Carbon Pricing as a Policy Instrument to Decarbonize Economies

July 2019

THE EARTH INSTITUTE
COLUMBIA UNIVERSITY
RESEARCH PROGRAM ON
Sustainability Policy and Management

enel
Foundation

Report Authors: Satyajit Bose, Allison L. Bridges & Kelsie DeFrancia

With the Assistance Of: Juan Jose Guzman & Julian Bishop

With Scientific Contribution and Funding By: Enel Foundation

The Earth Institute's Research Program on Sustainability Policy and Management researches and develops public policy, management and financial tools that can enable organizations to incorporate dimensions of sustainability in routine organizational decision-making.

spm.ei.columbia.edu

Enel Foundation is a non-profit organization focusing on the crucial role of clean energy to ensure a sustainable future for all. By developing partnerships with pre-eminent experts and institution across the globe, leveraging on the vast knowledge of its Founders, Enel Foundation conducts research to explore the implications of global challenges in the energy domain and offers education programs to the benefit of talents in the scientific, business and institutional realms.

enelfoundation.org

Summary of Findings

With scientific contribution and funding by the Enel Foundation, the Earth Institute's Research Program on Sustainability Policy and Management has conducted a comparative study on the suitability of different carbon pricing mechanisms as policy instruments to mitigate climate change in different economic and institutional contexts.

This study analyzes the jurisdictional characteristics of economies where carbon pricing mechanisms (both carbon taxes and cap-and-trade schemes) have been implemented or proposed as a means to support decarbonization. Firstly, we compare certain average economic and emission-related characteristics of 37 countries, which have implemented or are considering implementing carbon pricing with the global average to derive a set of stylistic facts that appear to be correlated with the adoption of carbon pricing. We differentiate between carbon tax (CT) and emissions-trading (ETS) jurisdictions where possible. Secondly, we review the historical experience of 11 national and 2 sub-national jurisdictions, which either implemented carbon pricing or attempted to do so in vain. Finally, we perform an in-depth review of two case study countries (Chile and Colombia) which are in the process of implementing carbon pricing policies, to identify the key drivers of adoption as well as any barriers that may impact successful policy implementation or effectiveness. Throughout our analyses, we review ETS and carbon tax impacts on five policy choice criteria: (1) effectiveness in delivering environmental outcomes; (2) regulatory stability; (3) costs and distributional effects; (4) the coherence and interaction with other environmental and tax policies; and (5) an evaluation of the impact of global trade.

The following are key findings of the study:

Carbon pricing mechanisms incentivize the changes needed in consumption, production and investment behavior to induce the transition to a low carbon future. As a policy instrument, carbon taxes have been more widely adopted and therefore more successful at reducing emissions, though recent adaptations of ETS systems may overturn this conclusion in the future. Carbon taxes have been favored by governments because of their lower cost of implementation, the comparative ease of implementation, the potential to increase government revenue, and the potential for offsetting reductions in income taxes. Among the countries with mature carbon pricing policies reviewed in this report, those with carbon tax policies demonstrated greater reductions in greenhouse gas (GHG) emissions than countries with only ETS. However, recent reforms to the EU ETS, the New Zealand ETS, and the California cap and trade will likely improve ETS effectiveness in reducing emissions.

The local carbon price burden of a country (which can be proxied by the carbon price imposed by policy x emissions per capita, divided by GDP per capita) is an indicator of the likelihood of regulatory stability. The indicator embodies the ability of the average citizen to shoulder the burden of carbon prices and incorporates the impact of the proportion of domestic energy derived from renewable sources. The two focus countries in this case study, Colombia and Chile, have very low local carbon price burdens relative to the average carbon pricing jurisdiction and are thus unlikely to face abortive cancelations of carbon pricing policies.

Revenue-neutrality and transparent and socially accepted use of proceeds are key drivers of social acceptance of carbon pricing where they have a significant regressive impact. Low-income earners spend a greater proportion of their income on basic needs such as fuel and, as a result, feel a greater burden when taxes are increased. Fiscal policy that broadly considers interactions between tax policies, such as personal taxes and corporate taxes, are important for the success of carbon tax policies.

The degree to which there is cross-sectoral policy coherence within a jurisdiction impacts (1) the likelihood that a carbon pricing policy will reach implementation, and (2) the outcome of the policy. Analysis of environmental policy interactions across the domains of energy, climate change, transportation and natural resource management helps identify potentially counter-productive policies. There is no consistent approach for cross impact analysis of environmental policy regimes.

Carbon leakage, while often discussed, is not an economically significant obstacle for the countries actually considering carbon pricing. Jurisdictions that have chosen to implement carbon pricing have higher overall export intensity than the global average, suggesting that carbon leakage is not a significant concern for export-oriented economies. While this result was initially surprising, it is consistent with findings that carbon pricing is adopted by high and middle income countries which are more focused on services, so that the carbon-intensity of their exports is likely to be low.

The policy objectives of carbon pricing instruments have changed over time. Following the 1988 Toronto Conference on the Changing Atmosphere, Finland, Sweden, Norway, and Denmark fulfilled their pledge to reduce emissions by implementing the first unilateral carbon taxes in the world. Today, developing countries are increasingly embracing carbon pricing policies as part of larger tax reform efforts to meet multiple goals. Although this shift suggests likely gains in regulatory stability and policy coherence, clarity in policy objectives is needed to ensure that citizen support and investor confidence is maintained throughout the implementation process.

As emissions trading systems such as the EU ETS and the New Zealand ETS implement reforms to address market distortions or imbalances, there will likely be a continuation of global interest in establishing regional, national, and sub-national carbon markets. There is increasing interest in linked ETS systems such as the Regional Greenhouse Gas Initiative in the United States at the sub-national level and the proposed linked ETS of the Pacific Alliance at the supra-national level. Better alignment of policy frameworks is needed to ensure effective carbon price signals, particularly in newly developing systems in emerging markets.

A well-publicized implementation schedule, including a multi-phased approach to pricing, is needed to reduce economic or social shocks that can result from carbon pricing policies. Public perceptions of government effectiveness can impact the ability of a policy to be adopted, implemented, and sustained over time. Regardless of whether the burden of carbon pricing policies is real or perceived, the willingness of firms or households to accept additional taxation or emissions caps is critical for policy success.

CONTENTS

1. Introduction

According to the 2018 *IPCC Special Report: Global Warming of 1.5°C*, global warming will reach 1.5°C above pre-industrial levels between 2030 and 2052. The net present value of estimated damages from greenhouse gas emissions amounts to $2.7 trillion[1]. The commitments made as part of the Paris Agreement imply a finite carbon emissions budget for countries and companies. In the absence of an effective market price on the emissions of carbon, there is little incentive for the private sector to economize on carbon emissions. Carbon pricing mechanisms incentivize the changes needed in consumption, production and investment behavior to induce the transition to a low carbon future. This study analyzes carbon pricing mechanisms, specifically price-based mechanisms such as carbon taxes and quantity-based constraints such as cap-and-trade schemes, as a means to support decarbonization. The study comprises three parts. Firstly, we compare certain average economic and emission-related characteristics of 37 countries which have implemented or are considering implementing carbon pricing with the global average to derive a set of stylistic facts which appear to be correlated with the adoption of carbon pricing. We differentiate between carbon tax (CT) and emissions-trading (ETS) jurisdictions where possible. Secondly, we review the historical experience of 11 national and 2 sub-national jurisdictions which either implemented carbon pricing or attempted to do so in vain. Finally, we perform an in-depth review of two case study countries (Chile and Colombia) to identify the key drivers, or motivations, for adoption of carbon pricing policies as well as any barriers that may impact successful policy implementation or attainment of stated objectives.

To address climate-related risks to human and natural systems, governments around the world continue to set economic incentives and policies for decarbonization. As part of a growing toolkit of economic instruments that internalize the cost of greenhouse gas (GHG) emissions, governments have a choice among command-and-control regulations, carbon taxes, cap-and-trade systems, emission-reduction-credit systems, clean energy standards and the elimination of fossil fuel subsidies (Aldy & Stavins, 2012). Among these, carbon pricing schemes (comprising CT and ETS), are an important aspect of a comprehensive strategy for achieving sustainability targets. According to the World Bank, a total of 57 carbon pricing initiatives had been implemented or were scheduled for implementation as of June 2019 (World Bank Group, 2019b)[2]. Representing almost 20% of global GHG emissions, these initiatives cover 11 gigatonnes of equivalent carbon dioxide (GtCO2e). By setting an explicit price on GHG emissions, usually through an emissions trading system (ETS) or a tax on carbon, these programs provide a source of revenue while also working to mitigate emissions and incentivize the development of clean technologies. However, it should be noted that less than 5% of priced GHG emissions are

[1] See the report prepared by Trucost plc and the TEEB Coalition: *Natural Capital at Risk: Top 100 Externalities of Business*, April 2013. Accessed at https://www.trucost.com/wp-content/uploads/2016/04/TEEB-Final-Report-web-SPv2.pdf

[2] Of the 57 initiatives, 37 represent national jurisdictions.

currently priced at levels consistent with reaching the temperature goals of the Paris Agreement (World Bank Group, 2019b).

Tradable permits for the regulation of air pollution, first emerging in the economics literature in the 1960s, were implemented in the United States (US) in the 1970s. Endorsed by the US Environmental Protection Agency (EPA) under the Clean Air Act in 1977, market-based mechanisms to address sulfur dioxide and chlorofluorocarbons (CFCs) slowly gained traction throughout the 1980s in the US, Europe, and Canada (Voß, 2007). With growing awareness of the potential consequences of anthropogenic GHG emissions, the newly established Intergovernmental Panel on Climate Change (IPCC), founded in 1988, called for an international tradeable quota system. By the 1990s, the United Nations Framework Convention on Climate Change (UNFCCC), established in 1992, called on countries to agree to mandatory GHG emissions targets. The US, with its practical experience of emissions trading, led an alliance of countries supporting the proposal for an international carbon trading market at the third Conference of the Parties to the UNFCCC (COP 3) in Kyoto in 1997 (Stowell, 2005). At this time, the European Union (EU) was in favor of uniform binding commitments to reduce emissions by 15% but was generally opposed to, or at least highly skeptical of emissions trading as a mechanism for carbon abatement (Skjærseth & Wettestad, 2010). However, between 1998 and 2000, the European Commission built up knowledge, based on the US experience, and crafted support among stakeholders for the EU ETS (Skjærseth, 2010). The outputs of COP 3 led to the Kyoto Protocol, a treaty committing parties to the reduction of emissions. The Kyoto Protocol established three cost-containing flexible mechanisms to facilitate the trading of emissions reductions: the Joint Implementation (JI) for trade between developed countries, the Clean Development Mechanism (CDM) for trade between developed and developing countries, and trading of unused Assigned Amount Units (AAUs) by countries whose emissions were lower than required under the treaty.

Following the 1988 Toronto Conference on the Changing Atmosphere, Nordic countries pledged to reduce emissions by implementing the first unilateral carbon taxes in the world. The European Commission's carbon tax proposals in the 1990s failed due to the requirement of unanimity in the European Council, in a context where a number of EU countries were unwilling to allow EU-level taxation of any sort (Ismer & Haussner, 2016). In 1999, the UK announced intentions to implement a Climate Change Levy, a new tax on industrial energy use. Corporations responded negatively to the announcement in the UK and formed the Emissions Trading Group to lobby for an ETS over a carbon tax both in the UK and within the EU. The UK then allowed the industry sectors to commit to reduced energy use in return for an 80% reduction in the tax. The voluntary UK ETS, launched in 2002, was a venue to trade the resulting commitments to abate. Although there was very limited participation by sectors in the ETS, it did serve as the first cross-sector model of emissions trading in the world (Smith & Swierzbinski, 2007). Following the withdrawal of the US from the Kyoto Protocol in 2001, the European Commission pushed for the creation of an EU ETS. Despite early disagreements over the scope of the system and the cap, the EU ETS was linked to the Kyoto Protocol and launched in 2005 with the EU cap representing the total of the National Allocation Plans (NAP) for member states with no cap on the import of external credits (Skjærseth, 2010). The EU ETS operates in 31 countries, covers approximately 45% of EU GHG emissions and is still the largest carbon market in the world (EC, 2016). Additionally, in March 2019, Switzerland agreed to link the Swiss ETS with the EU ETS, which will allow its companies to trade in the broader EU emissions market. After Phase 4 reforms to the EU ETS adopted in 2018, prices are around \$22-28 per tCO_2e (World Bank Group, 2019b).

Learning from the early challenges faced by the EU ETS market in generating stable price signals, a few jurisdictions primarily outside the EU have pursued price-control mechanisms, including carbon price floors and ceilings[3]. In the absence of linkages with other markets, setting an appropriately designed upper limit can ensure that the cost of abatement does not exceed carbon reduction benefits, and a price floor can better reflect the long-term scarcity of allowances in the market. Reforms to the EU ETS include a more stringent decline schedule for the emissions cap and a Market Stability Reserve that will ensure that the supply of permits returns to scarcity by the next trading period beginning in 2021.[4]

ETS and carbon taxes in upper middle and middle-income countries are critical for achieving global carbon reduction targets. Recent international developments in the planning and implementation of carbon pricing mechanisms have occurred in China, Singapore, South Africa, Canada and Latin America. Having launched a national ETS in 2017, China is projected to soon be home to the largest carbon market in the world. Prices range between \$1 and \$11 per tCO_2e. In 2019, Singapore and South Africa have initiated carbon taxes at \$4 and \$8[5] per tCO_2e, respectively. Canada has adopted federal level and province level taxes and ETS mechanisms with prices ranging from \$16 to \$27 per tCO_2e. Carbon taxes have been implemented in Mexico (\$5), Chile (\$5), Colombia (\$6) and most recently in Argentina (\$6). Regional or national ETS markets are under consideration in Mexico, Colombia and Chile. Globally, ETS and carbon tax programs have significant variation in price, share of emissions covered, and revenues (World Bank Group, 2019b).

The steady growth of these national and subnational initiatives is associated with continuing growth in the total monetary value of traded permits and carbon tax receipts. With roughly US\$82 billion of value invested in these systems by December 2018 worldwide, investors use carbon pricing across jurisdictions to assess investment strategies and allocate capital toward low-carbon projects. The JI and CDM offset mechanisms have supported approximately US\$90

---

[3] The UK and Canada have utilized price floors since 2013 and 2016 respectively. In 2018, the Netherlands proposed a carbon price floor of \$15 per tCO2e rising to \$39 by 2030. In 2018, New Zealand announced the intention to consider price floors in enhancements to its ETS. New Zealand and state-level ETS in the United States have also proposed price containment reserves and/or price ceilings.

[4] The Market Stability Reserve adjusts the supply of allowances to improve price stability according to pre-defined rules. More information on EU ETS reform measures can be found in Emissions Trading Worldwide, International Carbon Action Partnership (ICAP), Status Report 2018.

[5] For the first phase, which will run until December 2022, tax breaks will reduce the effective rate of the carbon tax.

billion in cumulative GHG emission reduction investments under the Kyoto Protocol. In addition, a number of voluntary carbon pricing mechanisms have also proliferated globally in the last 15 years.

The private sector response to the jurisdictional efforts at decarbonization has been critical. The adoption of internal carbon pricing mechanisms not only help companies identify low-carbon investment opportunities, but also help manage climate associated risks. Collaborations and partnerships such as the UN Global Compact's Caring for Climate Business Leadership Criteria on Carbon Pricing, the Climate Disclosure Project (CDP), and the Portfolio Decarbonization Coalition (PDC) help companies both prepare for and drive divestment as fossil fuel subsidies are phased out. Interactions between global carbon pricing policies and private sector approaches are likely to be relatively important for low income countries, which have been slow to implement carbon pricing policies at the governmental level.

Internal carbon pricing initiatives by multi-national corporations, sector-based incentive programs, investor managed financial incentives such as Results-based Climate Finance (RBCF) and voluntary carbon offset markets have proliferated and show no signs of slowing. As reported in the 2017 CDP report, *Putting a Price on Carbon*, over 1,300 companies were either already using a plan that placed an internal price on carbon or planned to use one prior to 2019. In 2017, the majority (83%) of these companies that had adopted low-carbon business models were located in countries that have mandatory or planned carbon pricing policies. Corporate carbon prices vary across jurisdictions to take into account price differences and the impact of mandatory carbon pricing.

