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The Political Economy of Carbon Pricing: a Panel Analysis

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JEL Classification H23, Q58

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The political economy of carbon pricing: a panel analysis

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Abstract

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1 Introduction

The agreement reached in Paris at the end of 2015 was a diplomatic success. Its environmental benefits are, however, much less clear. If fully implemented, current Intended Nationally Determined Contributions (INDCs) submitted to the UNFCCC Secretariat place the world on an emissions path that is incompatible with least-cost 2°C scenarios, the goal stated in the Accord (United Nations/Framework Convention on Climate Change, 2015).[1]

As the IPCC Working Group II "reasons for concern" make clear, this level bears significant risks for human development and is likely to place unprecedented pressure on already stressed ecosystems (IPCC, 2014). Therefore, supplementary commitments to reduce Greenhouse Gases (GHG) emissions beyond existing INDCs are needed.[2] This will, in turn, require the setting up of new (or the strengthening of existing) environmental policy tools.

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[1]Compared with the emission levels under least-cost 2°C scenarios, aggregate GHG emission levels resulting from the implementation of the INDCs are expected to be higher by 8.7 (4.5 to 13.3) Gt CO2 eq (19 per cent, range 9-30 per cent) in 2025 and by 15.2 (10.1 to 21.1) Gt CO2 eq (36 per cent, range 24-60 per cent) in 2030 (United Nations/Framework Convention on Climate Change, 2016).

[2]*Targets*, in the present context, refer to stated emissions reductions objectives. The binding nature of these objectives obviously differs from one jurisdiction to the other: some of those targets are more credible than others and/or have received stronger legal status. For more information on the (legally) binding character of these targets, please see The Global Climate Legislation Database (2015).

Historically, these tools took the form of "command-and-control" regulations, production quotas and subsidies for electricity from renewable energy sources and, more recently, carbon pricing instruments such as carbon taxes or cap-and-trade systems (Bennear and Stavins, 2007).[3] The focus of this paper is on the latter category.

While the earliest occurrences of these tools can be traced back to the experiences of Northern European states (Finland - 1990, Sweden - 1991), their development has only gained momentum in the last few years. According to World Bank (2014), eight new carbon markets started operations in 2013, including the California Cap-and-Trade Program and five (sub-national) emissions trading schemes in China. These new schemes added to a group of existing carbon pricing tools such as the European Union Emissions Trading System or the Regional Greenhouse Gases Initiative (RGGI) in the United States as well as a range of taxes explicitly based on the carbon content of fossil fuels.[4]

Yet, the introduction of such tools is often faced with strong political economy constraints (Jenkins, 2014) that influence their design and prevent their full (i.e. socially optimal) implementation (Del Rio and Labandeira, 2009). Their influence on the implementation of carbon pricing policies is nonetheless currently under-researched by the literature. While substantial attention has been paid to the political economy of energy or renewable energy support (RES) policies, a relatively narrow set of studies have specifically focused on policies making use of carbon pricing mechanisms, be it in a specific national or subnational context, or in an international panel of countries.

Our study is a contribution to filling this gap. It aims at shedding light on the nature and working of political economy constraints on the development of carbon pricing policies by providing a quantitative assessment of some of them in an international panel of jurisdictions. We believe that a better understanding of the political economy dynamics at play may hold substantial implications for the design of climate mitigation strategies. Put differently, our paper is concerned with the design of climate mitigation strategies in the presence of political economy constraints. Such investigation deals with two questions in particular. How should we adapt the policy design to a specific institutional and economic context? Do political economy constraints

[3] Even though *carbon* per se is not a greenhouse gas but rather carbon dioxide is, we will refer to instruments putting a price on CO_2 emissions as carbon pricing instruments. Moreover, in this paper, carbon pricing instruments encompass both carbon taxes and emissions trading schemes even though the latter sometimes include other greenhouse gases than CO_2.

[4] For a comprehensive review of the latest developments in carbon pricing mechanisms, please see the full reports, available here: World Bank, 2014, World Bank, 2015.

constitute a robust rationale in favor of a policy mix as opposed to a single instrument?

The paper is organized as follows. Section 2 reviews the relevant strands of the literature. Section 3 briefly discusses carbon pricing (in theory and practice) and introduces the Effective Carbon Price. Section 4 presents the hypotheses and data. Section 5 discusses the empirical methodology used in the analysis and the results. Section 6 provides a contextualised discussion and section 7 concludes.

2 Literature review

More often than not, economic policies resulting from the legislative and political bargaining process constitute sub-optimal social outcomes. Political economy theory provides a useful analytical framework to rationalise them. Olson (1965) highlights the role played by groups with shared interests in shaping policy outcomes and the factors that drive their behaviour. In particular, he emphasises that the mere existence of a common and shared interest among a group of individuals is not sufficient to guarantee that the group will be institutionalised and seek "the furtherance of the interests of [its] members" (Olson (1965), p.5). A classic collective action problem arises where, in the absence of credible coercion devices, the group interest will not be furthered; even more so when the cost of doing so increases (e.g. when the number of members in the group rises). Building on Olson's conjecture, Stigler (1971) proposed the idea of regulatory capture, which views the State as a provider of regulation and the industry as an active seeker of regulation designed and operated for its own benefit.

