2022. https://unfccc.int/process-and-meetings/conferences/past-conferences/copenhagen-climate-change-conference-december-2009/copenhagen-climate-change-conference-december-2009

USCBC. 2013. “China’s Strategic Emerging Industries: Policy, Implementation, Challenges, & Recommendations”. Accessed September 6, 2022. https://www.uschina.org/sites/default/files/sei-report.pdf

U.S Department of State. 2014. “U.S.-China Joint Announcement on Climate Change.” The White House. Accessed September 6, 2022. https://obamawhitehouse.archives.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change

Wei, Ran. Ayub, Bakhtawer. Dagar, Vishal. 2022. “Environmental Benefits From Carbon Tax in the Chinese Carbon Market: A Roadmap to Energy Efficiency in the Post-COVID-19 Era.” Frontiers. Accessed September 6, 2022. https://doi.org/10.3389/fenrg.2022.832578

Yang, Dong-Xiao. Jing, Ya-quing. Wang, Chan. Nie, Pu-yan. Sun, Peng. 2021. „Analysis of renewable energy subsidy in China under uncertainty: Feed-in tariff vs. renewable portfolio standard.” Energy Strategy Reviews. 34 (March) https://doi.org/10.1016/j.esr.2021.100628

You, Xiaoying. 2021. “China’s 2060 climate pledge is ‘largely consistent’ with 1.5C goal, study finds.” Carbon Brief. Accessed September 5, 2022. https://www.carbonbrief.org/chinas-2060-climate-pledge-is-largely-consistent-with-1-5c-goal-study-finds/

Zhao, Lu-Thao. He, Ling-Yun. Cheng, Lei. Zeng, Guan-Rong. Huang, Zhimin. 2018. “The effect of gasoline consumption tax on consumption and carbon emissions during a period of low oil prices.” Journal of Cleaner Production. 171 (August) 1429-1436. https://doi.org/10.1016/j.jclepro.2017.10.117

10. Appendix

Common Report

Appendix 1: Further Statistics of the Quantitative Analysis

Figure 1. Regression with a Fixed Effect Model

```
. xtreg logintensity lEPS21, fe

Fixed-effects (within) regression               Number of obs     =      1,072
Group variable: id                              Number of groups  =         38

R-sq:                                           Obs per group:
     within  = 0.6559                                         min =         22
     between = 0.0448                                         avg =       28.2
     overall = 0.1738                                         max =         29

                                                F(1,1033)         =    1968.63
corr(u_i, Xb)  = -0.0793                        Prob > F          =     0.0000

------------------------------------------------------------------------------
logintensity |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lEPS21 |  -.2109925   .0047554   -44.37   0.000    -.2203238   -.2016612
       _cons |  -1.065851   .0094711  -112.54   0.000    -1.084435   -1.047266
-------------+----------------------------------------------------------------
     sigma_u |  .44817506
     sigma_e |  .13663717
         rho |  .91495621   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(37, 1033) = 296.26                  Prob > F = 0.0000

. estimates store fixed
```

Figure 2. Hausman Test: Determines that the random effect model is more suitable for the analysis