1.1. Policy Choice Background

The choice between cap-and-trade and carbon tax mechanism has varied across jurisdiction. Many jurisdictions have also utilized a mix of mechanisms. The theoretical analysis of the optimal choice of carbon pricing mechanism is well understood, as outlined by Weitzman (1974). Weitzman showed that when policies are evaluated based on economic efficiency, and the carbon budget is known with greater certainty than damage costs, quantity-based constraints such as emission trading schemes are preferred to carbon taxes. Conversely, when damage costs are known with greater certainty, price-based mechanisms are preferable for static efficiency. This means that in theory, if static efficiency is the overarching objective of policy choice, then an ETS should be selected when the quantity of abatement needs to be certain. Conversely, when the quantity can be uncertain, but the per unit cost of abatement needs to be certain, then a tax is the preferred choice. In practice, static efficiency is not the only important goal. A number of other considerations, such as ease of implementation, political feasibility, transparency, impact on incentives for innovation and dynamic considerations in the resolution of uncertainty complicate the choice of optimal policy instrument. The variety of country-specific contexts implies that the optimal choice will vary across jurisdiction. There is no current overarching theory that prescribes the optimal policy or combination of policies based on a finite set of jurisdiction-specific attributes.

Country specific conditions, such as the level of GDP per capita, the importance of renewable sources in the energy mix, or the salience of exports to the economy may potentially impact both the decision to adopt carbon pricing and the type of policy selected. In turn, the adopted choice (of an ETS or a carbon tax) may affect policy effectiveness, regulatory stability, and related *policy choice impacts* which determine the long-run efficacy of policy adoption.

1.2. Country Specific Conditions

The first step of our analysis is a comparison of the average country specific conditions of 37 jurisdictions and the European Union, which have implemented or are considering implementing carbon pricing, with the global average to derive a set of stylistic facts that appear to be correlated with the adoption of carbon pricing.

In choosing to adopt or in designing carbon pricing policies, national governments must balance economic growth objectives with greenhouse gas (GHG) emissions targets. The capacity of the economy to bear the cost of abatement is a function of the level and growth of GDP, as well as the structure of GDP[6]. The cost of abatement depends on the existing level of emissions per capita and the share of fossil fuels in the energy mix. To minimize any negative economic impact of carbon pricing, policy makers will strive to use revenues in a way that reduces abatement costs over time (through substitution or innovation) and/or offsets the potentially regressive impact on income distribution through social welfare programs. As trade-offs and compromises are often necessary for governments to advance the adoption of carbon pricing policies, earmarking revenues is common and can serve diverse purposes such as tax cuts, redistribution, green investment, or special funds such as the Colombia Peace Fund.

The salience of exports to the economy may determine whether carbon leakage is a concern. The level of concentration among emitters may affect whether it is feasible to implement carbon pricing. This can in principle act in opposing ways: a high concentration among emitters makes it easier to administer carbon pricing through monitoring, reporting, and verification (MRV) processes. On the other hand, a high concentration makes it more likely that emitters will be able to form effective coalitions to block carbon pricing or dilute its impact if implemented. The dependence of the government on revenues from carbon pricing and the stability of such revenues may also potentially affect the decision to adopt carbon pricing.

In Table 1, we list the country specific conditions we chose to review for the 37 countries that have adopted or are considering adopting carbon pricing policies.

Table 1. Country Specific Conditions Reviewed

1.	GDP per capita, level and growth rate
2.	Structure of GDP

[6] That is, the proportion of value added derived from the tertiary (services) sector relative to the primary (agriculture and natural resource extraction) and secondary (industrial and manufacturing) sectors.

3.	GHG emissions per capita
4.	Share of fossil fuels in energy mix
5.	Local carbon price burden
6.	Exports as a % of GDP
7.	Number of regulated emitters
8.	Expected revenue from carbon pricing as a % of government revenue
9.	Historical standard deviation of government revenue
10.	Use of proceeds (earmarked or general purpose)

We discuss the results of our analysis of these country-specific conditions in Section 2.

1.3. Policy Choice Impacts

The adopted choice of ETS or carbon tax can be expected to have different policy impacts. A goal of this project is to assess the relationship between the country specific conditions and the performance of the policies in terms of a set of five impacts. In order to review policy choice impacts, we need to narrow the range of countries we review to those which implemented or attempted implementation of policies at least 5 years ago. We therefore review the historical experience of 11 national and 2 sub-national jurisdictions which either implemented carbon pricing or attempted to do so in vain[7]. For this part of the study, we integrate an assessment of the following performance criteria: (1) effectiveness in delivering environmental outcomes, so that there is a high likelihood of remaining within the appropriate carbon budget; (2) regulatory stability, so that a dynamic program of policies can be implemented without risk of abortive cancelations; (3) costs and distributional effects, to ensure that the marginal costs of abatement are minimized while mitigating the adverse distributional impact of a potentially regressive increase in energy costs; (4) the coherence and interaction between and with other policies designed to further a transition to a global low carbon economy; and (5) an evaluation of the impact of global trade, both between and within corporations, so that carbon pricing mechanisms do not have unintended effects leading to cross-border carbon pricing arbitrage. These five policy choice outcomes are listed below in Table 2.

Table 2. Policy Choice Impacts

1.	**Policy Effectiveness**: effectiveness in delivering environmental outcomes
2.	**Regulatory Stability**: the absence of abortive cancelations

[7] Selected national jurisdictions: Australia, Denmark, Finland, France, New Zealand, Norway, Poland, Sweden, Switzerland, United Kingdom, and United States. Selected sub-national jurisdictions: California, US, and British Columbia, Canada.

3.	**Costs and Distributional Effects**: cost minimization and equitable incidence of burden
4.	**Policy Coherence:** Interaction between and with other policies
5.	**Impact of Trade**: minimization of carbon leakage

It would be ideal to utilize precise quantitative proxies for these policy choice impacts that could be measured for all jurisdictions considered. Unfortunately, this is not feasible. We examine the measurability of each of these policy choice impacts in turn below.

Policy Effectiveness: Given the recent implementation of carbon pricing policies in most jurisdictions, policy effectiveness (in the form of the consequent level of decarbonization or decoupling) is quantifiable in just a handful of the smallest jurisdictions which implemented carbon taxes in the 1990s. There is no shortage of economic impact or cost-benefit analyses of carbon pricing policies (see Böhringer et al., 2009; Jenkins, 2014). While there is consensus that carbon pricing mechanisms can result in net economic and social benefit, many of the measures of success are external to standard calculations of GDP, occur over long time periods and are computed solely for the domestic cost-benefit analyses of internal regulations and not for cross-country comparison.

Regulatory Stability: There are qualitative descriptions of regulatory stability but perhaps because of the varying political structures and degrees of governmental support across the 11 countries, this concept is difficult to quantify precisely. In Section 3, we discuss the performance of two quantitative indices but the results of our review are inconclusive on this aspect.

Costs and Distributional Effects: These can be captured quantitatively, and are utilized in the approach developed in Section 3.

Policy Coherence: This is necessarily a qualitative discussion at this stage due to the variety of interactions. Complementary policy tools include renewable energy targets, energy-efficiency standards, fuel-economy regulations, and subsidies for low-carbon technologies. These approaches interact with carbon pricing in sometimes unexpected ways.

Impact of Trade: The relative importance of exports can be captured quantitatively and the potential for carbon leakage is discussed in Section 3.

These policy choice impacts are then evaluated, in Section 3, across 11 national jurisdictions and 2 sub-national jurisdictions.

1.4. Application to Case Study Countries

The third and final part of the study consists of an evaluation of newly developing carbon pricing policies in Chile and Colombia, using the stylistic jurisdictional attributes of section 1.2 and the five policy choice impacts of section 1.3. We use the framework in order to identify the key drivers, or motivations, for adoption of carbon pricing policies as well as any barriers that may impact successful policy implementation or attainment of stated objectives. Our results are discussed in Section 4.

2. Drivers of Carbon Pricing Adoption

In this section, we review the country specific conditions listed in section 1.2 for the 38 jurisdictions listed in the World Bank's Carbon Pricing Dashboard as having implemented or considering the implementation of one or more carbon pricing policies. The countries include 24 countries that have implemented or plan to implement carbon taxes, 8 countries and 1 supra-national region that have implemented or plan to implement ETS mechanisms, and 5 countries that remain undecided, have implemented both taxes and ETS or a hybrid of the two policies[8].

Of the 10 country specific conditions reviewed, we were able to draw meaningful quantitative conclusions for the first six attributes. The average values of these six conditions for countries adopting carbon pricing was compared to international benchmarks in an effort to parse out potential patterns. The matrix in Table 3 summarizes the results of this comparison for the six attributes. We qualitatively discuss the conclusions of our review of the remaining 4 country specific conditions in section 2.2 below.

Table 3. Matrix of Stylistic Attributes of ETS/Carbon Tax Choice

	ETS	Carbon Tax
1. GDP per capita	Carbon pricing has been implemented in middle to high-income countries.	
	Lower per capita GDP ($28,000). Higher growth rate (4.2%)[9].	Higher per capita GDP ($41,000). Lower growth rate (2.4%).
2. Structure of GDP	Carbon pricing has been implemented in countries where the proportion of value added from the services sector exceeds 50%[10].	
	Lower share of services sector (59%).	Higher share of services sector (66%).
3. Emissions per capita	Carbon pricing countries have higher emissions per capita (7.3 tons) than the global average (5.0 tons).	
	Higher emissions per capita (7.4 tons)	Lower emissions per capita (7.0 tons)

[8] See the data_national tab of the accompanying spreadsheet for a list of jurisdictions and associated policy.

[9] Note that the two largest ETS jurisdictions are China and the EU. The inclusion of China as an ETS jurisdiction significantly reduces the average per capita GDP and significantly increases the growth rate of ETS jurisdictions in this analysis.

[10] To date, in all countries where carbon pricing has been implemented, the share of value added from the services sector exceeds 50%. Two countries where this share is less than 50% are considering carbon pricing (Cote d'Ivoire and Vietnam) but there are no plans for implementation yet.

4. Fuel Mix in Electricity Generation	Carbon pricing countries have a lower proportion of fossil fuel (72%) in the electricity generation mix than the global average (77%). There is no discernible difference between ETS and CT jurisdictions.	
5. Local Carbon Price Burden[11]	Carbon pricing countries have an average local carbon price burden of 0.32% of GDP per capita[12].	
	Lower local carbon price burden of 0.19% of GDP per capita.	Higher local carbon price burden of 0.27% of GDP per capita.
6. Exports as a Share of GDP	Carbon pricing jurisdictions have higher overall export intensity (34.2% exports as a % of GDP) than the global average (28.5% exports as a % of GDP).	
	Lower export intensity (33.9% exports as a % of GDP).	Higher export intensity (36.3% exports as a % of GDP).

We discuss some of these six attributes in order to identify jurisdictions where carbon pricing mechanisms have the greatest potential to lead to the policy choice impacts listed in section 1.3.

Of the 185 parties who have ratified the Paris Agreement, 96 parties (representing 55% of global GHG emissions), have stated they are planning or considering the use of carbon pricing instruments to meet their nationally determined contributions (NDCs).[13] To date, of the 37 national jurisdictions analyzed in this report that have implemented or are currently considering implementing carbon pricing, only 3 are lower-middle income economies (Côte d'Ivoire, Ukraine, and Vietnam). As carbon pricing can raise the cost of energy-intensive goods and services, many middle-income countries struggle to identify ways to price carbon in a way that does not impede the cost of living or economic growth. ETS regimes appear to have lower GDP per capita and higher growth, though these statistics are heavily impacted by the presence of China as an ETS regime. The EU, with very high GDP per capita and low growth relative to the global average, balances this somewhat.

All carbon pricing jurisdictions have a high share of services in GDP. Of the 37 nations that have expressed interest in carbon pricing policies, all but two derive over half of their economic output from the services sector. Carbon tax regimes have a higher share of services than ETS regimes. Perhaps this is because the incidence of carbon taxes are more obvious to end-users who are less likely to be concerned about such incidence in the service sector than in the primary or tertiary sector. Linkages between the economy and GHG emissions can be found across all sectors including transport, manufacturing, energy production, forestry, and agriculture. In general, as

[11] The local carbon price burden is defined as the carbon price imposed by policy times emissions per capita, divided by GDP per capita.

[12] Carbon pricing jurisdictions include three jurisdictions (Canada, Switzerland and the UK) which are classified as having features of both ETS and carbon tax regime. These three jurisdictions are not used to compute ETS and tax averages. Switzerland, in particular, has a very high local carbon price burden of 0.64%. Consequently, both the ETS and tax categories have average local price burdens that are less than the overall carbon pricing category average.

[13] For more information on each country, see World Bank Group, *State and Trends of Carbon Pricing, 2019.*

GDP rises, GHG emissions rise and per capita GDP rises in tandem with household energy demand. However, cross-sector policy interactions can result in a decoupling of per capita GDP and energy intensity, as seen in California. In order to design a carbon pricing policy that applies to a large percentage of emissions while also minimizing potentially negative economic impacts, policy makers tend to target the largest and most easily regulated emitters first. Countries with shrinking industrial and manufacturing sectors make greater progress toward emissions reduction targets by focusing on the energy sector. Among countries that have large industrial sectors, such as China (deriving 40% of its economic output from the industrial sector), carbon pricing strategies are strategically inclusive of both the industrial and energy sectors making trading schemes both more effective and more difficult to implement and control pricing. The ambitious national ETS of China, on track to be the largest carbon market in the world once fully implemented, will cover eight sectors beginning with the energy sector and expanding to include key industrial sectors in the coming years.

The need for sound laws and regulations, and the institutional capacity to uphold and implement them, is well documented as a necessary component of effective carbon pricing policies (EC, 2019). Laws and frameworks for implementation provide enabling conditions for new markets and reduce the uncertainty that undermines investor confidence. Among countries adopting carbon pricing policies, the degree of government control over the energy sector and the degree of private sector involvement varies significantly. Locally specific economic and political contexts have resulted in policy innovations that increase renewable adoption rates in various ways. Challenges in policy implementation are, however, common as the need for data accuracy and transparency is universal across carbon pricing mechanisms.

Carbon pricing countries have higher emissions per capita than the global average. Higher emissions per capita raise the cost of abatement on a per capita basis, encouraging governments to utilize carbon pricing to distribute the abatement cost according to emissions, rather than absorbing such costs economy-wide in a more general way. ETS regimes have a higher emissions per capita than carbon tax regimes.

Countries that have so far adopted or are considering carbon pricing have a lower proportion of fossil fuel in the electricity generation mix than the global average. There is no discernible difference between ETS and CT jurisdictions. Research suggests carbon pricing policies that target energy sector emissions have been inconsistently successful in increasing the percentage of renewables and in increasing the return on investment for renewables (Wagner, 2015). The incorporation of renewable energy and energy efficiency targets along with emissions reductions targets in the EU’s INDC aims to improve the cost-efficiency of abatement by increasing incentives for innovation in clean energy technologies (Corradini et al., 2018). In the case of Sweden, home to both the oldest and highest carbon tax in the world, a mix of policies applicable to the energy sector have resulted in steadily declining energy sector emissions, lower energy intensity, and switching to cleaner fossil fuels (Ackva and Hoppe, 2018). Success in reaching emissions reduction targets in the energy sector depends on specific national and sub-national characteristics. Additionally, carbon pricing policies depend on well-defined energy strategy policies, and time-lines for implementation, to enable the opening of markets for renewable energy generation. Both ETSs and carbon taxes must take into consideration how carbon pricing interacts with other environmental policies as well as broader fiscal policies, energy policies, and industrial policies – all of which can impact the carbon price signal. Renewable energy policy, fossil fuel subsidies, fuel efficiency standards, and transport sector policies are particularly important as are incentives for and likelihood of technological transformation.

An initially surprising result is that carbon pricing jurisdictions have higher overall export intensity than the global average, suggesting that carbon leakage is not a significant concern for export-oriented economies. While this result was initially surprising, it is consistent with the preceding findings on the level and structure of GDP. Since most carbon pricing jurisdictions have high GDP levels and are more focused on services, it is likely that the carbon-intensity of exports is low. Hence, carbon leakage, while often discussed, may not be an economically significant obstacle for the countries actually considering carbon pricing.

2.1. Stylistic Attributes of Adopting Countries

Our review of the jurisdictional attributes of the selected implementing countries suggests the following approach for identifying countries likely to have robust policy choice impacts (such as effectiveness and regulatory stability) in implementing carbon pricing:

Advanced Income Level and Economic Structure: High- and middle-income countries are likely to have the economic capacity and institutional infrastructure to impose the MRV systems necessary for carbon pricing. We should expect to observe that countries with high and middle incomes per capita and a value added from the service sector greater than 50% are the ones most likely to implement carbon pricing.

Reduced Relative Local Price Burden: We have observed that higher emissions countries have been the first to adopt carbon pricing policies. Carbon pricing jurisdictions have higher emissions per capita (7.25 tons) than the global average (4.97 tons). Among adopting countries, higher emission countries have a higher absolute cost of implementation. Looking at just emissions per capita, the impact on policy effectiveness and stability is ambiguous. By computing the local cost of per capita emissions as a proportion of per capita GDP, we arrive at a more precise estimate of the local burden of imposing carbon pricing. The average local price burden among carbon pricing jurisdictions is 0.32% of GDP per capita[14]. We should expect that countries with local price burdens below 0.32% are likely to display regulatory stability.