The relevance of these theoretical insights has long been discussed in the context of environmental policy making (Pearce, 2005). Congleton (1992) takes an institutional perspective to the issue and proposes that political institutions, rather than resource endowments, determine a country's environmental regulation. More precisely, he argues that due to their focus on longer term outcomes, democratic institutions tend to deliver more stringent environmental regulations.[5] At the same time, democratic systems allow a plurality of, sometimes divergent, interests to be voiced. Hahn (1990) attempted to identify rationales for the emergence of incentive-based mechanisms and suggested that environmental policy is the result of a "struggle" between different interest groups. In the context of carbon pricing, the introduction of (economy-wide) schemes may induce profound changes in the magnitude and distribution of welfare. Therefore, even if the welfare of the polity as a whole is greater in an economic system

[5]Note that this argument is at odds with the standard view that political representatives are self-interested and focused on short-term electoral cycles.

constrained by environmental policies, one may expect strong opposition on the part of both consumers and producers.

On the consumption side, some studies have shown that the willingness to pay for carbon emissions is low (Jenkins, 2014). Moreover, carbon pricing schemes have been found to be regressive, with varying degrees, in a wide range of institutional contexts (Wier et al., 2005; Grainger and Kolstad, 2010; Shammin and Bullard, 2009). However, carbon pricing schemes can be – and some actually are – designed to alleviate this effect (Bowen, 2015). On the production side, sectors with assets whose value would be severely diminished in case of carbon pricing are expected to strongly oppose policy change. See Joskow and Schmalesee (1998) for evidence of such behaviour in the case of the U.S. SO_2 market.[6]

Analyses taking advantage of the availability of panel data have also shed light on political economy dynamics. Marques et al. (2010) analyse the drivers of the deployment of renewable energy in European countries. Using fixed effects (panel data) regression and vector decomposition, they find evidence that the conventional energy sector lobby and the level of CO_2 emissions impede the deployment of renewable energy sources for electricity production. Chang and Berdiev (2011) focus on the electricity and gas industries and seek to disentangle the effects of government ideology, political factors and globalisation on energy regulation in 23 OECD countries over the period 1975-2007. They conclude that left-wing governments promote regulation in gas and electricity sectors and that less fragmented governments contribute to deregulation of gas and electricity industries. van Beers and Strand (2015) conduct an empirical analysis of the political determinants of fossil fuel pricing. Using data on 200 countries for the period 1991-2010, they analyse the effect of a set of economic and political variables on gasoline and diesel prices. Their main findings are that higher GDP levels lead to higher fuel prices (higher taxes or lower subsidy rates) and that plurality in voting or a presidential system leads to significantly lower gasoline and diesel prices than parliamentarian or proportional representation systems.

Lastly, some insights drawn from analyses of the liberalisation of energy markets are also relevant to our investigation. Pollitt (2012) takes stock of the energy market liberalisation processes to draw lessons about the role of policy in energy transitions. One key insight from the analysis is that liberalisation *per se* will have little impact on the shift toward a low carbon

[6] This links to a recent literature on stranded assets, which seeks to draw the attention toward assets that may suffer unanticipated or premature write downs in case of the introduction of carbon pricing policies.

energy mix. Rather, the willingness of societies to bear the cost of environmental policies will. Nonetheless, liberalisation is not necessarily *neutral* for carbon pricing policy formulation as it has made the cost of those policies increasingly apparent to consumers (Pollitt, 2012). This, in essence, can be linked to the argument of Jenkins (2014): some evidence from the U.S. suggests that citizens are quite sensitive to the direct costs induced by carbon pricing policies, even if the net cost is brought (close) to zero via tax rebates or other fiscal mechanisms.

However substantial the discussion of political economy factors in environmental policy formulation has been, relatively less attention has been paid to the political feasibility of carbon pricing policies and, equivalently, to the variables that influence their implementation and strength. Consequently, suggestions about a way forward for the implementation of carbon pricing when faced with *political economy* constraints are, at best, incomplete. To our knowledge, only Jenkins (2014), Gawel et al. (2014) and Del Rio and Labandeira (2009) bring the issue to the fore. Taking stock of these analyses, we will endeavour to shed light on the factors driving the implementation and stringency of carbon pricing policies. Before turning to that analysis, however, we briefly review the rationale and tools for a carbon price.

3 Carbon pricing policies: theory and practice

3.1 The theory

When the concerns about the effects of GHG accumulation on Global Mean Temperature – and likely adverse economic consequences – first emerged, "doing nothing" was considered as a legitimate option (Barbier and Pearce, 1990). To put it in Nordhaus' terms, at the time, "the best investment to ameliorate the CO_2 problem [...] [was] probably to expand our CO_2 knowledge" (Nordhaus, 1989). Roughly a quarter of a century later, substantial investment has gone into the expansion of that knowledge, and a broad consensus about the effects of additional CO_2 emissions has emerged: their accumulation in the atmosphere strengthens the greenhouse effect, leading to an increase in Global Mean Temperature.

This, in turn, bears adverse environmental effects and, ultimately, induces economic costs (Bowen, 2011). In other words, any tonne of CO_2 emitted in the atmosphere implies a marginal damage. Avoiding excessive emissions and the ensuing economic cost is the main rationale behind the reduction of GHG emissions.[7]

To achieve such reductions, various jurisdictions have implemented market-based tools to

[7] To the extent that regulatory authorities aim at reducing emissions below a Business As Usual scenario, this is equivalent to laying the case for a strictly positive price of carbon.

create a price on GHG emissions. Two mechanisms (and hybrid combinations[8]) have emerged: carbon taxes and Emissions Trading Schemes. The former places a set price on each unit of CO_2 emitted into the atmosphere, leaving an uncertainty about the resulting level of emissions; the latter sets an emissions cap and leaves to the market the creation of the ensuing price signal.