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
      lEPS21 |   -.2109925    -.2107821       -.0002104        .0002439
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.74
                Prob>chi2 =      0.3883
```

Figure 3. Panel Data Scatterplot

Appendix 2: Political Assessment of Clean air and Environmental Policies Tool

Table 1. Seven metrics on political feasibility

Political Economy Considerations	Metrics	Interpretation	Relevant Political Economy Literature
Public Opinion	Popular opposition	When the costs of implementing a policy are directly borne by the public, the policy is more likely to face a strong popular resistance.	Benes et al (2015); Cheon et al (2013); Overland (2010)
Market Structure	Market benefit/cost	When the affected industry expects benefits (costs) from the policy implementation, the policy is more (less) likely to be supported by the industry.	Benes et al (2015); Busby and Shidore (2017); Busby et al (2018)
	Market concentration	When the affected industry is characterized by a small number of producers and product lines, emissions mitigation will be more feasible from a collective action perspective.	Busby and Shidore (2017); Busby et al (2018); Olson (1965); Mitchell (2008)
	Organized interests	A presence of an organized interest group representing the affected industry will make implementing a policy easier (more difficult) when the industry expects benefits (costs).	Benes et al (2015); Bernhagen (2012); Grossman and Helpman (2001)
Government Capacity	Government concentration	When the authority over rulemaking and policy implementation activities are fully centralized, the degree of government concentration is high, which is often beneficial for effective policy making and implementation. When they are under control of state governments with (without) a coordination with the central government, government concentration is medium (low).	Busby and Shidore (2017); Busby et al (2018); Tsebelis (2002)
	Institutional capacity	Stronger institutional capacity improves the feasibility of implementing a policy.	Benes et al (2015)
	Government Willingness	A stronger Interest of those in power in the implementation of a policy improves political feasibility	Galston (2009) Political Feasibility: Interest and Power

Table 2. Meaning of –1, 0, +1 scores

Political Economy Considerations	Metrics	Interpretation of the scores		
		-1 (Unfavorable)	0 (Neither favorable nor unfavorable)	+1 (Favorable)
Public Opinion	Popular opposition	The public directly bears the costs of policy implementation.	N/A	The public does not bear the costs of policy implementation.
Market Structure	Market benefit/cost	An affected industry expects costs from policy implementation.	An affected industry expects neither benefits nor costs from policy implementation.	An affected industry expects benefits from policy implementation.
	Market concentration	The affected sector is *not* concentrated (i.e., characterized by a large number of producers and product lines that contribute to emissions.)	N/A	The affected sector is concentrated (i.e. characterized by a small number of producers and product lines that contribute to emissions.)
	Organized interests	The industry expects costs and is represented by organized interest groups, or The industry expects benefits but is *not* represented by organized interest groups.	The industry neither expects benefits nor costs.	The industry expects benefits and is represented by organized interest groups, or The industry expects costs but is *not* represented by organized interest groups.
Government Capacity	Government concentration	The government is not concentrated.	The level of government concentration is moderate.	The government is concentrated.
	Institutional capacity	The government has low institutional capacity (i.e., administrative apparatus for implementing a given policy).	The government has a medium level of institutional capacity (i.e. administrative apparatus for implementing a given policy).	The government has high institutional capacity (i.e., administrative apparatus for implementing a given policy).
	Government Willingness	The government has no interest in implementing the respective policy	The government is indifferent about the policy	It is in the governments interest to implement the respective policy

Individual Report – China

Appendix 1: Feasibility Scores

Section A. Political feasibility scores
-1: Unfavorable for policy implementation; 0: Neutral; +1: Favorable

		Public Opinion	Market			Government			Score	
Abbreviation	Explanation	Direct Cost to Public	Market benefit/cost	Market concentration	Organized interests	Government concentration	Institutional capacity	Government Willingness	Raw	Adjusted (+6)
EX-CT	*Introduction of a carbon tax*	1	-1	-1	1	1	1	-1	1	7
EX-ETS	*Expansion of the ETS*	1	-1	-1	1	1	1	1	3	9
IM-CO	*Commit to phasing out coal subsidies*	-1	-1	-1	-1	1	1	0	-2	4
IM-ET	*Increase fuel consumption tax*	1	0	1	-1	1	1	-1	2	8

Appendix 2: Scoring justification

EX-CT: Introduction of a carbon tax

Metric	Explanations