[14] This is relatively low because the actual carbon prices prevailing in most jurisdictions fall far short of the levels needed to meet the goals of the Paris Agreement.

Renewables in Electricity Generation Mix: Countries with a lower proportion of fossil fuels in the electricity generation mix have a stronger incentive to impose carbon pricing since, *ceteris paribus*, such countries have a lower relative cost of abatement. Jurisdictions that have so far introduced carbon pricing have a lower proportion of non-renewable fuel in electricity generation (72%) than the global average (77%). We should expect that among carbon pricing jurisdictions, those with higher renewable energy shares are more likely to have regulatory stability since the cost of abatement is relatively low.

Lower Carbon Intensity of Exports: Carbon pricing jurisdictions have higher overall export intensity (34% exports as a % of GDP) than the global average (29% exports as a % of GDP). Among adopting countries, export-intensive economies are likely to face competitive pressures if they specialize in carbon-intensive exports. Hence, we would expect that countries with export intensities lower than 34% and with relatively low carbon intensity of exports are more likely to have regulatory stability.

2.2. Inconclusive Country-Specific Conditions

Number of regulated emitters: This attribute was difficult to quantify with the available data. We were unable to find a consistent data source for this attribute for the range of countries considered.

Expected revenue from carbon pricing as a % of government revenue: This attribute was difficult to quantify. We were able to obtain expected revenue for approximately 20 jurisdictions. However, realized revenue was available for a handful of countries, as many of the jurisdictions have only recently implemented policies. We were not able to establish that the level of comparability for the expected revenue numbers that were available was sufficient to justify drawing conclusions from the available data.

Historical standard deviation of government revenue: We were able to compute this metric. The computed average share of government revenue in GDP is higher for carbon tax regimes (28%) than for ETS regimes (16%). However, there were a number of countries among the ETS regimes with unreliable data. Therefore we are reluctant to draw any conclusions from this metric or its derivative such as the standard deviation of the share of government revenue.

Use of proceeds (earmarked or general purpose): Notwithstanding the importance of the use of proceeds for the effectiveness of carbon pricing policies, it was not possible to collect conclusive evidence due to unclear/insufficient information, and is therefore not analyzed in this study.

3. Comparison of Mature Carbon Pricing Policies

Carbon pricing mechanisms that incentivize emissions reductions are tailored to the specific economic, political, and social contexts of the implementing country. Although success or failure can often be location dependent, the country specific conditions identified above are broadly representative of the initial characteristics that determine the appropriateness and efficacy of carbon pricing policies. Those conditions create an enabling environment for successful implementation, and continuation, of carbon pricing policies.

In order to assess policy effectiveness in jurisdictions with a long history of carbon pricing policies, this section analyzes policy performance based on the five policy choice impacts listed in Section 1.3 (policy effectiveness, regulatory stability, costs and distributional effects, policy coherence and the impact of trade). We review the historical experience of 11 national and 2 sub-national jurisdictions with a history of either success or failure in implementing carbon pricing policies. We use a set of economic, environmental and institutional indicators and indices (Table 4) to evaluate policy performance. All indicators were selected based on a review of available academic and gray literature.

Table 4. Key Indicators for Evaluating Carbon Pricing Policies[15]

Attribute	Indicator
Policy Choice	Carbon Tax or ETS
	Implementation Year
	Relation to other carbon pricing initiatives
Emissions	CO_2 emissions per capita (excluding LULUCF) (metric tons per year per capita)
	Total GHG (excluding LULUCF) per unit of GDP
	Carbon price and/or tax per ton (US$/$tCO_2e$)
	Share of jurisdiction's GHG emissions covered (%)
	Number of patents, technology development for climate change mitigation
Economic Structure	GDP, (current US$)
	GDP per Capita, PPP (current US$)
	GDP Growth Rate (%)
	Structure of Economic Output (%)
	Imports as a % of GDP
	Exports as a % of GDP
	HH Market Concentration Index
	Index of export market penetration
	Participation in Free Trade Agreements
Governance	Environmental Policy Stringency Index
	Governance Effectiveness Index
	Regulatory Quality Index
Revenue Structure	Government Revenue (% of GDP)
	Total Government Revenues (US$ Million)

[15] See the readme tab of the accompanying spreadsheet for detailed data descriptions and sources.

	Historical standard deviation of government revenue as % of GDP (2007-2017)
	Taxes on incomes, profits, and capital gains of individuals (% of total)
	Taxes on incomes, profits, and capital gains of corporates (% of total)
	Total Environmental Tax Revenue (% of GDP)[16]
	Government revenues from carbon pricing only (US$ Million)
	Revenue from carbon pricing as a % of government revenue
	Categorical analysis of use of proceeds (earmarked or general purpose)
Energy Sector	Share of Non-Renewable Energy Use in the Energy Mix (percentage of total final energy consumption)
	Share of Non-Renewable (% of electricity generation)
	Energy use (kg of oil equivalent per capita)
	Europe Brent Spot Price FOB ($US per Barrel)[17]

Sources: World Bank, OECD: Organisation for Economic Co-operation and Development, WITS: World Integrated Trade Solutions, IEA: International Energy Agency, and data available through national governments.

The review of mature carbon pricing systems of our selected focus countries is found in Table 5. Australia, France, and the United States (US) are included as representative of countries that have struggled to successfully implement national carbon pricing policies. The sub-national ETS in California, US, and the carbon tax implemented in British Columbia, Canada, are considered separately due to differences in data availability.

Table 5. Mature Carbon Pricing Policies: Selected Focus Jurisdictions

Country	Implementation Year	Type of Policy Instrument and Rational for Inclusion
Finland	1990	Finland, Sweden, Norway, and Denmark, following the 1988 Toronto Conference on the Changing Atmosphere, fulfilled their pledge to reduce emissions by implementing the first unilateral carbon taxes in the world.
Sweden	1991	
Norway	1991	
Denmark	1992	
Poland	1990	Poland included a carbon tax within broader reforms that took place in the early years of the country's economic and political transformation. Poland is an example of the way in which a lack of policy coherence (such as combined frameworks for fossil fuel subsidies and carbon pricing) can weaken policy outcomes.
EU	2005	The world's first international ETS was set up in the EU in 2005, and remains the largest carbon market in the world. The EU ETS operates in all 28 Member States of the European Union as well as Norway, Iceland, and Liechtenstein.

[16] According to the OECD's PINE Database, environmentally related taxes include energy products (including vehicle fuels); motor vehicles and transport services; and measured or estimated emissions to air and water, ozone depleting substances, certain non-point sources of water pollution, waste management and noise, as well as management of water, land, soil, forests, biodiversity, wildlife and fish stocks.

[17] Since 2013, Brent crude has been the global oil benchmark and is most relevant for the focus countries reviewed in this analysis.

Switzerland	2008	Although included in the 1999 Act on the Reduction of Carbon Dioxide Emissions (CO_2 Act), the carbon levy in Switzerland did not take effect until 2008, the same year the national ETS was launched. The country provides an example of a combined national ETS and carbon tax system.
New Zealand	2008	Implementing a carbon pricing scheme in 2008, following the Climate Change Response Act of 2002, New Zealand's ETS differs from other global models in that it did not initially set a cap on the volume of emissions and it includes the forestry sector. The Government of New Zealand announced in 2018, however, that the system will now implement a cap limiting the number of tradable units in an effort to increase investor confidence.
US	N/A	Although home to two successful sub-national ETSs, the United States has been unable to pass a nationwide carbon pricing policy.
Australia	2012	A carbon tax was introduced in 2012 and repealed in 2014 after a change in leadership.
UK	2013	Announced in 1999 and implemented in 2001, the Climate Change Levy is a fuel tax on industrial and commercial users. Criticized for not being a true carbon tax, the UK additionally implemented a carbon price floor in 2013 to incentivize low-carbon electricity generation.
France	2014	Passed in 2014 and implemented in 2017, the carbon tax was suspended in 2018 following civil unrest.

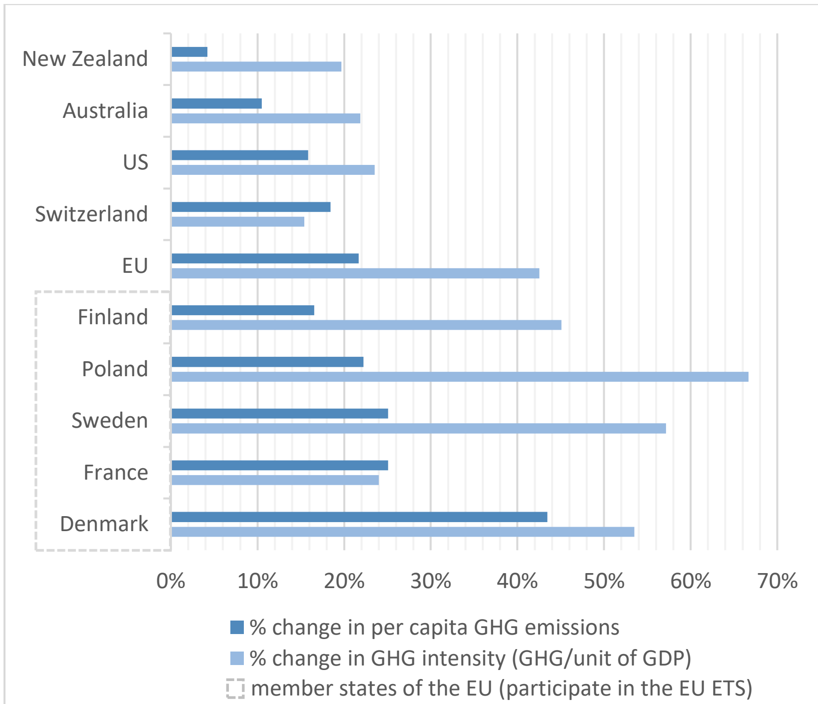
3.1. Policy Effectiveness

Figure 1 summarizes the reduction in GHG emissions since the implementation of a carbon pricing policy in the focus countries. The EU ETS covers 31 countries (the 28 Member States of the European Union as well as Norway, Iceland, and Liechtenstein) and applies to approximately 45% of total EU GHGs (European Commission, 2016b). It should be noted that emissions reductions result from multiple drivers including economic conditions, fuel switching, and energy and environmental policies other than carbon pricing mechanisms. As this analysis does not attempt to establish a causal relationship, a counterfactual baseline is not calculated. Moreover, no attempt is made to distinguish between the incremental impact of a national policy versus that of the EU ETS within the EU country. As the focus of this review is the jurisdictional characteristics of nations where carbon pricing mechanisms have been implemented, the EU ETS itself is not a focus of this analysis. When implemented in Phase 1, the EU ETS applied primarily to energy intensive manufacturing and power generation and has since expanded to other sectors. Firms obligated to participate in the EU ETS are exempt from carbon taxation schemes.[18]

[18] More information on the effectiveness of the EU ETS in general can be found in "Evaluation of the EU ETS Directive" (European Commission, 2015).

The countries with the greatest decline in per capita emissions were those with nation-wide carbon tax policies that also participate in the EU ETS, with the exception of Finland. In New Zealand and Switzerland, the suite of environmental policies that include national level ETSs did not result in significant changes in GHG emissions intensity or emissions per capita in comparison to other focus countries. For countries that either repealed or never adopted a carbon pricing policy (France, US, and Australia) the reduction is calculated for the period 2005-2016.

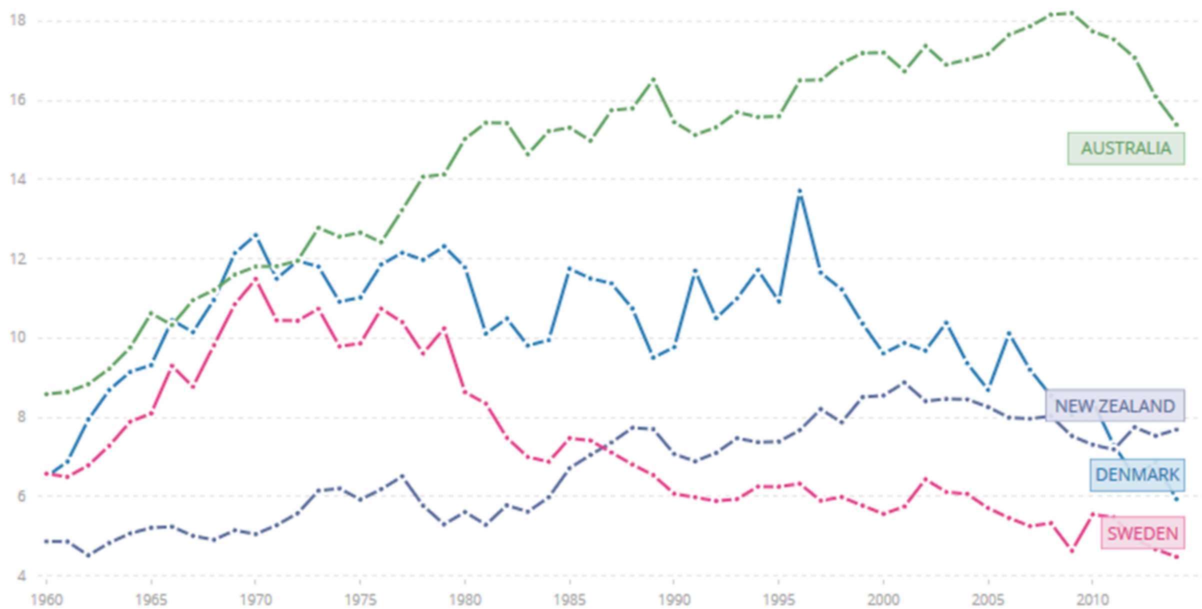
Figure 1. Reduction in GHG emissions since policy implementation (%)[19]



Denmark, with the greatest reduction in both GHG intensity and per capita GHG emissions, implemented an energy tax in 1977 and later implemented a carbon tax in 1992. The combined taxes sent price signals encouraging energy efficiency while also generating $70 billion in revenue (Sovacool, 2013). According to the OECD, the share of CO_2 emissions from energy use priced by taxes (excise and carbon) in Denmark is 54% while the EU ETS prices 28% (OECD, 2016).[20] Figure 2 below is a multi-decadal comparison of Denmark to Sweden, another EU country with a mature carbon pricing policy, as well as New Zealand, a country with only an ETS, and to Australia, a country with a repealed national carbon pricing policy. Since 2000, all countries experienced a reduction in GHG emissions as a result of aggregate environmental or energy policies as well as technology-driven efficiency gains in key sectors.

[19] Norway is omitted because of the high level of volatility in emissions data for the years collected. The UK is also excluded due to the short time period since implementation of the carbon tax floor.
[20] Entities participating in the EU ETS are exempt from the carbon tax.

Figure 2. CO_2 emissions, excluding LULUCF (metric tons per capita)[21]



Countries design carbon pricing policies based on their locally unique GHG emissions inventory and economic structure. As seen in Table 5 below, of the 11 focus countries, only Denmark and Sweden have significantly uncoupled GHG emissions and GDP growth. Poland has experienced a reduction in GHG emissions and strong annual growth in GDP since adopting a carbon tax in 1990 though it is unlikely that these phenomena are related. The carbon tax only applies to 4% of GHG emissions and its level is very low ($0.08). The emissions reduction in Poland is largely attributed to modernization of coal-fired power plants and the shuttering of energy-intensive plants during the transition to a market economy (World Bank, 2011). Poland continues to generate 80% of its electricity from non-renewable sources.

Table 6. GDP Growth Rate and Emissions Intensity[22]

Country and Year Since Policy Implementation	GDP Growth Rate (annual)	Total GHG (excluding LULUCF) per unit of GDP
Australia		
0	3.19	0.64
5	2.05	0.57
current	1.96	0.50
Denmark		
0	1.96	0.43
5	3.26	0.41
10	0.47	0.32
current	2.24	0.20

[21] LULUCF: land use, land-use change, and forestry; Source: World Bank Open Data
[22] UK is excluded. Data availability is limited to two years (2013-2014).

Finland		
0	0.68	0.51
5	4.21	0.52
10	5.63	0.40
current	2.60	0.28
France		
0	1.61	0.25
5	1.97	0.22
current	1.82	0.19
New Zealand		
0	-1.55	0.61
5	2.02	0.55
current	3.03	0.49
Norway		
0	3.08	0.28
5	5.03	0.25
10	2.09	0.23
current	1.92	0.17
Poland		
0	0.00	1.23
5	6.95	1.04
10	4.56	0.71
current	4.81	0.41
Sweden		
0	-1.15	0.28
5	1.52	0.29
10	1.56	0.21
current	2.30	0.12
Switzerland		
0	2.15	0.13
5	1.85	0.12
current	1.09	0.11
United States		
0	3.35	0.51
5	2.53	0.46
current	2.27	0.39

Source: OECD: Organisation for Economic Co-operation and Development

New Zealand has experienced strong annual growth in GDP and decreasing emissions but is not considered to have successfully uncoupled GDP and GHG emissions. Characterized by a large agricultural sector, the country derives nearly half of its total emissions from agriculture, forestry, and other land use. The New Zealand ETS was originally planned to cover all sectors, uniquely including forestry and agriculture, over a phased five-year period. The system also allowed for the unlimited importation of carbon credits from other international markets (Diaz-Rainey and Tulloch, 2018). The phased implementation, introduced to address concerns that the ETS would impact the competitiveness of New Zealand's agricultural products, ultimately resulted in an indefinite delay in the inclusion of the agricultural sector.