Even though both mechanisms share the same underlying motivation and, under complete knowledge and perfect certainty, are theoretically equivalent and deliver the same environmental outcome, they relate to two slightly different views about carbon pricing.[9] The first view emphasises the use of carbon pricing mechanisms to internalise the externality associated with GHG emissions and hence is more sympathetic to carbon taxes. In that case, the price of carbon should closely track the Social Cost of Carbon (SCC). The second stresses the achievement of a set carbon budget over a given planning horizon in a cost-effective way. In that case, the price will follow the dynamically cost-effective price path (Rubin, 1996).

Finally, theory provides us with one additional insight: provided that the public authority can credibly commit to a state-contingent carbon price path and in the absence of transaction costs, the signal (i.e. the price of carbon) should be economy-wide (Tirole, 2012). The externality associated with the release of GHG into the atmosphere is the same regardless of its source (i.e. sector of origin) or type of use. Therefore, the price signal associated with GHG emissions ought to be the same across the economy and cover all emissions.[10] Any departure from this situation will inevitably introduce distortions between sectors and/or types of users.

3.2 The practical implementation

The schemes referred to in the above differ in their institutional design and practical implementation. On the one hand, most carbon taxes are based on the carbon content of fossil fuels which are used as input in the production process of various economic sectors.[11] On the other

[8] Hybrid schemes combine elements of price and quantity schemes by, e.g. setting floors and caps on the prices delivered by quantity schemes (Roberts and Spence, 1976; Weitzman, 1978).

[9] Outcomes may differ when there is uncertainty about either the marginal cost or benefit of abatement and the relative superiority of one instrument over the other depends on the relative slopes of the marginal abatement and cost curves around the optimum (Weitzman, 1974). Weitzman's original article considers only a static one-period model and so is more relevant to flow rather than stock pollutants like $\mathrm{CO_2}$. Pizer (2002) considers a multi-period calibrated model of $\mathrm{CO_2}$ and confirms Weitzman's conclusion that taxes are superior to quotas for $\mathrm{CO_2}$, while Hoel and Karp (2002) extend the analysis to stochastic dynamic formulations, again supporting the same conclusion.

[10] If transaction costs (i.e. costs of monitoring and verification) are positive, then optimal coverage may not be 100%. In that case, additional emissions should be included only if the marginal benefit in terms of enhanced cost efficiency outweighs the marginal cost of monitoring and verifying emissions. However, as far as CO_2 emissions are concerned, it isn't clear that transaction costs are high – after all, one can easily tax the source of carbon, i.e. fossil fuels. It is true, however, that there are technical difficulties in implementing schemes covering other greenhouse gases and that, hence, it might be sub-optimal to aim at a 100% coverage of CO_2e.

[11] It is to be noted, however, that carbon tax schemes need not be based on this indirect measurement approach. Direct measurement of actual emissions at the source is technically feasible.

hand, an Emissions Trading Scheme is based on actual verified emissions at covered (stationary) plants.[12] Therefore, an ETS can include fugitive emissions and not only emissions from fuel combustion.

In 2015, 35 national and 21 subnational jurisdictions had an operating Emissions Trading Scheme while 15 national and 1 subnational jurisdiction had a carbon tax targeting at least one type of fossil fuel (i.e. coal, oil or natural gas). Among all jurisdictions operating an ETS, 47 cover industry and 54 cover the power sector while the same sectors are included in 14 and 12 carbon tax schemes, respectively. The following table provides a summary of the sectors covered by any type of scheme and the number of jurisdictions in which scheme they are included.[13]

Table 1: Sectoral coverage – # of jursidictions

	Carbon tax schemes (total: 16)	ETSs (total: 56)
Industry	14	47
Power	12	54
(Road) Transport	12	5
Aviation*	4	31
Buildings (residential and commercial)	12	8
Agriculture or Forestry	11	2
Waste	12	1

*Domestic aviation only.
Note: The figures presented in this table count each jurisdiction participating in the EU-ETS as a separate scheme.

As we shall see in the next section, recent – and less recent – experience with carbon pricing policies suggests that their implementation has rarely, if at all, followed theoretical prescriptions. For example, most of the schemes under consideration entailed low coverage at time of introduction – due to, e.g., user(sectoral) or fuel-based exemptions, or a combination of the two. Besides, careful observation of policy developments shows no consistency between the stated environmental goals (and implied GHG budgets) and carbon prices. Several political economy factors may explain these discrepancies. We now turn to their analysis.

4 Carbon pricing and its drivers

Following our discussion in section 3, we argue that introducing a carbon pricing mechanism involves two stages. First, a decision on whether or not to enact a pricing scheme, regardless of the price level or the coverage. Second, a discussion about the appropriate (or politically

[12] Emissions from the aviation sector, which have recently been included in some ETSs, are estimated based on the fuel consumption of each aircraft, multiplied by the appropriate emissions factor (European Commission, 2012).

[13] A description of the sectoral nomenclature is available in appendix B and a complete list of the jurisdictions operating a carbon pricing mechanism in 2015 is available in appendix E.

feasible) intensity (i.e. price level and coverage).

Therefore, our empirical investigation shall consist of two stages: the first one consists of a panel logit regression with a dummy variable reflecting the presence or absence of a pricing mechanism as dependent variable; the second one is a standard (fixed-effects) panel regression with the Effective Carbon Price as dependent variable, which we describe in the next section, before turning to our hypotheses and the description of our explanatory variables.

4.1 Carbon price and coverage: an Effective Carbon Price

Following 'first-best' theoretical prescriptions, applied macroeconomic integrated assessment models often assume a single economy-wide carbon price. Consequently, the ensuing discussions implicitly assume that the introduced scheme covers 100% of a jurisdiction's GHG. Yet, when it comes to actual policy-making one realises that coverage is, at best, partial, and varies over time (see, e.g., World Bank, 2014). Therefore, the price tag alone cannot appropriately reflect the intensity of a carbon pricing scheme. It has to be analysed together with its coverage. Moreover, as will be shown in section 4.1.2, the carbon price is usually not unique within jurisdictions, let alone across them.