Popular Opposition	The public bears the direct cost because the tax would be imposed on all goods produced and passed through to the consumer. Analysis have also shown that a carbon tax would impose a disproportionately large burden on low-income households who for instance must spend a greater share of their budget on energy (Parry and Wingender 2016). However, according to a recent OECD survey, most of the Chinese population is significantly more in favor (between 67%-82% depending on the respective policy and revenue utilization) of a carbon tax than high-income countries with on average only 38% support (Dechezleprêtre et al 2022). Considering the severe threats caused by climate change (air pollution, flooding, food security etc.) in China (Ye 2022), more than half of the public states they would be likely to support a carbon tax initiative. Accordingly, 58% even believe their own household would gain from such tax (most positive opinion within the survey) (Dechezleprêtre et al. 2022). Therefore, the public appears to be willing to bear direct costs in order to combat the rising challenges of climate change. (+1)
Market benefits/cost	Economists predict that an introduction of the carbon tax in China, would be able to decrease the carbon emissions of the whole but industry output, real GDP and resident welfare would largely be damaged and trigger economic recession in China (Zhang 2019). The industry would therefore face severe costs. (-1)
Market concentration	The market is not concentrated as all would be affected by a carbon tax (depending on its design) (-1)
Organized Interests	China is an authoritarian party-state and power is centralized and therefore only few interest groups managed to emerge over the last years, trying to influence policy making (Yang 2007). As many influential sectors and companies however are state-owned, for instance the coal-industry, their interests are in line with the policy making and opposition would not be accepted. Therefore, the industries expect costs, but their interests are either in line with the state's interest or not represented (Konno 2018). (+1)
Government concentration	The authority over rule-making, and policy implementation activities are fully centralized as a carbon tax would be implemented centrally by the China's Ministry of Ecology and Environment (MEE) and China's state taxation administration (STA). (+1)
Institutional Capacity	As recently proven throughout the response to the COVID-19 response the Chinese institutional capacity is (although criticized internationally) high (Li 2022). Accordingly, the World Bank Government Effectiveness Index for China has been rising rapidly in the last years with a climax in 2020 of 0.65 (far above the world median). (World Bank 2020) (+1)
Government Willingness	Although the Chinese Government is still the biggest emitter, the CCPI country experts regard its climate policy as ambitious, with clear policies and timelines (with breakdowns into local and sectoral plans in some areas) (Burck et al 2021). However, the country receives a very low rating for GHG Emissions and Energy Use. Given the economic implications and threat of a recession, the government willingness for the respective policy is currently rated as low (Zhang 2019). (-1)

EX-ETS: Expansion of the ETS

Metric	Explanations
Popular Opposition	The ETS is designed under the ‚polluter pays' principle. However, as production costs increase and investments in low-carbon machinery etc. must be made, the carbon price could be passed through to the public. However according to a recent OECD survey, the majority (<50%) of the Chinese public is in favor of carbon pricing instruments (except for those affecting meat consumption or prices) (Dechezleprêtre et al 2022). (+1)
Market benefits/cost	Economists predict that a more stringent ETS in China, would be able to decrease the carbon emissions but industry output, real GDP and resident welfare would be damaged (Parenteau and Cao 2016). The industry would therefore face severe costs. (-1)
Market concentration	The market is not concentrated as many product lines would be affected by an expanded ETS (-1)
Organized Interests	China is an authoritarian party-state and power is centralized and therefore only few interest groups managed to emerge over the last years, trying to influence policy making (Yang 2007). As many influential sectors and companies however are state-owned, for instance the coal-industry, their interests are in line with the policy making and opposition would not be accepted. Therefore, the industries expect costs, but their interests are either in line with the state’s interest or not represented (Konno 2018). (+1)
Government concentration	The authority over rule-making and policy implementation activities are fully centralized and would be implemented centrally by China’s Ministry of Environment and Ecology (Carpenter 2021). (+1)
Institutional Capacity	As recently proven throughout the response to the COVID-19 response the Chinese institutional capacity is (although criticized internationally) high (Li 2022). Accordingly, the World Bank Government Effectiveness Index for China has been rising rapidly in the last years with a climax in 2020 of 0.65 (far above the world median) (World Bank 2020) (+1)
Government Willingness	The Chinese Government is still the biggest emitter, and the climate tracker rates targets as ‘highly insufficient’ to meet the 1.5° target. According to the Climate Change performance Index, China also receives a ‘low’ rating overall, although with mixed ratings across emissions, energy use, renewable energy and climate policy (Burck et al 2021). On the contrary, the Green Future Index ranks China on position 26 in 2022 (compared to 45 in 2021) due to its Green Innovations and Climate Policy (Green Future Index 2022). The Chinese government has making progress and committed to fight climate change but is not following through consequently just yet. However, given the recent increase in stringency for the ETS (in 2021, not displayed in OECD data yet), the government willingness to (cost-effectively) mitigate emissions utilizing the instrument. (+1)