3.2. Regulatory Stability

This section considers governance attributes that impact the likelihood that carbon pricing instruments will be adopted and sustained. These attributes are government effectiveness and regulatory stability. Regulatory stability is captured in the OECD Regulatory Quality Index and represents the "ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" with higher scores corresponding to better governance. The OECD Government Effectiveness Index (also with higher scores indicating better governance) is a composite score based on 31 data sources capturing "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies."

Table 7. Government Effectiveness and Regulatory Quality, Focus Countries[23]

Country	Date	Government Effectiveness	Regulatory Quality
Australia	2005	1.75	1.60
	2016	1.57	1.90
Denmark	1997	1.76	1.78
	2016	1.88	1.58
Finland	1995	1.72	1.55
	2016	1.83	1.82
France	2005	1.67	1.25
	2016	1.41	1.07
New Zealand	2008	1.68	1.80
	2016	1.84	2.04
Norway	1996	1.95	1.53
	2016	1.87	1.70
Poland	1995	0.68	0.72
	2016	0.70	0.95
Sweden	1996	1.92	1.32
	2016	1.77	1.85
Switzerland	2008	2.04	1.56
	2016	2.01	1.91
United States	2005	1.54	1.61
	2016	1.48	1.50
United Kingdom	2008	1.64	1.79
	2016	1.41	1.71

Sources: OECD Regulatory Quality Index, OECD Government Effectiveness Index

[23] Government effectiveness and regulatory quality indices range from -2.5 (weak) to 2.5 (strong).

Regulatory quality has increased in all focus countries that have a carbon pricing policy with the exception of Denmark. Although Denmark has had the greatest success in lowering GHG emission while uncoupling economic growth, the decrease in the regulatory quality index in Denmark was likely the result of a period of regulatory change undertaken to boost competitiveness, business efficiency, and business innovation. Unsurprisingly, the degree of perceived government effectiveness has decreased between 2005 and 2017 in the countries with controversial changes in leadership and failed carbon pricing policies (US, Australia, and France). Although the carbon tax policy in the UK has experienced recent success, changes in leadership and the controversial exit from the EU has also led to a declining score in government effectiveness. Relatedly, France and the US experienced a decrease in the score for regulatory quality for the same period.

As mature carbon pricing instruments are mostly found in European countries, the 7th Environment Action Programme (EAP) of the European Commission guides the target objectives of these, and other, environmental policies. The EAP specifically calls for improved implementation of existing legislation suggesting challenges remain in addressing institutional barriers. Perceptions of government effectiveness and locally unique political environments can be significant impediments to the adoption and implementation of effective carbon pricing policies. In Australia, the carbon pricing scheme that was introduced in 2012 was well designed to account for both equity and efficiency. However, a change in political leadership, combined with a growing negative perception of the tax, led to its repeal in 2014.

The effectiveness of an ETS as a policy instrument is reliant on stringent systems for monitoring, evaluation, and reporting so that baseline and additionally assessments are accurate. Both New Zealand and Switzerland, with national level ETSs, have increased their score for regulatory quality since policy adoption. Among the focus countries, seven are members of the European Union and are therefore subject to binding environmental targets of the EU in order to trade in the EU ETS market. This participation in regional ETSs underscores the need for high scores in both government effectiveness and regulatory quality in all focus countries.

3.3. Costs and Distributional Effects

Carbon tax revenue is a relatively small contribution to overall tax revenues in all countries (less than 5%) suggesting that the role of the tax in reducing taxes on labor is minimal. At the margin, however, the percentage is more pronounced. As concluded by the OECD, corporate taxes are most harmful for growth, followed by personal income taxes (Convery, Dunne, and Joyce, 2013; OECD, 2009). Of the countries profiled with mature systems, only Poland experienced a significant increase in environmental tax revenue, as a percentage of GDP, since adopting a carbon tax (20%)[24]. Finland and New Zealand have also moderately increased environmentally related tax revenue by 5% and 6%, respectively. All other focus countries have experienced a

[24] The OECD database "Policy Instruments for the Environment (PINE)" contains data on environmentally related taxes, fees and charges, tradable permits, deposit-refund systems, environmentally motivated subsidies and voluntary approaches used for environmental policy. This data is used to construct the environmentally related tax revenues.

decrease in environmental tax revenue with Norway and Sweden decreasing the most with 36% and 24%, respectively, since policy adoption. At the same time, taxes on incomes, profits, and capital gains of individuals (as percentage of total revenue) have stayed approximately the same in countries with carbon pricing policies, while they have increased in France, Australia, and the U.S. Taxes on incomes, profits, and capital gains of corporations (as a percentage of total revenue), have increased in all countries with mature carbon pricing policies and decreased in France, Australia, and the U.S. Poland is the exception to this trend as taxes have increased on individuals and decreased for corporations.

These shifts in the tax structure of the focus countries suggest not only that the tax regimes are dynamic and respond to economic or political shifts, but also that revenue from environmental taxes can decrease as more efficient industries and technologies enter the market, in part as a result of the environmental pricing policies themselves. Countries with sustained carbon pricing policies display a willingness to maintain the status quo on individual taxes while increasing corporate tax rates and carbon taxes. Countries with failed carbon tax policies appear to have reduced corporate tax rates while steadily increasing individual tax rates, perhaps eroding citizen support for carbon taxes. This trend, in part, explains the widespread public intolerance for the carbon tax in France, the U.S., and Australia.

France differs from other OECD countries in that the country derives substantially higher revenues from social security contributions, payroll taxes, and property taxes. Although the country has an overall lower proportion of total revenues derived from taxes on personal income in comparison to the OECD average, an increase in the fuel tax led to widespread social unrest during the "yellow vest" protests indicating the tax might be more politically feasible as a revenue-neutral tax similar to the more mature carbon taxation structures in Nordic countries. Studies on the distributional effects of carbon pricing suggest taxes should strive to be "revenue-neutral' by implementing measures such as fuel allowances or income tax reductions in order to guard against the equity issues that arise from distortions in the price of fuel (Scott and Eakins, 2004).

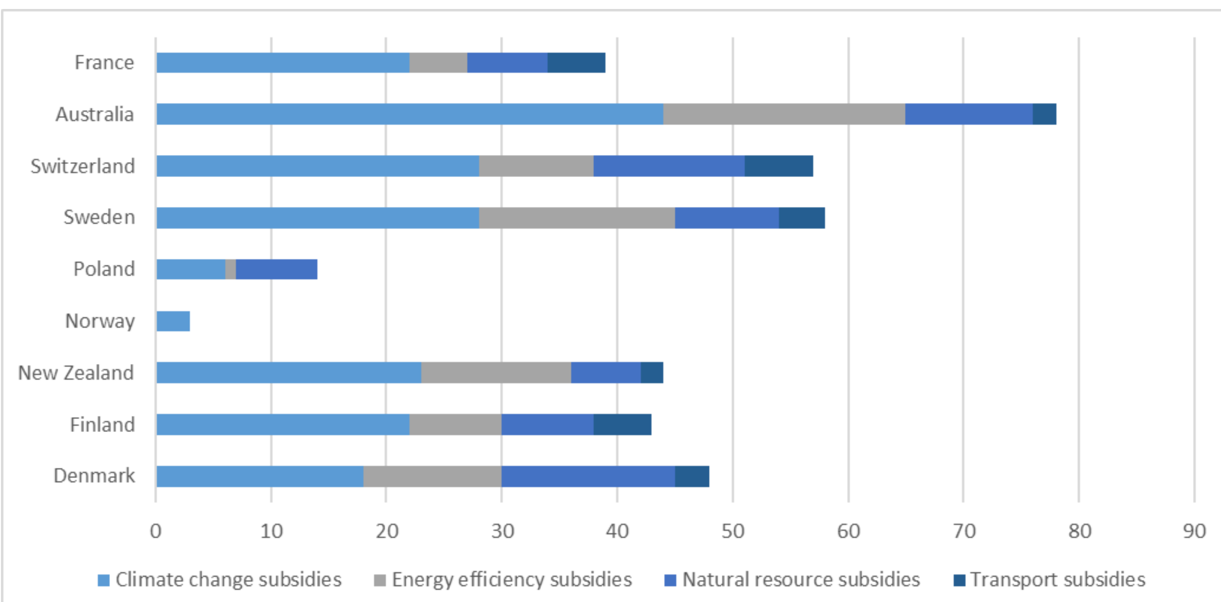
Among environmentally related tax revenue, taxes on energy use are a greater source of revenue than taxes on motor vehicles and transport in all focus countries (OECD PINE, 2014). Specific taxes on road transport fuels, however, tend to be higher than taxes applied to the energy sector. Fuel poor households (those spending more than 10% of income on energy) are particularly impacted by regressive carbon tax policies. Although estimates of transportation fuel consumption suggest higher income deciles experience greater costs as a result of environmental taxes, there is less difference in electricity consumption across deciles suggesting a greater regressive impact as found in Ireland following the introduction of a carbon tax (Convery, Dunne, and Joyce, 2013).

3.4. Policy Coherence

Although still debated, a lack of policy coherence was identified as a contributing factor in the price collapse that occurred in the EU ETS in 2012-2013 (EC, 2015). In general, emissions reduction obligations for EU countries are split between the EU ETS and other sectors that fall under the "effort sharing decision." However, the Renewable Energy Directive of 2009, which set a national binding renewable target for 2020, resulted in an unexpectedly rapid uptake of renewable technologies. The rapid adoption of renewable energy reduced demand for allowances and distorted the price signal. This paper evaluates the internal coherence of policies in the environmental domain by assessing adoption patterns of policy instruments that collectively support decarbonization. In principle, ETS systems can more easily and dynamically fit with overlapping policies as they impose a cap and then can drive decarbonization or simply ensure that the emissions target is achieved. Taxes on the other hand may fail to adjust to policy interactions on a dynamic basis.

To assess trends in policy instrument adoption preferences and coherence across environmental domains, data available through the OECD database Policy Instruments for the Environment (PINE) was reviewed. A matrix identifying environmental policy domains and cross sectoral policy outputs was developed for each focus country. All policy outputs that have stated environmental objectives related to carbon pricing were reviewed including ETS, fees, taxes, deposit refund systems, subsidies, and voluntary approaches. Environmentally motivated subsidies and taxes were found to be the most common environmental policy outputs. The number of policy instruments per domain since 1950 are summarized below in Figures 3 and 4.

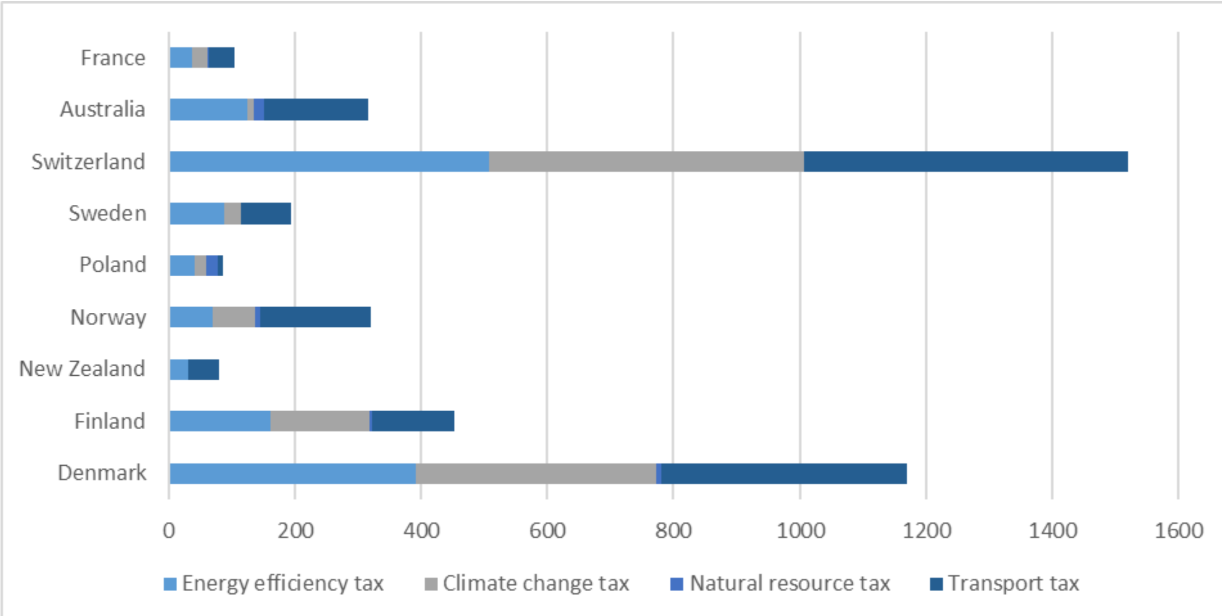
Figure 3. Environmentally motivated subsidies by Environmental Domain[25]
(total number adopted since 1950)



Source: OECD PINE Database

[25] According to the OECD, "A subsidy is environmentally motivated if it reduces directly or indirectly the use of something that has a proven, specific negative impact on the environment. It can take many forms: VAT exemptions on electric cars, feed-in tariffs on renewable energy generation, tax credits for environmentally relevant investment, or provision of public funds for nature conservation projects."; The United States is omitted because state level data available from the OECD PINE database is not comparable to the country level data reported above.

Figure 4. Taxes by environmental domain (total number adopted since 1950)



Source: OECD PINE Database

We have chosen to include policy instruments dating back to 1950 because the institutional legacy of instrument choice in the environmental arena matters for carbon-pricing policy choice. This approach is intended to demonstrate the importance of understanding carbon pricing policies as part of a suite of economic instruments that work synergistically to meet environmental goals. The historical patterns of adoption of policy instruments across environmental domains reflect the tolerance of the political environment for specific instruments as well as instrument preferences within the institutional legacy of each jurisdiction. A well-balanced implementation of tax schemes across all relevant domains is apparent in Denmark, the focus country with the steepest decline in carbon emissions. Subsidies are favored for climate change and energy efficiency over the transport sector. Trading schemes are most commonly applied to the energy and industrial sectors with limited implementation in natural resource management. These findings suggest that historical preferences for policy instruments across the domains of energy efficiency, transport, natural resource management, and climate change may not contribute to climate change goals as effectively as the well-balanced application of taxing schemes across relevant sectors.

While policy coherence can be a broad measure that spans both vertical and horizontal interactions across legal and institutional arenas, the approach taken here is to evaluate coherence in terms of policy goals, policy outputs (the instruments adopted to achieve goals), and policy implementation.[26] Market-based instruments such as carbon taxes and ETS are most commonly applied to the energy and transport sectors. Effective carbon rates are measured based on fossil fuel taxes, carbon taxes, and the price of tradable emission permits. An estimated 90% of emissions are not priced at levels sufficient to reflect climate costs (OECD, 2016). Comprehensive cross-sectoral analysis of carbon rates in industry, road transport, agriculture and fisheries is beyond the scope of this analysis but can be found in the OECD report *Effective Carbon Rates 2018*.

Analysis of interactions between carbon, energy, and financial markets is well documented and suggests a strong correlation between carbon and energy pricing (Alberola, Chevallier, and Chèze, 2008; ADB, 2016; Lin and Jia, 2019). While carbon-electricity correlations in the EU ETS can have a positive effect on the cost efficiency of the market, it also suggests carbon market volatility can result from energy market uncertainty and macroeconomic shocks (Koch, 2014; EC, 2015). Particularly important to establishing an effective ETS is the evaluation of fuel switching (coal and natural gas) and electricity prices. Accurate assessment of these factors help guide hedging strategies and mitigate risks associated with carbon market volatility.

Energy taxes are the largest percentage of revenues raised through environmental taxation (OECD, 2018). Energy taxes vary considerably between countries and across sectors and fuels – this variation plays a role in how carbon pricing policies are designed and implemented. As a review of average tax rates can result in misleading results, and energy market cost-benefit analyses of tax reform policies are numerous (Moltke et al., 2018 and Brink et al., 2016), this report instead considers the political economy of electricity supply and the alignment of economic and environmental goals. Only 19% of carbon emissions from non-road sectors (representing 95% of total carbon emissions from energy use in OECD countries) are taxed (OECD, 2018). For electricity generation, many suppliers are exempt from national taxes if they are eligible to participate in regional ETS. According to the OECD, for electricity generation, more than 80% of the effective carbon rate is the result of permit prices. Thorough review of energy taxation policies by the OECD (2018) suggests that energy taxes are largely poorly designed and ineffective in meeting the substantial environmental and climate challenges. Concern over global competitiveness and distributional impacts are among the primary barriers to policy reform and improved outcomes.