In order to accurately account for these two dimensions of carbon pricing mechanisms and reflect their intensity, we introduce the concept of an Effective Carbon Price (ECP).[14] This price, computed on a yearly basis, is an emissions-weighted average of all carbon price signals present in an economy at a point in time. The weights are the quantity of emissions covered at each price as a share of that jurisdiction's total GHG emissions. Before turning to a detailed discussion of the methodology for the calculation of the ECP, we review its two underlying components: coverage and price.

4.1.1 Coverage

The coverage of carbon pricing schemes is usually defined at the sectoral level although, as will be clarified below, carbon taxes are defined per fuel type too. The main difference between emissions trading schemes and carbon taxes lies in that the former often cover multiple gases whereas the latter only apply to the carbon content of fossil fuels and, by extension, to CO_2 emissions.[15]

[14] The methodology behind the computation of the Effective Carbon Price is similar to that suggested for the Effective Carbon Rate (OECD, 2015). However, unlike the OECD, which accounts for both explicit carbon prices and energy duties that indirectly price carbon, we focus on explicit carbon prices only.

[15] Some countries do have a tax on other GHGs, although these were initially introduced for ozone layer preservation motives. For example, Denmark levies a duty on CFCs, PFCs and HFCs (OECD, 2016). The scope of the present analysis is restricted to carbon taxes. However, since CO_2 emissions constitute the main source of GHG emissions, we believe that it does not impair the validity of the study.

Provided that accurate measurement of sectoral GHG emissions is available, one can easily translate sectoral and gas coverage into "covered" GHG emissions as a share of total GHG emissions. Total GHG emissions (excluding land use change) are taken from the CAIT Climate Data Explorer (2015) of the World Resources Institute. ETS-covered emissions ("verified emissions") are taken from the respective schemes' registries while the tax-covered emissions are computed using estimated sector-fuel disaggregated CO_2 emissions (IEA, 2016).[16]

The combination of these three sources allows for the calculation of coverage figures (as a share of a jurisdiction's total GHG emissions) for 136 national jurisdictions between 1990 and 2012.[17] In addition, coverage figures are computed (or collected from secondary sources) for 63 subnational jurisdictions for the same time period (50 US States and 13 Canadian Provinces and Territories).

Figure 1 provides an overview of the coverage of carbon pricing mechanisms in selected jurisdictions. Panel (a) clearly shows that there is significant variation in coverage of carbon tax schemes across jurisdictions. Between 1992 and 2005, Denmark's scheme covered roughly 70% of its GHG emissions, the highest share among all jurisdictions considered, while Finland's coverage was only 30%. It is also striking to see that if those schemes imply a significant coverage in terms of respective national emissions, they mean very little in terms of world GHG emissions, as illustrated by the "World" line. Except for the "structural break" observed in 2005 for some countries, which reflects the fact that they adapted their legislation to avoid an overlap with the EU-ETS, coverage of GHG emissions by tax schemes is, for each country individually, relatively stable over time. Similarly, the coverage induced by the ETS in the selected countries does not show significant variation over time.[18] Yet, one notes that all countries that are part of the EU-ETS exhibit different coverage figures, despite the ETS being harmonised across all countries. A potential explanation for these cross-country differences is that they reflect the differences in economic structure across participating countries.

In addition to the jurisdictions presented in Figure 1 several others have introduced carbon pricing policies. Switzerland introduced a carbon tax in 2008 covering about 28% of its total emissions.[19] The coverage remained relatively stable over time, with the scheme covering 27%

[16]Since the institutional design of emissions trading schemes and carbon taxes differ slightly, calculation of the coverage occurs according to different methodologies. See appendix B for a description of the methodology and a list of national ETS registries.

[17]The panel dimension is constrained by IEA emissions data availability; the time dimension by CAIT data availability.

[18]This is essentially due to the fact that the scope of the EU-ETS has not been modified over the period of analysis, which ends in 2012.

[19]The pilot phase of the Swiss ETS started in 2008. During that phase, the firms covered by the tax scheme

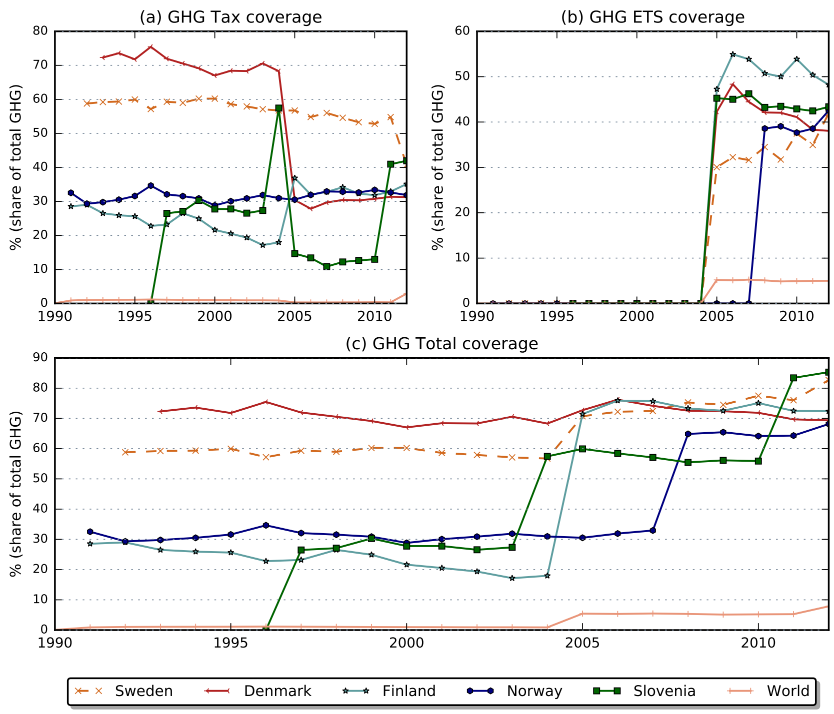

Figure 1: Carbon pricing coverage – selected EU-ETS countries

of emissions in 2012. In that same year, Japan introduced a carbon tax covering 69% of its emissions. Other jurisdictions opted for ETSs. This is the case of New Zealand, which introduced its scheme in 2010 with a coverage of 43% (gradually increased to 54% following inclusion of waste treatment activities in the scheme).