IM-CO: Commit to phasing out coal subsidies

Metric	Explanations

Popular Opposition	The public bears direct costs from increased energy prices and commodity prices. Additionally, employment could suffer from diverting from coal. (Clark and Zhang 2022) (-1)
Market benefits/cost	As coal plants lose revenue they are faced with direct costs from the policy (Xiang et al 2019). Additionally, energy would get substantially more expensive until renewables are fully rolled out. (-1)
Market concentration	The coal industry is concentrated with the majority of companies being large, consolidated, state-owned entities. However, all sectors would be faced with higher energy prices, making the affected market not concentrated. (-1)
Organized Interests	The Chinese coal industry is dominated by large state-owned companies which employ millions of workers and enjoy close connections to the top leadership in government. (Caldecott et al 2017). (-1)
Government concentration	The authority over rule-making and policy implementation activities are fully centralized and would be implemented centrally by National Energy Administration (NEA 2022) (+1)
Institutional Capacity	As recently proven throughout the response to the COVID-19 response the Chinese institutional capacity is (although criticized internationally) high (Li 2022). Accordingly, the World Bank Government Effectiveness Index for China has been rising rapidly in the last years with a climax in 2020 of 0.65 (far above the world median) (World Bank 2020) (+1)
Government Willingness	The Chinese Government is still the biggest emitter, and the climate tracker rates targets as ‘highly insufficient’ to meet the 1.5° target. According to the Climate Change performance Index, China also receives a ‘low’ rating overall, although with mixed ratings across emissions, energy use, renewable energy and climate policy (Burck et al 2021). On the contrary, the Green Future Index ranks China on position 26 in 2022 (compared to 45 in 2021) due to its Green Innovations and Climate Policy (Green Future Index 2022). China has announced to end coal until 2060, however 2021 its coal output rose almost 6% compared to 2020 and has been utilized to balance our power shortages (Climate Tracker 2022). The Chinese government has making progress in terms of target setting but its committed has been lacking in the past (0)

IM-ET: Increase fuel consumption tax

Metric	**Explanations**
Popular Opposition	The public bears direct costs from increased diesel tax, the burden would especially affect low income, rural households more than the urban population (Zhao et al 2018). Subsidies/ Tax cuts for electric vehicles or similar goods would only be beneficial for households who can afford to buy those. Nonetheless, according to a recent OECD survey, most of the Chinese population is significantly more in favor (between 67%-82% depending on the respective policy and revenue utilization) of higher taxes than high-income countries with on average only 38% support. When earmarking some of the revenue to cash transfers to poorer households, the Chinese support reaches 82% (Dechezleprêtre et al. 2022). Therefore, the

	public appears to be willing to bear direct costs in order to combat the rising challenges of climate change. (+1)
Market benefits/cost	The policy creates market benefits to automakers but costs to oil companies with a decline of demand (in the long run). The industry receiving support from tax revenue would benefit while another is facing costs. (0)
Market concentration	The affected sector is concentrated (i.e., characterized by a small number of producers (many state-owned) and product lines that contribute to emissions (Meidan 2016). (+1)
Organized Interests	The Chinese oil industry is dominated by three large state-owned companies which employ millions of workers and enjoy ministerial status as they outrank a number of other bureaucracies–and close connections to the top leadership (Meidan 2016). (-1)
Government concentration	The authority over rule-making and policy implementation activities are fully centralized and would be implemented centrally by China's Ministry of Land and Resources and China's state taxation administration (STA 2022). (+1)
Institutional Capacity	As recently proven throughout the response to the COVID-19 response the Chinese institutional capacity is (although criticized internationally) high (Li 2022). Accordingly, the World Bank Government Effectiveness Index for China has been rising rapidly in the last years with a climax in 2020 of 0.65 (far above the world median) (World Bank 2020) (+1)
Government Willingness	The Chinese Government is still the biggest emitter, and the climate tracker rates targets as 'highly insufficient' to meet the 1.5° target. According to the Climate Change performance Index, China also receives a 'low' rating overall, although with mixed ratings across emissions, energy use, renewable energy and climate policy (Burck et al 2021). On the contrary, the Green Future Index ranks China on position 26 in 2022 (compared to 45 in 2021) due to its Green Innovations and Climate Policy (Green Future Index 2022). Considered all, the Chinese government has making progress and committed to fight climate change but is not following though consequently just yet. That the willingness to increase the excise tax is generally low however clearly visible in the comparison to other countries, where excise taxes make 25-50% of fuel prices. (Zhao et al 2018) (-1)