In terms of economic significance, there is little difference between an excise tax on energy and a carbon tax. While carbon tax coverage remains low (6%), taxes on oil products are high in several focus countries and there have been increases in fuel taxes (OECD, 2018). Although many of the early adopters of carbon pricing policies established clear energy or environmental objectives, today diversification of the fuel mix, ambitions for regional integration, and energy security all play a role in policy design. Norway, for example, generated 99% of its electricity from

[26] The identification of causal linkages to specific changes in household or industry practices are beyond the scope of this analysis. Likewise, in-depth analysis of policy integration in the upstream decision making process is not addressed.

renewable resources when they first adopted a carbon tax on mineral products and petroleum activities in the early 1990s. Increasing the tax rate in 2018, the country is striving to address an increase in per capita carbon emissions that resulted from increased use of thermal plants used by large industrial installations and emissions increases in the transport sector.

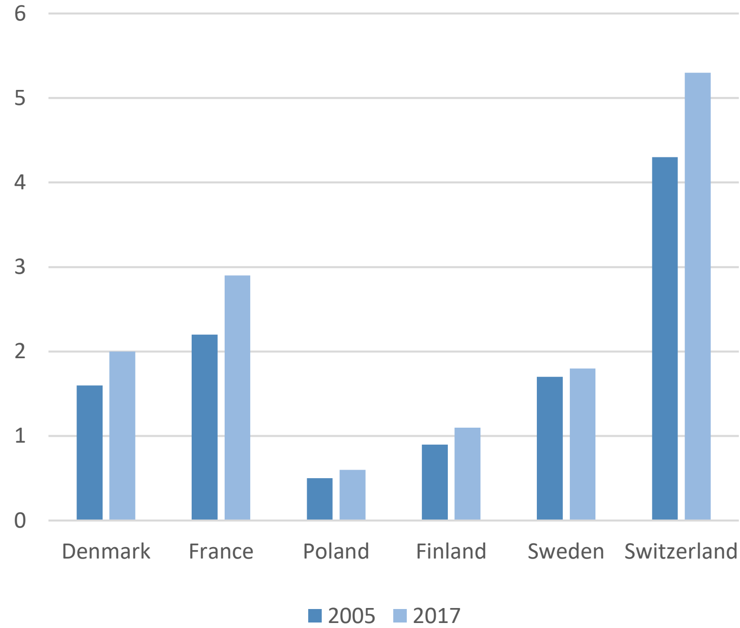
Among focus countries, only Norway experienced an increase in the percentage of electricity generated from non-renewable resources. Countries with the greatest reduction in non-renewable electricity since the adoption of carbon pricing instruments were Sweden (47%) and Denmark (38%). Countries without carbon pricing policies experienced more modest reductions in non-renewables capacity in the period 2005-2016 (Australia, 9%; France, 15%, and the U.S., 21%).

Environmentally harmful subsidies exist in most focus countries but vary by sector and by progress towards reform (Fedrigo-Fazio, 2013). For example, preferential treatment is given to the coal industry in Poland. Prior to 2012, coal was exempt from excise taxes. After 2012, in line with obligations to the EU, the country introduced an excise tax on coal, but significant exemptions weaken the effectiveness of the excise tax to result in fuel switching (IEEP, 2011). Although Poland remains one of least carbon efficient economies in the EU, reform to the subsidies would be both politically difficult and have significant social impacts. The government has chosen, instead, to focus on the transportation sector to meet nationally determined contributions by 2030.

As a factor of production, natural resources such as those found in Poland impact productivity and growth. However, technological and management innovations have opened new possibilities for gains in resource efficiency. Research suggests there are significant opportunities for improved resource efficiency across the energy, waste, and commercial sectors (Ecorys, 2011). These improvements result in cost savings, employment opportunities, and reductions in energy use. As seen in Figure 5, focus countries with the oldest carbon pricing policies have experienced gains in resource productivity since 2005 and gains are consistent across both countries with ETS systems and countries with carbon tax policies.

With strong growth in the global market for eco-industries, estimated to be USD 2.3 trillion by 2020, there is incentive for countries to promote research and development of green technologies. There has been an increase in the number of patents for technology development for climate change mitigation in all focus countries since environmental pricing policies began to be introduced in the early 1990s. By leveraging market mechanisms to incentivize cost-effective emissions reductions, ETSs are often viewed as the optimal policy choice for incentivizing green technology innovations or activities missed by other policies.

Figure 5. Resource productivity, 2005-2017
Ratio of GDP to Domestic Material Consumption[27]



Although the transportation sector is responsible for 14% of direct global GHG emissions (IPCC, 2014), carbon pricing is not widely applied in the sector and is beyond the scope of this analysis. Policies that promote performance standards for fuel efficiency, as well as fuel switching and travel demand management, are more common given the comparative ease of adoption and implementation when compared to carbon pricing mechanisms. The International Civil Aviation Organization (ICAO) has made strong advances towards an international carbon offsetting system that will require airlines to monitor and report emissions beginning in 2019 and begin offset activity in 2021 (ICAO, 2019). The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will begin with a voluntary pilot phase (2021-2023) and then advance to universal participation by all States in the second phase (2027-2035).

3.5. Impact on Trade

Debates on the effectiveness of climate policies often focus on potential losses in competitiveness and carbon leakage. Determination of the effectiveness of carbon pricing schemes in isolation can result in misleading results as comprehensive consideration of global markets and interactions between national level market-based instruments is often not feasible.

[27] Resource productivity is defined by the European Commission as "the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy."

In theory, carbon leakage would lead to a shift in emissions from a region that has implemented carbon pricing to one that has not, negating the global impact of carbon pricing policy. Carbon leakage is possibly a concern for countries vying to remain competitive in industrial or manufacturing sectors. In reviewing the risk of carbon leakage, the EU ETS Directive (Article 10a) suggests a sector is exposed to significant risk of carbon leakage if the cost of production will increase more than 5% as a result of the pricing policy or if the trade intensity with non-EU countries is above 10%.[28] In principle, the implementation of an ETS or a tax regime can provide free allowances or graduated tax exemptions to ease the impact on competitiveness, if the possibility of carbon leakage is significant.

To consider changes in market structure and trade dynamics, this report considers (1) the trade balance, (2) the economic structure, (3) the HH Market Concentration Index to capture the dispersion of trade value across export partners (trade value concentrated with a few countries results in a value closer to 1), and, lastly, the Index of Export Market Penetration to measure the degree to which a country's products are reaching proven markets (a low value indicates there may be barriers to trade).

The literature on the impact on competitiveness of domestic carbon prices suggests that increase in net imports of carbon-intensive goods is likely to be relatively small. In an econometrically estimated model of the output and import demand of two energy intensive sectors (cement and steel) in the EU, Branger et al. (2016) find that there is no significant impact of carbon prices on net import demand. They therefore conclude that there is low likelihood of carbon leakage in the short term. Aldy & Pizer (2015) estimate how production and net imports change in response to energy prices using a 35-year panel of approximately 450 US manufacturing industries. They use the estimated relationships to model the impact of a $15 per ton carbon price. They estimate that for the most energy-intensive industries, the highest increase in net imports amounts to 0.8%. This increase in net imports is less than one-sixth of the drop in domestic output, implying that carbon leakage is low even in the most energy-intensive industries. As a proportion of production costs in the manufacturing sector, carbon pricing costs are miniscule compared to labor costs. Labor unit costs in the EU are 10-30 times higher than in emerging markets (Naegele & Zaklan, 2019). Naegele & Zaklan find that as a result, for 95% of European manufacturing, the EU ETS cost adds no more than 0.65% to material costs. They test for impacts of environmental stringency in the trade flows between the EU and its partners between 2004 and 2011 and find no evidence that carbon-pricing differentials had any impact on trade flows.

The structure of economic output for all focus countries has been dominated by the services sector since the adoption of the carbon pricing policy. Poland's export portfolio has become significantly more diversified while also reaching a greater proportion of proven markets (Figure 6). Research suggests that while carbon taxes can lead to a reduction in output from high-carbon industries, they can also generate an increase in low-carbon industries (Branger and Quirion,

---

[28] For more on carbon leakage see EU ETS, Carbon Leakage, https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

2014; Chen and Guo, 2017). To compensate for the loss in competitiveness among high-carbon industries that may result from relatively stringent environmental policies (Figure 7), some observers have proposed border carbon adjustments (BCAs). For example, the governing Green Party in Sweden is proposing to work with the EU to impose BCAs on countries that plan to leave the Paris Agreement (Orange, 2018).

Figure 6. Index of Export Market Penetration

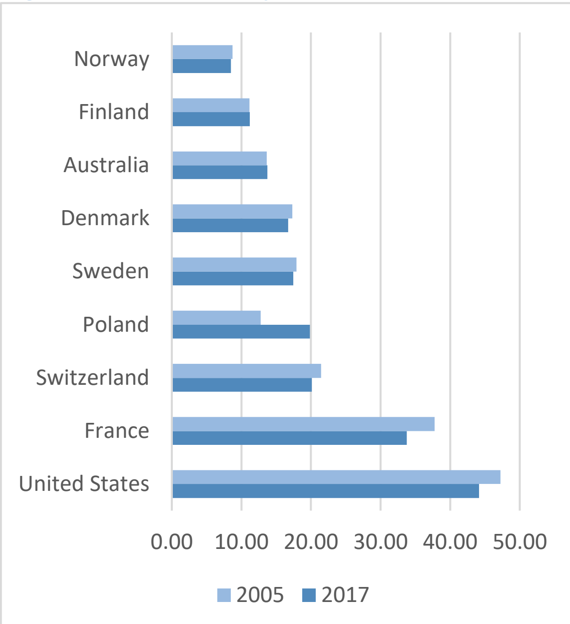
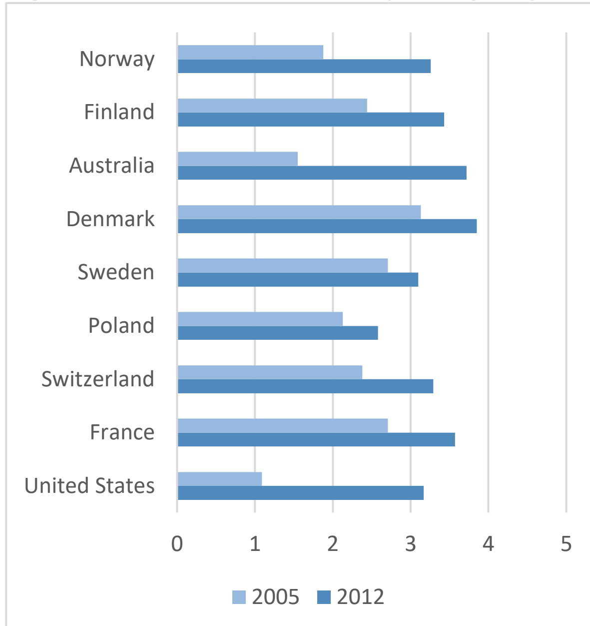


Figure 7. Environmental Policy Stringency Index[29]



With a recent trend toward protectionism over trade liberalization, countries will be less able to import low-cost carbon-intensive goods made in higher emitting countries. The "embedded emissions" in these types of goods are difficult to quantify and vary considerably across industries. Research indicates that without adopting carbon pricing policies that work to reduce consumption of goods with high carbon intensities, it will be difficult to meet emissions reduction targets (Bjørn et al., 2018; Mehling et al., 2018). By taxing imports or enabling importers to purchase tradeable allowances, BCAs help account for embedded emissions accrued during manufacturing. California, adopting BCAs in 2013, has experienced a drop in electricity suppliers moving generation to nearby states with less stringent laws (Mehling et al., 2018). Although discrimination of products is forbidden by the World Trade Organization (WTO), whether or not BCAs qualify for an exception to this rule is under debate (Fouré, Guimbard and Monjon, 2016; Tamiotti, 2011).

[29] Carbon pricing policies, adopted and implemented in far-reaching environmental and energy policy regimes, have wide cross-sectoral scope. To account for aggregate policy impacts, the analysis used the OECD Environmental Policy Stringency Index, a country-specific and internationally-comparable measure of the stringency of environmental policy, defined by the OECD as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior. 2012 is the most recent year available for all countries.

3.6. Sub-national Jurisdictions

Globally, 28 sub-national jurisdictions have adopted either a carbon tax or an ETS. Gaining popularity at the provincial level throughout Canada, British Columbia (BC) introduced the first carbon tax in North America in 2008. Targeting emissions from all sectors (with some exemptions for the industry, aviation, transportation and agriculture sectors) the tax applies to 70% of the provinces emissions, including fossil fuel combustion, and may extend to include fugitive emissions and emissions from the burning of forestry residues (WB, 2019). Following a phased introduction schedule the tax rate started at C$10/t CO2 in 2008 and rose to C$30 by 2012 (Murry and Rivers, 2015). For gasoline, the tax started at C$0.024 per liter and increased annually for five years until reaching C$0.067 per liter in 2012 (Lawley and Thivierge, 2018). Unlike France, the BC tax is revenue-neutral and by 2015 had generated C$6 billion in revenue and C$7 billion in tax cuts to businesses and households (Murry and Rivers, 2015).

Research on the enabling conditions for the implementation of the carbon tax in BC suggests the following factors were important to its popularity: the revenue-neutrality of the tax, the prevalence of hydropower for electricity generation, strong voter interest (with only 32% opposing the tax), due at least in part to its revenue neutrality, and high level political support by figures with authority and influence to pass the carbon tax through legislature (Axford, 2018; Harrison, 2013). Evaluation studies, based on counterfactual scenarios, estimate the carbon tax policy has resulted in an 8-9% reduction in GHG emissions (Beck et al., 2015) and an 11-17% reduction in gasoline sales per capita (Murry and Rivers, 2015). Although, as noted, rigorous assessment of the impact of the policy on economic growth is beyond the scope of this paper, general trends in GDP growth demonstrate that BC maintained an annual GDP growth rate above the average for Canada between 2008 and 2015 (0.5% for BC and 0.4% for the country as a whole).

California, well known for its prioritization of environmental policies, is also the second heaviest emitter of carbon dioxide among states in the US (EIA, 2019). In terms of carbon intensity however (emissions/GDP), California is among least carbon intensive in the US decreasing its carbon intensity 42% between 1990 and 2015. Aiming to reduce emissions to 80% of 1990 levels by 2050 (as a signatory of the Under2 Coalition), per capita emissions in the state were 10.94 metric tons of CO2 equivalent in 2016 – more than twice the global average of 4.97 but almost equal to the average for high-income countries (10.71).[30] As in Denmark, California has grown its economy while also reducing emissions. With an almost 16% growth in GDP between 2006 and 2016, the state was successful in reducing emissions 11% in the same period (Next 10, 2018). The state has also experienced an increase in energy productivity (18%), almost equal to gains made in the EU. With numerous laws and regulations passed since 2000 that aim to reduce greenhouse

[30] The Under2 Coalition is an international agreement committing states, countries and regions to reducing GHG emissions by 80 to 95% compared to 1990 levels, or limiting emissions to 2 annual metric tons per capita, by 2050. For more information, see https://www.under2coalition.org/.

gas emissions, California was already experiencing steady emissions reductions prior to the implementation of the ETS in 2012.

The statewide cap and trade initiative applies to all GHG emissions from the industry, power, transport and buildings sectors and includes industrial process emissions (WB, 2019). Expanding in 2015 to also include natural gas and transport fuel suppliers, the system now covers 85% of California's emissions. Auction proceeds are held in the Greenhouse Gas Reduction Fund (GGRF) and are allocated to projects that aim to address global warming. The cumulative appropriations of the fund reached US$6 billion in 2017 and approximately US$2 billion in climate investments were implemented by 2017 (primarily in air quality monitoring, pollution controls, cleaner harvesting equipment, and wildfire prevention). Research indicated many GHG emitting facilities were in disadvantaged neighborhoods (Cushing et al., 2018). As mandated by law, nearly one third of the funding from the GGRF is used to benefit these communities directly (Next 10, 2018). The California cap and trade is linked to the Quebec cap-and-trade program and was briefly linked with the Ontario cap-and-trade prior to the announcement that Ontario would abolish the program in 2018.

The success of environmental governance in California may not be replicable throughout the US as the state benefits from both a strong political commitment to environmental action and regulatory capacity. In the energy sector, numerous incentives for renewable energy have had strong support resulting in an increase of 130% in generation capacity between 2006 and 2016, primarily from solar energy generation. In comparison, the renewable generation capacity in the US increased 238% in the same period, the EU increased 281%, and China increased 6,279% (Next 10, 2018). However, as a proportion of total GHG emissions in the state, the electric power sector is only (16%) suggesting policies that address emissions in the transportation sector (40% of total GHG emissions) may have a greater overall impact in terms of reducing emissions.