At the subnational level, another group of jurisdictions can be identified: US States participating in the Regional Greenhouse Gases Initiative (RGGI). This scheme is a regional initiative gathering initially 10 (but now 9) North-Eastern US States.[20] Figure 2 shows the implied coverage of the scheme in the 10 participating states over the period 2009 (start year)-2012. It is again striking to see that substantial cross-state variation characterizes coverage. New Hampshire exhibits the highest coverage over the entire period, oscillating between 36.41% in 2009 and 34.42% in 2012. The coverage in all other participating states is between 13.19% (New Jersey - 2009) and 34.42% (New Hampshire - 2012). Outside the RGGI initiative, British Columbia launched its own carbon tax scheme in 2008, covering roughly 70% of its total GHG emissions while, in 2013, California introduced a Cap-and-Trade (CaT) mechanism covering approximately 32% of its emissions.[21]

were given the opportunity to opt-in the ETS. The significance of the Swiss ETS over that period is relatively limited. Hence it is not included in the data.

[20] The state of New Jersey pulled out of the scheme in 2012.

[21] In 2012, the coverage of the California CaT was 32%. It remained unchanged until the end of the first compliance period (December 31st, 2014). As of January 1st, 2015, new activities were added to the scheme,

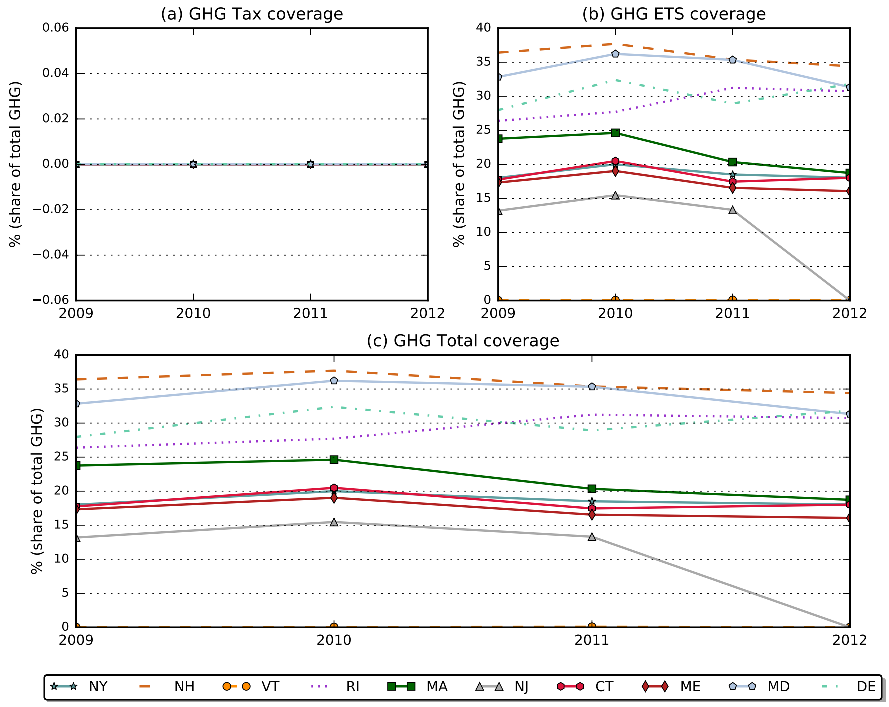

Figure 2: Carbon pricing coverage – US RGGI

4.1.2 Price

Coverage is only one side of the coin. The other is the price level. Countries that have introduced carbon pricing policies have experimented with different strengths of the price signal. The price varies mainly along three dimensions: time, jurisdiction, and sector.[22] In other words, the price signal varies both across and within countries, introducing distortions between countries as well as between sectors of a given country. Importantly, however, distortions introduced by the Emissions Trading Schemes are between covered and non-covered sectors (since the price signal is the same across all covered sectors) whereas a carbon tax scheme also introduces distortions among covered sectors since the tax rate applicable to each of them may differ. Figure 3 displays the total (i.e. the sum of the tax rate and the ETS allowance price, as applicable) price of CO_2 (in 2014 \$(US)/tCO2e) in selected sectors of selected countries for coal.[23]

The carbon price does not vary much across fuels. In other words, most tax schemes apply the same tax rate to all fossil fuels. The most significant variations arise across countries and, hence, across sectors within those countries. A look at panel (b) of Figure 3 shows that, among

increasing coverage to about 85% of California's total GHG emissions.

[22]Note that for tax schemes, the CO_2 tax rate can further vary according to the type of fuel within each sector.

[23]Figures A.1 and A.2, available in appendix A, show the total price for oil and natural gas, respectively.

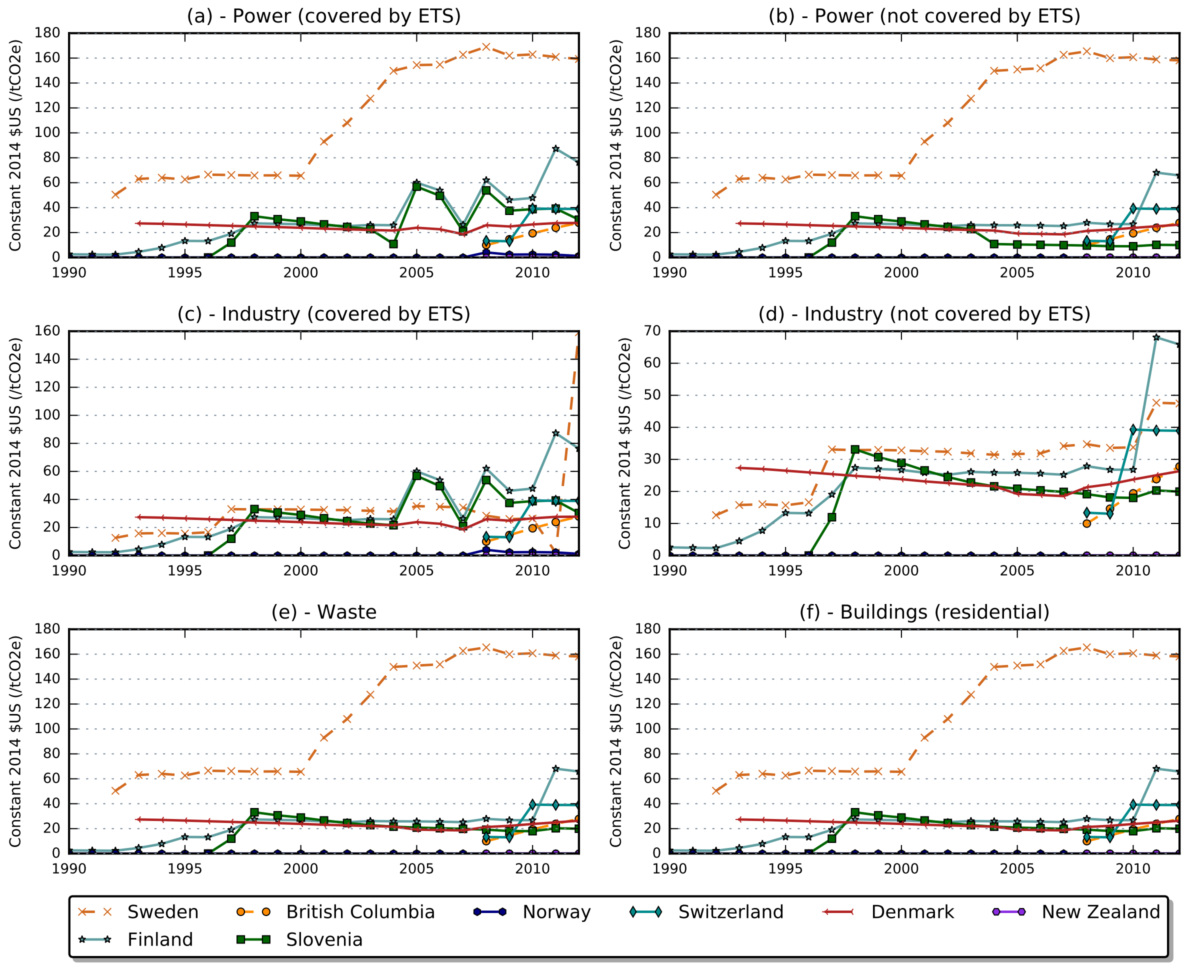

Figure 3: Total carbon price over time – coal/peat

the selected countries, the power sector in Sweden is confronted to the highest price signal whereas the sectors in the other countries face much lower carbon prices.

Price heterogeneity across types of fuels is however not observable in jurisdictions whose emissions are covered by an ETS only. A case in point is the US RGGI. The price of emissions in the power sector is the same across all participating states, regardless of the fossil fuel used.[24]

The multiplicity of price signals within (some) jurisdictions identified here raises the question of their aggregation at an economy-wide level. As alluded to earlier, the aggregation method used here uses shares of total GHG emissions as weights. This is the focus of the next section.

4.1.3 The Effective Carbon Price (ECP)

Combining coverage and price information allows for the calculation of an Effective Carbon Price (ECP). The ECP can be computed at the sectoral or economy-wide level. In the former case, the weights are the emissions as a share of that sector's total GHG emissions; in the latter,

[24]The yearly average price (/tCO2e) of allowances in the RGGI was: $US 3.3 in 2009, $US 2.28 in 2010, $US 1.99 in 2011, $US 2.49 in 2012.

the weights are the emissions as a share of the jurisdiction's total GHG emissions.

Computing the ECP requires that each emitted ton of GHGs be attributed the correct price signal. That is, emissions that are covered by either a tax or an ETS receive the corresponding tax rate or permit price as price tag while emissions of a sector covered by a tax and an ETS receive the sum of the tax rate and the permit price. Hence, although the ECP has been computed using sector-level price and coverage data, its actual value boils down to the average price of emissions as computed by the ratio of the total economy-wide carbon price revenue divided by total GHG emissions.[25]

The evolution of the ECP in selected countries over the period 1990-2012 is presented in Figure 4. One observes that among all selected countries, only Sweden's ECP has increased steadily over time. All other countries exhibit either constant (e.g. Norway) or decreasing (e.g. Denmark) ECPs. Moreover, contrary to what is generally understood, the ECP varies across countries that are part of the EU-ETS. This is due in part to the presence of carbon taxes in some – but not all – countries, which create an additional price signal for some emissions. Second, and perhaps more importantly, it is due to differences in the relative size of sectors and their respective CO_2 intensity, as mentioned in section 4.1.1. This feature is particularly well illustrated by the Effective Carbon Price of states participating in the US RGGI (Figure 5): despite a single common price for emissions allowances, the effective carbon price differs across them.