4. Country Case Studies: Chile and Colombia

The adoption of domestic carbon taxes in four Latin American countries, with consideration of national or regional ETS mechanisms has increased the potential for these countries to make accelerated progress toward meeting emission reduction targets. We perform a detailed comparative analysis of the context for carbon pricing in two of these countries, Chile and Colombia. Both countries place strong emphasis on developing systems for monitoring, reporting, and validation in forums such as the Carbon Pricing in the Americas (CPA) and the Pacific Alliance and appear committed to developing a regional ETS. Additionally, there is strong motivation throughout the region to transition to renewables in order to improve energy security, diversify the fuel mix, safeguard against droughts caused by climatic shifts and disruptions to the supply of natural gas.

As described above, the selected countries implemented carbon pricing policies in support of efforts to improve environmental outcomes. This environmental motivation is less present in countries with newer pricing policies as the economic case for increasing revenues from environmental taxes is stronger now than in previous decades. Environmental tax policies today are largely seen as offering both the opportunity to reduce emissions and increase revenue for social reform, particularly in emerging markets (Andersen & Ekins, 2009). Whether environmental taxes are adopted to raise revenues, such as in Ireland where the country aimed to meet the requirements of its post-recession bailout, or to implement the "polluter pays" principle, environmental taxes are increasingly being adopted within broader tax reform packages.

Chile and Colombia are easier jurisdictions to compare than the average carbon price implementing jurisdiction. They are both Latin American countries with similar GDP growth rates, sectoral economic structure and reliance on government revenue. Chile is a high-income economy and Colombia is an upper middle-income economy. Colombia has lower carbon emissions per capita and a higher reliance on renewable sources (primarily hydro) in the electricity generation mix. We note especially that the lower emissions per capita of Colombia significantly reduces its local carbon price burden relative to Chile (0.6% vs. 0.10%). Their key attributes are listed below.

Table 8. Key Attributes of Case Study Countries

Attribute		Chile	Colombia
GDP per Capita, 2017, PPP (current US$)		$24,635	$14,552
GDP Growth Rate, 2017 (%)		1.50	1.80
Structure of Economic Output, 2017 (%)	Agriculture	4.00	6.00
	Industry	30.00	29.00
	Manufacturing	10.00	11.00
	Services, value added	57.60	55.70
CO2 emissions per capita, 2014 (metric tons/year/capita)		4.69	1.76
Non-Renewable Generation, 2015 (as a % of Electricity Output)		56.00	32.00
Carbon price and/or tax per ton (US$/tCO2e)[31]		$5.00 (carbon tax)	$5.00 (carbon tax)
Local price burden, carbon price X emissions per capita / GDP per capita (in %)		0.10	0.06

[31] According to the World Bank's Carbon Pricing Dashboard, the Chile carbon tax "applies to CO2 emissions from mainly the power and industry sectors, as it applies to all establishments with stationary sources of a thermal input capacity greater than 50 megawatts. The tax covers all fossil fuels." The Colombia carbon tax "applies to GHG emissions from all sectors with some minor exemptions. The tax covers all liquid and gaseous fossil fuels used for combustion."

Government Revenue, 2017 (% of GDP)	20.2	19.8
Historical standard deviation of government revenue, 2007-2017 (% of GDP)	1.37	0.84
Imports (% of GDP)	27	20
Exports (% of GDP)	29	15
Share of jurisdiction's GHG emissions covered	39	24
Relation to other carbon pricing initiatives	Tax and MRV system designed to be ETS compatible with regional and global ETS systems.	Emitters can achieve carbon neutrality through the use of offset credits generated from projects in Colombia.
Estimated government revenues from carbon pricing[32], 2017 (US$ million)	$160	$158
Categorical analysis of use of proceeds (earmarked or general purpose)	Tax revenues flow to General Treasury, with some indication that the largest share will be spent on education. Some sources report usage for general social and/or environmental betterment.	Revenue is earmarked for the Colombia Peace Fund to support ecosystem protection and coastal erosion management.

Chile and Colombia differ slightly in terms of revenue volatility with Chile having a higher historical standard deviation of government revenue between 2007 and 2017. This volatility resulted from the trade intensity of Chile and the volume of exports as a percentage of GDP. Producing nearly one third of the global supply of copper, Chile has made strides in diversifying the economy after being hard hit by volatility in copper prices and a recession in 2009 (OECD, 2018).

Well-endowed with renewable energy resources, and home to a strong environmental movement, Chile has become a regional leader in the adoption of policies for renewable energy. Enabling policies together with declining technology costs has led to a steadily rising percentage of renewables in the energy mix. The government has sought to create a stable regulatory environment in the energy sector in the past decade by establishing the Ministry of Energy, the Chilean Energy Efficiency Agency, and the National Electricity Coordinator (ISO) (IEA, 2018). Colombia, although South America's largest coal producer, primarily generates power from vast hydroelectric sources. The country has struggled to provide a stable regulatory environment amidst a decades-long struggle with a rebel insurgency. However, the country has worked to transition away from a highly regulated economy and to gradually liberalize the energy sector.

Applying the framework introduced in Section 2, Colombia and Chile have a high likelihood of implementing effective and stable carbon pricing policies. They have upper middle (Colombia) to

[32] As estimated by the respective countries' governments.

high (Chile) incomes and advanced structural compositions of GDP. Their local burdens are low relative to other adopting jurisdictions. They also enjoy low local price burdens and low relative export intensity. Between the two countries, Colombia's carbon price may be more stable than Chile's, based on the historical standard deviation of GDP and trade diversity. However, Chile's significant investment in the development of institutions for monitoring, reporting, and evaluation of an ETS suggest a strong commitment to program success. The following sections will evaluate the local context and the degree to which an enabling environment is in place for the implementation and continuation of carbon pricing instruments in Chile and Colombia.

4.1. Chile

Emissions

The National Greenhouse Gas Inventory of Chile indicates that in 2010, CO_2 accounted for 76.6% of total GHG emissions, followed by CH_4 (12.5%) and N_2O (10.6%) (MOE, 2014). GHG emissions from the energy sector increased 104% between 1990 and 2010. Accounting for 74.7% of total GHG emissions in 2010, energy sector emissions are driven by electricity generation and transport (70% of total sector emissions). Second-growth natural forests and biomass from forestry plantations are the primary drivers of carbon removal with the land use, land use change, and forestry (LULUCF) sector reporting removal of approximately 50,000 $GgCO_2eq$ in 2010 (73% of total emissions).

The carbon intensity target of Chile, as summarized in the country's Intended Nationally Determined Contribution (INDC) to the Paris Agreement, is to reduce carbon emissions (per unit of GDP) by 30% below 2007 levels by 2030. In addition, conditional upon the grant of international monetary funds, Chile has committed to reduce its emissions per unit of GDP by 35-45% by 2030 relative to 2007 levels (Government of Chile, 2015). Separately, to promote carbon removal from LULUCF, the country aims for the sustainable development and recovery of 100,000 hectares of primarily native forest land (an annual equivalent of around 600,000 tons of CO_2) and the reforestation of an additional 100,000 hectares.

Legislative Timeline

Year	Major Development
1996	National Advisory Committee on the Global Climate
2006	National Climate Change Strategy
2008	Law 20.698 (Non-conventional Renewable Energies, NCRE) enacted - requires that 20% of the energy under supply contracts be generated from non-conventional renewable energies by 2025.
2009	Inter-Ministerial Committee on Climate Change created - includes the Ministries of Foreign Affairs, Finance, Economy, Public Works, Agriculture, Mining, Transportation and Telecommunications, Energy, and Environment

2010	Creation of the Ministry of Environmental Evaluation Services, the Superintendent for the Environment, and the Council of Ministers for Sustainability
2012	Establishment of the Partnership for Market Readiness (PMR) Steering Committee - includes representatives from the Ministries of Foreign Affairs, Finance, Economy, Agriculture, Mining, Transport & Telecommunications, Energy and Environment[33]
2014	Tax Reform Law 20.780 enacted - includes a carbon tax and a tax on the initial sale of lightweight vehicles. The carbon emission tax, effective January 1, 2017, establishes an annual tax benefit lien on CO2 produced by facilities whose stationary sources have an aggregate thermal power equal or higher than 50 MWt. The lightweight vehicle tax, implemented in 2014, charges a tax that is inversely proportional to vehicle performance.
2017	National Climate Change Action Plan (2017-2022)
	Decree No. 18 of the Ministry of the Environment - legal instrument enabling green taxes to operate
	Exempt Resolution 1.053 (SMA) - establishes the protocols (methodologies and procedures) to measure emissions of PM, NOx, SO2 and CO2
2018	Energy Ministry signs agreement with major energy utilities to gradually phase out coal-fired plants that do not have carbon capture and storage (CCS) systems, and stop generating electricity from coal by 2040

Regulatory Stability

Complex carbon pricing schemes call for sophisticated monitoring, reporting and verification (MRV) systems that ensure the quality of information gathered and robust protocols for accounting. Supported by a coordinated effort between the Ministry of the Environment (MMA) and the Superintendence of the Environment (SMA), the current MRV system of Chile is being strengthened.[34] The aim is to design an "ETS compatible" MRV system in order to prepare the country for future cooperative approaches with other nations or jurisdictions, in accordance with Article 6 of the Paris Agreement.

These mechanisms are primarily controlled by the Ministry of the Environment (establishing criteria for taxable status), the Registry of Emissions and Transfer of Pollutants (overseeing taxable entities), the Superintendence of the Environment (establishing accounting methodology), and the Internal Revenue Service (carrying out accounting methodology), the revenues from which go to the Treasury. Looking forward, Chile has signaled the possibility of

[33] The Partnership for Market Readiness (PMR) brings together key actors to develop innovative approaches to GHG mitigation using markets and carbon pricing. Contributing participants include the European Commission together with the United States, Australia, Denmark, Finland, Germany, Japan, Netherlands, Norway, Spain Sweden, Switzerland, and the United Kingdom. Implementing participants include the middle-income countries of Argentina, Brazil, Chile, China, Colombia, Costa Rica, India, Indonesia, Jordan, Mexico, Morocco, Peru, South Africa, Sri Lanka, Thailand, Tunisia, Turkey, Ukraine, and Vietnam. The World Bank Group provides secretariat services including leading the technical work and policy programs as well as organizing and delivering meetings and events and collaborating on e-learning tools.

[34] More information on the Partnership for Market Readiness is available from the web platform for the PMR - Chile Project (http://www.precioalcarbonochile.cl/).

increasing the carbon tax, lowering the threshold for taxable status, and implementing an ETS in the future (it's worth noting that Santiago itself has had an ETS since 1997).

To develop the institutional capacity needed for the MRV system, a guide for the monitoring and reporting of GHG emissions was developed. The guide establishes rules for monitoring and reporting of GHG emissions (monitoring plan and methodologies) that work to ensure MRV practices are consistent, comparable, accurate, and transparent. The guide also sets rules that apply to the facility data collection and reporting obligations (including systems for measurement, calculation factors, sampling plans, and measurement standards).

In addition to the MRV guide, a "GHG Verification Protocol" was developed. The Protocol regulates the verification of emission reports and establishes guidelines on obligations of the Technical Entities of Environmental Audits (ETFA). The ETFA provides verification and accreditation of verification entities.

Several methodological guidelines and proposals for institutional arrangements for an MRV platform, and technical recommendations to develop a recognition program for the private sector initiatives, were included in the emission reductions accounting framework. Several MRV guidelines for the energy sector are complete. With technical assistance from GIZ, the country aims to design a platform for MRV that will record and track migration actions and develop a recognition program for the private sector.

Costs and Distributional Effects

In September 2014, under a second (but non-consecutive by nature of their election laws) Michelle Bachelet administration, Chile passed sweeping tax reform (Law 20.780) aimed at increasing government revenue, in large part to fund a campaign promise of free education in the wake of student protests that disrupted the country from 2011 to 2013. In addition to raising the corporate tax rate from 20% to 25% or 27% (depending on the domicile of the entity), this reform (subsequently altered by Law 20.899 in January 2016) introduced a series of "green taxes" intended to both increase tax revenue and address climate change, a major concern for the coastal nation. There are three such green taxes:

- The sale of lightweight vehicles is taxed with respect to their urban performance and NOx emissions.
- Emissions of NOx, particulate matter (PM), and SO_2 from stationary sources are taxed with respect to their effect on surrounding communities (as a function of social cost, pre-existing air quality, and population density).
- Emissions of CO_2 from stationary sources are subject to a direct carbon tax. As such, these green taxes target both local and global pollution. Stationary sources are defined as those with boilers or turbines that (either individually or collectively) have thermal power

greater than or equal to 50 megawatts (MW). Intuitively, this excludes renewable and non-traditional power generation, such as biomass. This is all in line with their "polluter pays" approach to emissions.

On January 1, 2017, Chile became the first country in South America to implement and collect a carbon tax, levying US$5/tCO2e for large industrial and power generation sources. As a participant in the Partnership for Market Readiness, Chile prepared a Grant Agreement in 2014 in parallel to the approval of the tax reform legislation that passed the same year. Although the initial Grant Agreement was in support of the establishment of an ETS, this approach was broadened to include carbon pricing mechanisms in general.

While many critics of the policy argue that US$5/tCO2e is not an adequate price at which to significantly alter behavior and foster a transition to sustainable energy sources, the phased implementation of carbon tax schemes is recommended in order to allay fears of decreasing competitiveness. As such, the current carbon tax serves largely to develop and test institutional mechanisms of monitoring, reporting, and verification (MRV).

In addition to the existing tax reform law that allowed for the carbon tax, President Sebastian Piñera's administration announced that it will draft a new climate change law. It is expected that the bill will enter Congress in 2019. Town hall meetings will be held throughout Chile to gather input from civil society, as well as the private and public sectors.

A roadmap, prepared by the administration, identifies alternatives for a comprehensive carbon pricing system. This roadmap allows for modifications to enhance the current carbon tax in Chile and calls for additional measures, such as offsets, revenue recycling, clean technology, and low-income household subsidies, among others. Implementation of a domestic and regional ETS is also part of the policy roadmap.

The annual tax revenue from the carbon tax is approximated to be US$160 million, a small portion (<2%) of the expected US$8.3 billion from the broader tax reform at large. These tax revenues flow to the Ministry of Finance's General Treasury of the Republic, and it has been proposed that the largest share of the revenues will be spent on improvements to the education system. That said, some sources describe usage of the tax revenue for social and/or environmental betterment, an ambiguous (and adaptable) position.

According to the Ministry of the Environment (MMA) and the Superintendence of the Environment (SMA), 94 establishments were subject to the carbon tax. These establishments represent approximately 40% of total CO_2e emissions in Chile. Initial estimates from the SMA indicated an annual carbon tax revenue of approximately US$160 million with 88% of the share from CO_2 emissions. Noted implementation challenges and design shortcomings of the carbon tax include limited scope and low-price level (US$5 per ton of CO_2).

A study conducted on the currently established Measurement, Reporting and Verification (MRV) system proposed broadened coverage of emitting sources. Coverage would increase from 94 establishments that currently report under the green tax to approximately 400 establishments. The main emitters of GHG and local polluting gases would be comprehensively covered at the national level by reducing the threshold from 50 MW to 10 MW and moving towards all emitting sources with over 15,000 tCO_2/year.

Policy Coherence

The Carbon Tax is just one facet of a broader effort by the Chilean government to transition to (and pioneer) sustainable energy practices in light of the tremendous environmental risk posed by climate change in the context of Chile's coastal, low-lying geography. Related tools and policies include:

- Chile's National Greenhouse Gas Inventory System
- National Climate Change Action Plan 2016-2021
- National Energy Agenda, Ministry of Energy
- National Sustainable Construction Strategy, Ministry of Housing and Urban Development
- Nationally Appropriate Mitigation Actions (NAMAs), all sectors
- Forest Carbon Partnership Facility (FCPF), generates offsets from the LULUCF sector
- Energy Policy 2050

Chile's overarching national energy initiative, Energy 2050, consists of four pillars, one being Environmentally-Friendly Energy, aiming for renewable energy sources to constitute 60% of the electricity generation matrix by the year 2035 and at least 70% by the year 2050. This runs parallel with the Ministry of Energy's Mitigation Plan and Adaptation for Energy Sector Climate Change Plan. Ultimately, these policies are all in pursuit of achieving the goals set forth by the Paris Climate Agreement in 2015 (35-45% reduction of GHG emissions intensity of GDP below 2007 levels by 2030).