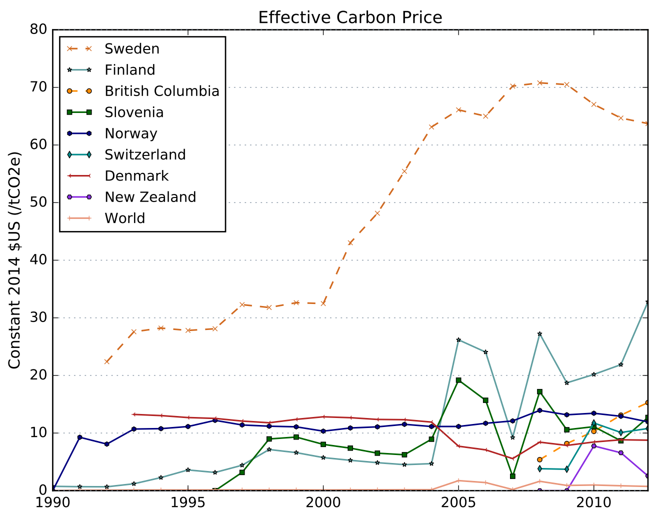

Figure 4: ECP – selected jurisdictions

[25]See appendix C for a formal presentation.

Lastly, some countries' ECP exhibit more variability than others. For this specific group of countries, this is due to the relative importance of emissions covered by the EU-ETS as opposed to those covered by the respective national carbon taxes. Indeed, the (futures) price of EUAs, i.e. EU-ETS emissions allowances, exhibited strong variability between 2005 and 2012.

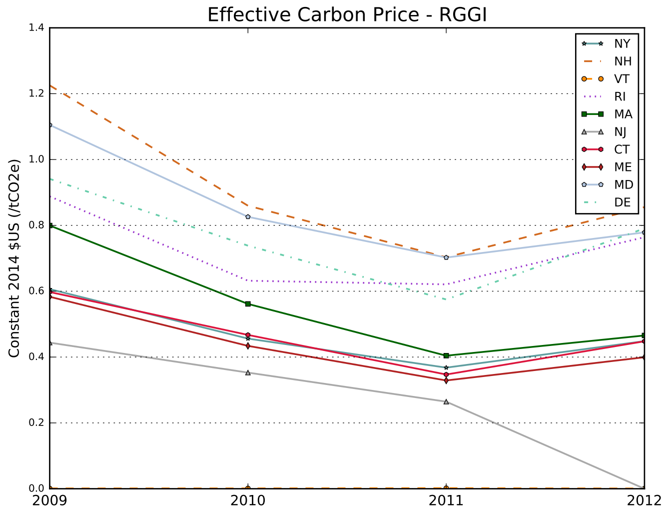

Figure 5: ECP – RGGI

4.1.4 Assessing the 'policy gap': the ECP versus the Social Cost of Carbon (SCC)

In addition to capturing the effective level of the CO_2 price tag in any given economy, the Effective Carbon Price provides a metric to assess what may be termed the 'carbon policy gap', i.e. the difference between the effective price of carbon and its socially optimal price for that economy. Indeed, should the regulatory authority aim at internalising the externality resulting from GHG emissions and assuming a 100% coverage of GHGs-emissions, the ECP should closely track the evolution of the SCC over time. Estimates of the Social Cost of Carbon (SCC) are different for each jurisdiction and hence the ECP should be evaluated against the relevant SCC. As an illustration, table 2 provides estimates of the SCC for the United States in 5-year steps for the period 2010-2050.

4.2 Hypotheses and data

4.2.1 Electricity sector

Any form of carbon pricing that includes the power sector imposes costs on those electricity producers that produce electricity from fossil fuels. Therefore, we expect the structure of the electricity production mix to influence the stance that the electricity sector takes towards any

Table 2: US EPA - Social Cost of CO_2, 2010-2050 (2014 \$US/tCO_2)

Discount Rate Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	11	35	57	98
2015	13	41	64	120
2020	14	48	71	140
2025	16	53	78	158
2030	18	57	83	173
2035	21	63	89	192
2040	24	69	96	209
2045	26	74	102	225
2050	30	79	108	242

Source: Interagency Working Group on Social Cost of Carbon (2013). Note: For each year and each discount rate, SCC values are calculated by combining distribution estimates of five different scenarios from three Integrated Assessment Models (i.e. DICE, FUND and PAGE). Each scenario and model receive equal weight, producing an "average" distribution of the SCC. The average (mean) of that distribution is the value reported in the first three columns of the above table. The fourth column reports the 95^{th} percentile value of that distribution for a 3% interest rate.

carbon pricing regulation (Olson, 1965). The larger the share of electricity produced from fossil-fuelled power plants, the higher the potential profit decreases and capital losses and, hence, the less politically feasible carbon pricing regulation will be.

This argument needs to be nuanced, however. First, the extent to which carbon pricing policies affect the value of covered firms depends on their capacity to *pass* the additional cost *through* to consumers. Under perfect competition and 100% pass through of the cost of carbon, electricity producing firms' profits will remain largely unaffected. On the contrary, if firms are unable to pass the cost through entirely, then the change in equilibrium market price will not entirely reflect the increase in cost and firms' (economic) profit will be affected. Second, one does not necessarily expect the electricity generating sector to react in the same way to a carbon tax and a cap-and-trade system. In the case of the former, the sector will, at best, remain unaffected whereas in the case of an ETS, the possibility of capturing significant "windfall profits" exists if emissions permits are freely allocated.