An analysis of the importance of the Clean Development Mechanism (CDM) in Chile highlighted the experience of private sector actors who participated in project-based mechanisms. The aim of the study was to identify how Certified Emission Reduction Units (CERs) can continue to contribute to emission reductions as supplementary measures that reside within a carbon pricing system. The national carbon tax has generated interest in the possibility of using certified emission reductions, such as CERs from CDM projects, as tax rebates for regulated entities.

The analysis emphasized the importance of CDM projects in mobilizing funds from the private sector to produce emission reduction projects. At the time of the study in 2017, there were 102 Chilean projects registered under the CDM, ranging from renewable energies to landfill methane capture. These projects represent approximately 7.4 $MtCO_2e$ per year. Of total projects, 63 are currently still in operation and only 30 projects verified their reductions under CDM standards and were awarded the corresponding CERs. The other half are still in the verification process. The 30 projects that have been verified account for approximately 4 million tons of CO_2/year of reductions. Participants in the EU ETS can use international credits from Chile towards fulfilling part of their obligations under the EU ETS until 2020.

The CDM study also identified possibilities for incorporating CERs in a national carbon pricing mechanism.

- Reverse Auction Mechanism. In this scenario the Government of Chile defines a budget to buy CERs for projects that contribute to the fulfillment of the NDC's of Chile. CDM projects that no longer reduce emissions would be encouraged to reactivate carbon reducing activities.
- CERs as offsets of the current carbon tax. This approach would allow companies subject to the carbon tax to reduce their tax burden with CERs.

Lastly, Chile is a member of the Pacific Alliance, which includes Colombia, Mexico, and Peru. According to PMR, some of these countries are exploring possibilities of regional market mechanisms and ETSs (Cali Declaration, 2017), though such a prospect is long-term and uncertain. The Paris Agreement emphasizes the importance of implementing carbon pricing instruments and calls for a cooperative platform called "Carbon Price in the Americas" (CPA). The platform was envisioned to support work on carbon pricing systems and promote carbon markets. Preparations for a robust MRV system in Chile support this objective.

4.2. Colombia

Emissions

In 2015, Colombia submitted an economy-wide intended NDC, pledging to unconditionally reduce its GHG emissions by 20% from business as usual by 2030 (and increased to 30% reduction by 2030). Colombia's Congress ratified the Paris climate agreement in 2017.

In February of 2017, the government of Colombia implemented the region's third carbon tax after Mexico and Chile. As part of the national government's strategy to reduce the financing gap that resulted from the sharp decline in oil prices since 2014, a tributary reform was passed in December of 2016 (law 1819). The law states that the approximately US$5 tax per ton of emitted carbon dioxide is imposed in relation to the amount of carbon in fossil fuels, specifically gasoline, kerosene, jet fuel, diesel fuel (ACPM), and fuel oil. Liquefied petroleum gas is also taxed for its carbon content, but only when sold to industrial users. The action that generates the carbon tax is reserved to the sale of any of the fuels within Colombian territory and both producers and importers are responsible for collecting the tax. One notable aspect of the law is the exclusion of coal from the fossil fuels associated with the tax due to pressure from industry groups. The price on carbon will be adjusted for inflation every year beginning in 2018.

Legislative Timeline

Timeframe	Major Development
December 2016	Law 1819 – The new tax code establishes a USD $5 carbon tax for domestic consumption of most major fossil fuels in Colombia except coal.
April 2017	Decree 691 – The Fund for a Sustainable Colombia changes name and is now called the Colombia in Peace Fund.
June 2017	Decree 926 – The Ministry of Sustainable Development of Colombia establishes the regulation allowing for companies to receive tax breaks by investing in carbon-emission mitigation projects in Colombia.
July 2017	Law 1844 – The Colombian congress ratifies the 2015 Paris Climate Agreement.
July 2018	Law 1930 – Modifies the usage distribution of the carbon tax revenues by establishing that 70% of all revenues must be directed towards the implementation of the Peace Accords with environmental sustainability criteria.
July 2018	Law 1931 – Creates Colombia's Carbon ETS giving the Ministry of the Environment three years to develop all required regulation.

Regulatory Stability

Among the many controversial modifications to the Colombian tax system the reform attempted to make, the carbon tax attracted the least amount of attention. This means that it was enacted by the Colombian congress without much public debate according to Javier Sabogal, cabinet advisor to Colombia's Minister of the Economy. As stated by the same government official, "the reform was presented as a way to enhance Colombia's nomination to the Organization of Economic Cooperation and Development" (OECD) (Monge, 2018).

Colombia has strong institutional and regulatory frameworks in place that will contribute to successfully meeting Colombia's NDC goals. These include:

- The 2014-2018 National Development Plan
- National Climate Change Policy (2017)
- National Climate Change System (SISCLIMA)
- National Climate Change Adaptation Plan
- Structural tax reform (carbon tax)
- An upcoming climate change law
- Inter-Ministerial Committee on Climate Change
- Design and approval of eight Sectoral Mitigation Action Plans for Transportation, Energy, Hydrocarbons, Mining, Industry, Agriculture, Housing and Waste
- The development of a portfolio of 6 NAMAs for Coffee, Livestock, Panela, Logistics Industry, Non-interconnected Z ones (ZNI) and Energy Efficiency in Hotels
- The creation of a Monitoring, Reporting, and Verification (MRV) system
- The development of departmental portfolios of mitigation measures (UNDP, 2018)

Costs and Distributional Effects

According to the Ministry of the Economy's original projections, the US$5 price on carbon would be around US$200 million in additional revenue to the country per year. However, according to the Colombian revenue service (DIAN), the carbon tax generated only US$158 million during its first year in 2017, and by September of 2018 revenues totaled USD $79 million. In addition to the carbon tax, the Colombian congress enacted law 1931 in July of 2018 creating the country's Carbon Emissions Trading Scheme (ETS) in order to meet Colombia's Nationally Determined Contribution (NDC) following the 2015 Paris Climate Agreement. As of December of 2018, the Ministry of Sustainable Development in Colombia is yet to decree the specific regulations that will govern the carbon ETS.

Current environmental advocacy groups have repeatedly called for the addition of coal consumption and exports in the taxable base of the carbon tax. While efforts to include this change in the fall 2018 tax reform promoted by the Ministry of the Economy have failed, it is highly likely that this regulatory change will take place in the near future. This would increase carbon tax revenues by 30%, assuming 2017 national coal production numbers from the National Administrative Department of Statistics (DANE). Concerning the carbon ETS, the Ministry of the Environment is yet to determine the exact industries that will need to meet emission standards, as well as the emission caps beyond which payment through credits or fines will be required. According to law 1931 of 2018, all regulation must be enacted by 2021.

Article 223 of law 1819 of 2016 directs that all the revenue generated from the tax would go towards the Fondo para una Colombia Sostenible (Fund for a Sustainable Colombia). As stated by the law, the revenues were intended towards "resolving coastal erosion, conserving water sources and ecosystem protection, among other uses." Following the signing of the Colón Theater Agreement between the Colombian government and the FARC guerrilla group in late 2016, the name of the fund was changed in 2017 to the "Colombia in Peace Fund." In this new fund, the revenues of the carbon tax were expected to make up more than 50% of the total budget aimed at implementing the peace treaty. In 2018, law 1930 changed the distribution of the carbon tax funds such that 25% of the revenue is intended toward "resolving coastal erosion, conserving water sources, financing the payment for environmental services scheme, reducing and monitoring deforestation and ecosystem protection." The most significant change made towards the destination of the carbon tax states that 70% of the revenue be used towards "implementing the peace agreement with environmental sustainability criteria." The remaining 5% of the revenue would be directed towards the National Protected Areas System.

The carbon tax represents only around 2% of the price paid per gallon of diesel. This fact has made various advocacy groups call into question the effectiveness of the policy in mitigating emissions by stating that the tax does not significantly decrease demand for fossil fuels. Given the law is still in its infancy, it is difficult to empirically determine the truthfulness of these assertions. Additionally, pressure from industry interest groups makes it highly unlikely that the price established by Law 1819 of 2016 will be significantly increased in the near future.

5. Conclusions

In the absence of an effective market price on the emissions of carbon, there is little incentive for the private sector to economize on carbon emissions. Carbon pricing mechanisms incentivize the changes needed in consumption, production and investment behavior to induce the transition to a low carbon future. This study analyzes the jurisdictional characteristics of economies where carbon pricing mechanisms (both carbon taxes and cap-and-trade schemes) have been implemented or proposed as a means to support decarbonization. We have compared the country-specific conditions of 37 countries and the European Union that have implemented or are considering implementing carbon pricing with the global average to derive a set of stylistic facts which appear to be correlated with the adoption of carbon pricing. Secondly, we reviewed the historical experience of 11 national and 2 sub-national jurisdictions which either implemented carbon pricing or attempted to do so in vain. Finally, we perform an in-depth review of two case study countries (Chile and Colombia) which are in the process of implementing carbon pricing policies, to identify the key drivers of adoption as well as any barriers that may impact successful policy implementation or effectiveness.

Well-designed carbon pricing policies that take into account effectiveness in emissions reductions, regulatory stability, the potential for negative distributional effects, interactions with other policies and the impact on global trade, are more likely to contribute to the cost-effective attainment of environmental and social targets. As carbon pricing policies can work to incentivize various outcomes including resource efficiency, green technology development, low-carbon intensity industries, electricity generation from renewables, and low-carbon transportation, the policy objective should be clear, and sector specific targets clearly identified. Table 9 summarizes the findings of this report across the key parameters that determine carbon pricing instrument selection.

As a policy instrument, carbon taxes have so far been more widely adopted and therefore there is a wider empirical experience of policy effectiveness to review. While taxes appear to have been more successful at reducing emissions, recent adaptations of ETS systems may overturn this conclusion in the near future. Carbon taxes have been favored by governments because of their lower cost of implementation, the comparative ease of implementation, the potential to increase government revenue, and the potential for offsetting reductions in income taxes. Among the countries with mature carbon pricing policies reviewed in this report, those with carbon tax policies demonstrated greater reductions in greenhouse gas (GHG) emissions than countries with only ETS. However, recent reforms to the EU ETS, the New Zealand ETS, and the California cap and trade will likely improve ETS effectiveness in reducing emissions.

As research suggests, there will always be a tradeoff between the scope of the pricing policy and the effective rate or price. As the second oldest ETS, the New Zealand ETS provides a context for analyzing the potential benefits and challenges of linking national, subnational, or international carbon markets. Evidence suggests that despite early theoretical support for linking carbon systems – with the intention to reduce marginal abatement costs and prevent “carbon leakage” – the import of offsets determines prices more than fundamentals such as energy prices or economic conditions (Diaz-Rainey and Tulloch, 2018). Analysis suggests falling international prices for carbon in 2011 depressed NZ ETS prices which led to the banning of international CERs and ERUs. The New Zealand experience suggests that the global standard of limiting importation of offsets to less than 20% of market share can lessen the likelihood of market distortion and strengthen market integrity.

As carbon pricing policies are commonly implemented first in the energy and industry sectors, gradual introduction of pricing mechanisms allow for adequate lead time in adjusting to new regulations. For example, a review of the Regional Greenhouse Gas Initiative (RGGI) led to pricing reforms that included reducing the cap by 3% annually between 2021 and 2030 and introducing an Emissions Containment Reserve (ECR) that requires states to withhold up to 10% of annual allowances. This withholding secures emissions reductions should prices fall below the established trigger price of US$6 (ICAP, 2018).

Taxes have the benefit of wide application and should be considered for cross-sectoral adoption as there are improvements in the analysis of material flows, resource efficiency, and sustainable production and consumption. Whether a fee is added to a carbon intensive good or service or an emissions cap is set creating a market for allowances, governments implement carbon pricing mechanisms in order to incentivize low-cost abatement. While the effects of the two pricing options should be comparable, emissions trading systems (ETSs) come at a slightly higher cost as governments must establish capacities for regulatory oversight, auctions and monitoring, reporting, and verification (MRV) processes. Despite the higher cost, however, ETSs are better able to set firm limits on emissions so that policy effectiveness can be better targeted.

The local carbon price burden of a country (which can be proxied by the carbon price imposed by policy x emissions per capita, divided by GDP per capita) is an indicator of the likelihood of regulatory stability. The indicator embodies the ability of the average citizen to shoulder the burden of carbon prices and incorporates the impact of the proportion of domestic energy derived from renewable sources. The two focus countries in this case study, Colombia and Chile, have very low local carbon price burdens relative to the average carbon pricing jurisdiction and are thus unlikely to face abortive cancelations of carbon pricing policies.

Revenue-neutrality and the transparent and socially accepted use of proceeds are key drivers of political acceptance of carbon pricing where they have a significant regressive impact. Low-income earners spend a greater proportion of their income on basic needs such as fuel and, as a result, feel a greater burden when taxes are increased. Revenue-neutrality, as demonstrated by the Canadian example, significantly increases the political feasibility of carbon taxes. Fiscal policy that broadly considers interactions between tax policies, such as personal taxes and corporate taxes, are important for the success of carbon tax policies.

In order to be effective and immune to strategic arbitrage, ETS systems need to have significant diversity and depth of participants. While it is easiest for a government to achieve static effectiveness by targeting a small number of emitters or by implementing carbon taxes over building a new market infrastructure, market depth and diversity reduce the marginal cost of abatement. Supra-national ETS systems can serve as critical market linkages between many smaller national economies where low-cost implementation points to a local carbon tax. Mature deregulation of electricity markets, along with liberalized entry of foreign and private participants in energy markets, such as in Chile, have been important enabling conditions for the design of an ETS system. ETS systems are more politically feasible when linked to broader socio-economic goals, such as energy market development and cross-border integration.

The degree to which there is cross-sectoral policy coherence within a jurisdiction impacts (1) the likelihood that a carbon pricing policy will reach implementation, and (2) the outcome of the policy. Analysis of environmental policy interactions across the domains of energy, climate change, transportation and natural resource management helps identify potentially counter-productive policies. There is no consistent approach for cross impact analysis of environmental policy regimes. As carbon taxes may not be as responsive to market shifts as ETS, there is a need to regularly review tax schemes to insure they remain relevant and well targeted. Additionally, as fuel switching and resource efficiency improves, environmental taxes will begin to taper as seen in Sweden.

A well-publicized implementation schedule, including a multi-phased approach to pricing, is needed to reduce economic or social shocks that can result from carbon pricing policies. Public perceptions of government effectiveness can impact the ability of a policy to be adopted, implemented, and sustained over time. Regardless of whether the burden of carbon pricing policies is real or perceived, the willingness of firms or households to accept additional taxation or emissions caps is critical for policy success. In addition to aiming to be revenue neutral, common implementation strategies allow for the gradual increase of carbon prices and taxes or increasingly stringent adjustments to the price cap over time. This allows for gradual cross-sectoral economic adjustment and minimizes the likelihood that the increased cost could lead to a shift in production toward jurisdictions with lower production costs.

Carbon leakage, while often discussed, is not an economically significant obstacle for the countries actually considering carbon pricing. Jurisdictions that have chosen to implement carbon pricing have higher overall export intensity than the global average, suggesting that carbon leakage is not a significant concern for export-oriented economies. While this result was initially surprising, it is consistent with findings that carbon pricing is adopted by high and middle income countries with which are more focused on services, so that the carbon-intensity of their exports is likely to be low. Although border carbon adjustments have been proposed as ways to alleviate carbon leakage where that is a concern, in practice, such adjustments have to be crafted with care to remain consistent with international trade commitments.

Table 9. Matrix of Key Parameters for Selection of Carbon Pricing Policies

	ETS	Carbon Tax
Policy Effectiveness	Provides certainty of abatement quantity, but renders the price per unit of abatement uncertain. ETS are effective in reducing carbon emissions, but the instrument is yet to be proven in all sectors. The advent of a market stability reserve in the EU ETS and permit import restrictions in the New Zealand ETS demonstrate the feasibility of efforts to maintain market stability.	Does not guarantee abatement quantity, but the certain price per unit of abatement ensures a stable price to spur decarbonization efforts. Carbon taxes are effective in reducing carbon emissions and often replace or complement existing excise taxes, particularly in the energy sector.
Regulatory Stability	Reform efforts and increasingly efficient ETS policies will improve the likelihood that a stable regulatory environment can be maintained. The investment required in institutional infrastructure needed for ETS implementation helps consolidate political will for regulatory stability.	Phased introduction of new taxes and regulations are necessary to ensure taxpayer support and investor confidence.
Costs and Distributional Effects	Costs associated with effective ETS include investment in capacity for monitoring and verification.	Lacking political will and the potential for regressive impact can hamper political vetting, implementation, and continuation. Revenue neutral carbon taxes are increasingly viewed as more equitable, a view that helps consolidate wide political and public support.
Policy Coherence	Overlapping polices, along with the economic downturn, undermined the effectiveness of the EU ETS. Reform efforts have targeted strategies to safeguard against an allowance surplus by improving policy coherence with the Renewable Energy Directive and the Energy Efficiency Directive.	Carbon tax policy must be considered in the context of both environmental policies and taxes as well as fiscal policy and taxation, including individual and corporate tax rates.
Impact on Trade	Carbon leakage, though theoretically important has not been critical empirically.	Border carbon adjustments have been proposed as supplements to a carbon tax to address possible competitive disadvantage and emissions leakage, but many details remain to be worked out to address scope and compatibility of BCAs with international trade agreements.

References

Ackva, J., & Hoppe, J. (2018). *The Carbon Tax in Sweden: Fact sheet* (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Federal Republic of Germany). Adelphi.

Alberola, E., Chevallier, J., & Chèze, B. (2008). Price drivers and structural breaks in European carbon prices 2005–2007. *Energy Policy*, *36*(2), 787–797. https://doi.org/10.1016/j.enpol.2007.10.029

Aldy, J. E. and W. A. Pizer (2015). "The Competitiveness Impacts of Climate Change Mitigation Policies." Journal of the Association of Environmental and Resource Economists 2(4): 565-595.

Aldy, J. E. and R. N. Stavins (2012). "The Promise and Problems of Pricing Carbon: Theory and Experience." Journal of Environment and Development 21(2): 152-180.

Andersen, M., & Ekins, P. (Eds.). (2009). *Carbon-Energy Taxation: Lessons from Europe*. Oxford University Press.

Asian Development Bank Staff. (2016). *Emissions Trading Schemes and Their Linking: Challenges and Opportunities in Asia and the Pacific*. Manila, PHILIPPINES: Asian Development Bank Institute. Retrieved from http://ebookcentral.proquest.com/lib/columbia/detail.action?docID=4620966

Axford, C. (2018, December 17). British Columbia's Carbon Tax Is Working. Retrieved April 10, 2019, from https://medium.com/the-sensible-soapbox/british-columbias-carbon-tax-is-working-3ea81114be5a

Beck, M., Rivers, N., Wigle, R., & Yonezawa, H. (2015). Carbon tax and revenue recycling: Impacts on households in British Columbia. *Resource and Energy Economics*, *41*, 40–69. https://doi.org/10.1016/j.reseneeco.2015.04.005

Best, R., & Burke, P. J. (2018). Adoption of solar and wind energy: The roles of carbon pricing and aggregate policy support. *Energy Policy*, *118*, 404–417. https://doi.org/10.1016/j.enpol.2018.03.050

Bjørn, A., Kalbar, P., Nygaard, S. E., Kabins, S., Jensen, C. L., Birkved, M., … Hauschild, M. Z. (2018). Pursuing necessary reductions in embedded GHG emissions of developed nations: Will efficiency improvements and changes in consumption get us there? *Global Environmental Change*, *52*, 314–324. https://doi.org/10.1016/j.gloenvcha.2018.08.001

Böhringer, C., Löschel, A., Moslener, U., & Rutherford, T. F. (2009). EU climate policy up to 2020: An economic impact assessment. *Energy Economics*, *31*, S295–S305. https://doi.org/10.1016/j.eneco.2009.09.009

Branger, F., & Quirion, P. (2014). Would border carbon adjustments prevent carbon leakage and heavy industry competitiveness losses? Insights from a meta-analysis of recent economic studies. *Ecological Economics*, *99*, 29–39.

Branger, F., et al. (2016). "Carbon Leakage and Competitiveness of Cement and Steel Industries under the EU ETS: Much Ado about Nothing." Energy Journal 37(3): 109-135.

Brink, C., Vollebergh, H. R. J., & van der Werf, E. (2016). Carbon pricing in the EU: Evaluation of different EU ETS reform options. *Energy Policy*, *97*, 603–617. https://doi.org/10.1016/j.enpol.2016.07.023

CDP. (2017). *Putting a price on carbon: Integrating climate risk into business planning*. United States: CDP.

CDP. (2019). Climate Disclosure Project. Retrieved April 9, 2019, from https://www.cdp.net/en

Chen, W., & Guo, Q. (2017). Assessing the Effect of Carbon Tariffs on International Trade and Emission Reduction of China's Industrial Products under the Background of Global Climate Governance. *Sustainability*, *9*(1028).

Columbia University. (2018). *Carbon Taxes Would Drive GHG Emissions Reductions with Minimal Impact on U.S. Economy, Oil and Gas Production*. Columbia University Research Series. Retrieved from https://energypolicy.columbia.edu/july-2018-carbon-tax-research-series

Convery, F., Dunne, L., & Joyce, D. (2013). *Ireland's Carbon Tax and the Fiscal Crisis: Issues in Fiscal Adjustment, Environmental Effectiveness, Competitiveness, Leakage and Equity Implications* (No. OECD Evironment Working Papers No. 59). Paris: OECD Publishing.

Corradini, M., Costantini, V., Markandya, A., Paglialunga, E., & Sforna, G. (2018). A dynamic assessment of instrument interaction and timing alternatives in the EU low-carbon policy mix design. *Energy Policy*, *120*, 73–84. https://doi.org/10.1016/j.enpol.2018.04.068

Cushing, L., Blaustein-Rejto, D., Wander, M., Pastor, M., Sadd, J., Zhu, A., & Morello-Frosch, R. (2018). Carbon trading, co-pollutants, and environmental equity: Evidence from California's cap-and-trade program (2011-2015). *PLoS Medicine*, *15*(7), e1002604. Retrieved from https://doaj.org

De Clara, S. & Mayr, K. (2018). The EU ETS phase IV reform: implications for system functioning and for the carbon price signal. Oxford Energy Insight: 38. The Oxford Institute for Energy Studies.

Diaz-Rainey, I., & Tulloch, D. J. (2018). Carbon pricing and system linking: Lessons from the New Zealand Emissions Trading Scheme. *Energy Economics*, *73*, 66–79. https://doi.org/10.1016/j.eneco.2018.04.035

Ecorys. (2011). *The role of market-based instruments in achieving a resource efficient economy* (No. ENV.G.1/FRA/2006/0073). Rotterdam: European Commission: DG Environment.

European Commission. (2015). *Evaluation of the EU ETS Directive*. European Commission.

European Commission. (2016a, November 23). Carbon leakage [Text]. Retrieved April 9, 2019, from https://ec.europa.eu/clima/policies/ets/allowances/leakage_en

European Commission. (2016b, November 23). EU Emissions Trading System (EU ETS) [Text]. Retrieved April 9, 2019, from https://ec.europa.eu/clima/policies/ets_en

European Commission. (2016c, November 23). Monitoring, reporting and verification of EU ETS emissions [Text]. Retrieved April 9, 2019, from https://ec.europa.eu/clima/policies/ets/monitoring_en

European Environment Agency (EEA). (2016). Environmental taxation and EU environmental policies [Publication]. Retrieved February 22, 2019, from https://www.eea.europa.eu/publications/environmental-taxation-and-eu-environmental-policies

Fedrigo-Fazio, D., Withana, S., Hirschnitz-Garbers, M., & Gradmann, A. (2013). Steps towards greening in the EU – Monitoring Member States' achievements in selected environmental policy areas (No. ENV.G.1/FRA/2010/0044). European Commission: DG Environment.

Fouré, J., Guimbard, H., & Monjon, S. (2016). Border carbon adjustment and trade retaliation: What would be the cost for the European Union? Energy Economics, 54, 349–362. https://doi.org/10.1016/j.eneco.2015.11.021

Government of Chile. (2015). INTENDED NATIONALLY DETERMINED CONTRIBUTION OF CHILE TOWARDS THE CLIMATE AGREEMENT OF PARIS 2015. Santiago, Chile. Retrieved from https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Chile%20First/INDC%20Chile%20english%20version.pdf

Harrison, K. (2013). The Political Economy of British Columbia's Carbon Tax (OECD Environment Working Papers No. 63). OECD Publishing. Retrieved from https://search-proquest-com.ezproxy.cul.columbia.edu/docview/1447222759?pq-origsite=summon

Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Mitigation of Climate Change, Working Group III Contribution to the Fifth Assessment Report. Switzerland: The Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf.

Intergovernmental Panel on Climate Change (IPCC). (2018). IPCC Special Report: Global Warming of 1.5˚C. Switzerland: The Intergovernmental Panel on Climate Change.

International Carbon Action Partnership (ICAP). (2018). Emissions Trading Worldwide: International Carbon Action Partnership (ICAP) Status Report 2018. Berlin: ICAP.

International Civil Aviation Organization (ICAO). (2019). What is CORSIA and how does it work? Retrieved April 9, 2019, from https://www.icao.int/environmental-protection/pages/a39_corsia_faq2.aspx

International Energy Agency (IEA). (2018). ENERGY POLICIES BEYOND IEA COUNTRIES: Chile 2018.

Ismer, R. and M. Haussner (2016). "Inclusion of Consumption into the EU ETS: The Legal Basis under European Union Law." Review of European Comparative & International Environmental Law 25(1): 69-80.

Jantzen, J., & van der Woerd, H. (2015). Environmental expenditures in EU industries: Time series data for the costs of environmental legislation for selected industries over time Final report. European Commission.

Jenkins, J. D. (2014). Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design? Energy Policy, 69, 467–477. https://doi.org/10.1016/j.enpol.2014.02.003

Koch, N. (2014). Dynamic Linkages among Carbon, Energy and Financial Markets: A Smooth Transition Approach. Applied Economics, 46(7–9), 715–729. Retrieved from https://ezproxy.cul.columbia.edu/login?qurl=https%3a%2f%2fsearch.ebscohost.com%2flogin.aspx%3fdirect%3dtrue%26db%3deoh%26AN%3d1428218%26site%3dehost-live%26scope%3dsite

Lawley, C., & Thivierge, V. (2018). Refining the evidence: British Columbia's carbon tax and household gasoline consumption. The Energy Journal, 39(2). https://doi.org/10.5547/01956574.39.2.claw

Lin, B., & Jia, Z. (2019). What are the main factors affecting carbon price in Emission Trading Scheme? A case study in China. Science of The Total Environment, 654, 525–534. https://doi.org/10.1016/j.scitotenv.2018.11.106

Mehling, M. A., Asselt, H. van, Das, K., & Droege, S. (2018). Beat protectionism and emissions at a stroke. Nature, 559(7714), 321. https://doi.org/10.1038/d41586-018-05708-7

MINISTRY OF THE ENVIRONMENT OF CHILE. (2014). CHILE'S NATIONAL GREENHOUSE GAS INVENTORY, 1990-2010. Chile: Climate Change Office.

Moltke, A. von, McKee, C., Morgan, T., Töpfer, K., McKee, C., Morgan, T., & Töpfer, K. (2017). Energy Subsidies : Lessons Learned in Assessing their Impact and Designing Policy Reforms. Routledge. https://doi.org/10.4324/9781351283205

Monge, C. (2018). Colombia Puts a Tax on Carbon. Clean Energy Finance Forum.

Naegele, H. and A. Zaklan (2019). "Does the EU ETS cause carbon leakage in European manufacturing?" Journal of Environmental Economics & Management 93: 125-147.

Next10. (2018). 2018 California Green Innovation Index, 10th Edition. Retrieved from https://next10.org/sites/default/files/2018-ca-green-innovation-index.pdf

Nilsson, M., Zamparutti, T., Petersen, J. E., Nykvist, B., Rudberg, P., & McGuinn, J. (2012). Understanding Policy Coherence: Analytical Framework and Examples of Sector-Environment Policy Interactions in the EU. Environmental Policy & Governance, 22(6), 395–423. https://doi.org/10.1002/eet.1589

Orange, R. (2018). "Swedish governing party threatens US with green trade war." The Local, Sweden. Retrieved from https://www.thelocal.se/20180904/swedish-party-threatens-us-with-green-trade-war.

OECD. (2011). Interactions Between Emission Trading Systems and Other Overlapping Policy Instruments (General Distribution Document, Environment Directorate). Paris: OECD.

OECD. (2018). Cost-Benefit Analysis and the Environment. Retrieved February 22, 2019, from https://read.oecd-ilibrary.org/environment/cost-benefit-analysis-and-the-environment_9789264085169-en

Organisation for Economic Cooperation and Development (OECD), & World Bank Group (WBG). (2015). The FASTER Principles for Successful Carbon Pricing: An approach based on initial experience. (No. 99570) (pp. 1–38).

Organisation for Economic Cooperation and Development (OECD). (2018a). Effective Carbon Rates 2018: Pricing Carbon Emissions Through Taxes and Emissions Trading. Paris: OECD Publishing.

Organisation for Economic Cooperation and Development (OECD). (2018b). OECD Economic Surveys Chile February 2018 OVERVIEW (OECD Economic Surveys).

Organisation for Economic Cooperation and Development (OECD). (2018c). Policy Coherence for Sustainable Development 2018: Towards Sustainable and Resilient Societies. Paris: OECD Publishing. Retrieved from https://doi.org/10.1787/9789264301061-en.

Organisation for Economic Cooperation and Development (OECD). (2018d). Taxing Energy Use 2018: Companion to the Taxing Energy Use Database. Paris: OECD Publishing.

Organisation for Economic Cooperation and Development (OECD). (2019). Database on Policy Instruments for the Environment. Retrieved April 9, 2019, from https://pinedatabase.oecd.org/

Partnership for Market Readiness (PMR). (2015). Partnership for Market Readiness (PMR) Project Implementation Status Report (ISR). Ministry of Energy.

Republic of Chile. (2015). PMR Project Implementation Status Report (ISR). Partnership for Market Readiness.

Republic of Chile. (2018). Partnership for Market Readiness (PMR) Project Implementation Status Report.

Scott, S., & Eakins, J. (2004). Carbon Taxes: Which Households Gain or Lose? ERTDI20 Environmental Protection Agency, Ireland.

Skjærseth, J. B. (2010). EU emissions trading: Legitimacy and stringency. Environmental Policy & Governance, 20(5), 295–308. https://doi.org/10.1002/eet.541

Skjærseth, J. B. and J. Wettestad (2010). "Making the EU Emissions Trading System: The European Commission as an entrepreneurial epistemic leader." Global Environmental Change 20(2): 314-321.

Smith, S. and J. Swierzbinski (2007). "Assessing the performance of the UK Emissions Trading Scheme." Environmental and Resource Economics 37(1): 131-158.

Sovacool, B.K. (2013). Energy policymaking in Denmark: Implications for global energy security and sustainability. Energy Policy, (61), 829-839.

Stowell, D. (2005). Climate trading : development of greenhouse gas markets. New York, N.Y. :, Palgrave Macmillan.

Tamiotti, L. (2011). The legal interface between carbon border measures and trade rules. Climate Policy; London, 11(5), 1202–1211. http://dx.doi.org/10.1080/14693062.2011.592672

The Institute for European Environmental Policy (IEEP). (2012). STUDY SUPPORTING THE PHASING OUT OF ENVIRONMENTALLY HARMFUL SUBSIDIES (No. 07.0307/2011/611259/ENV.F.1).

UN Global Compact. (2014). Business Leadership Criteria on Carbon Pricing | UN Global Compact. Retrieved April 9, 2019, from https://www.unglobalcompact.org/library/1051

Under2 Coalition. (n.d.). Retrieved April 10, 2019, from https://www.under2coalition.org/climate-group

UNDP. (2018). NDC Support Program. Retrieved from http://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/latin-america-and-caribbean/colombia.html

UNEP & CDP. (2019). The Portfolio Decarbonization Coalition. Retrieved April 9, 2019, from https://unepfi.org/pdc/

US Energy Information Administration (EIA). (2019). State-Level Energy-Related Carbon Dioxide Emissions, 2005-2016. Retrieved April 10, 2019, from https://www.eia.gov/environment/emissions/state/analysis/

Voß, J.-P. (2007). Innovation processes in governance: the development of “emissions trading” as a new policy instrument. Science & Public Policy (SPP), 34(5), 329–343. https://doi.org/10.3152/030234207X228584

Wagner, G. (2015). Push renewables to spur carbon pricing. Nature; London, 525(7567), 27–29. Retrieved from https://search.proquest.com/docview/1710030057/abstract/C0E7272ED95F4F57PQ/1

Weitzman, M. L. (1974). Prices vs. Quantities. The Review of Economic Studies, 41(4), 477–491. https://doi.org/10.2307/2296698

World Bank Group. (2011). Transition to a Low-Emissions Economy in Poland. Washington D.C.: World Bank.

World Bank Group. (2017). Partnership for Market Readiness, Carbon Tax Guide: A Handbook for Policy Makers. Retrieved from http://documents.worldbank.org/curated/en/728421535605566659/Carbon-Tax-Guide-A-Handbook-for-Policy-Makers

World Bank Group. (2018). Poland’s Greenhouse Gas Emissions.

World Bank Group. (2019a). The World Bank: Carbon Pricing Dashboard.

World Bank Group (2019b). State and Trends of Carbon Pricing 2019. Washington, DC, World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/31755.