The possibility of capturing such profits has probably played a significant role in dampening the opposition of affected sectors to the introduction of such schemes. Several studies have examined that possibility and the associated rent-seeking behaviour both theoretically (Rode, 2013) and empirically (Markussen and Svendsen, 2005). The empirical evidence suggests that powerful (and CO_2 intensive) sectors were successful in influencing the design of GHG trading systems. In fact, except for the US RGGI, all emissions trading schemes have been introduced with close to 100% free allocation of emission permits (World Bank, 2014). Although it is difficult to explicitly account for such effects in our econometric investigation, it is likely to reduce the magnitude of the coefficients on the variables accounting for the role of CO_2 intensive sectors, including the electricity sector.

To investigate the role played by the electricity generating sector, we use the share of electricity generation in total electricity generation from coal, gas and oil, respectively.[26] These variables have previously been used in the literature by Marques et al. (2010). For national jurisdictions, the data is taken from the World Bank, World Development Indicators (2016). The data for US States and Canadian Provinces are taken from the U.S. Energy Information Administration (2015) and Statistics Canada (2016a), respectively. We expect these variables to negatively affect the odds of implementation and the stringency of carbon pricing policies.

4.2.2 Industry

The electricity producing industry is not the only sector likely to express concerns about a policy that holds the potential to increase production costs. Other energy-intensive sectors, broadly defined as "industry" are likely to oppose a carbon pricing scheme. Moreover, as emphasised by Aldy and Pizer (2012), those sectors that are export-oriented should be even more reluctant as the introduction of a carbon price risks putting them at a competitive disadvantage in international markets. The strength of this international competitiveness concern will, in turn, depend on the relative size of the sector in the economy and its carbon intensity. Not all sectors, however, suffer from this problem. In particular, sectors whose activities cannot easily be relocated away from the destination market (e.g. the power sector, cement production) are less prone to relocation due to the introduction of carbon pricing mechanisms or, more generally, tighter environmental policies. For instance, among all the schemes considered in this study, 66 out of 72 cover the power sector and 61 out of 72 cover industry (see Table 1).

There are two channels via which costs to industry could be pushed upward by a carbon pricing policy. The first is a direct channel: CO_2 intensive industries that fall within the scope of a carbon pricing scheme will have to pay the price for their own CO_2 emissions. The second is a more indirect one: the introduction of carbon pricing policies, which cover the electricity generating sector, will lead to an increase in wholesale (and retail) electricity prices (as has been observed after the introduction of the EU-ETS (Sijm et al., 2008) which, in turn, will raise the production cost of electricity-intensive industries. This argument closely follows that of Cadoret and Padovano (2016).

We consider the value added of industry (as a share of GDP) as proxy for the strength of

[26] Note that since the only countries retaining a substantial share of oil in their electricity production mix are Middle East and Northern Africa (MENA) countries and small island states, this variable can also be interpreted as a proxy for a geographical dummy including the said countries.

the lobbies of energy-intensive (electricity-intensive) industries. Data for national jurisdiction is taken from the World Bank, World Development Indicators (2016) whereas data for US States and Canadian Provinces is computed based on data from Bureau of Economic Analysis, U.S. Department of Commerce (2016) and Statistics Canada (2016b), respectively. We expect the relative share of industry to influence negatively both the odds of the implementation and the stringency of the policy.

4.2.3 Political and institutional variables

A relatively high degree of institutional capacity is a prerequisite for the introduction of any form of regulation and, a fortiori, to introduce a carbon pricing scheme. Consequently, we introduce an institutional capacity indicator. Following Steves et al. (2011), that indicator is constructed as the simple average of the World Bank's "Government Effectiveness" and "Regulatory Quality" indicators (World Bank, World Governance Indicators, 2016).[27] We expect institutional capacity to be positively correlated with the presence of a carbon pricing scheme but not necessarily with the level of the ECP. Indeed, the "institutional burden" arises from the creation of such a scheme, regardless the level of the price associated with it.

Second, we explore the effect of several aspects of the political structure of each jurisdiction with the aim of disentangling their role in the development of carbon pricing policies. First, we consider the type of political regime (democracy vs. autocracy). The role of the political system has been discussed in earlier literature by, e.g., Congleton (1992). He argues that autocrats' time horizon is shorter than that of democratic planners and they therefore set weaker environmental targets. Yet, on the other hand, liberal democracies tend to offer the possibility for different interest groups to express their views and "weigh" on the legislative process. In such a case, regulatory outcomes will be a balancing act that reflects the relative bargaining power of the different interest groups (Hahn, 1990). This could work both in favour or against the introduction of carbon pricing policies, depending on the relative lobbying strengths of interest groups in the jurisdiction. The democracy composite indicator is taken from the Center for Systemic Peace, Polity IV project (2015). National averages are assigned to corresponding subnational jurisdictions.

Next, following the literature on the political economy of environmental policy we consider the role of government ideology. Previous studies have found left wing governments to implement

[27] Note that the estimates of government effectiveness and regulatory quality are only available at the national level. Subnational jurisdictions are assigned the value the corresponding national jurisdiction.

more stringent environmental policies (Chang and Berdiev, 2011; Cadoret and Padovano, 2016). Fankhauser et al. (2015), however, found the political orientation of the government to be irrelevant to the number of climate laws passed in their sample of jurisdictions. To investigate such effects we create a variable *Left*, which takes value 1 whenever the ruling party is identified as left wing party and 0 otherwise. The national-level data on political orientation of government is taken from Cruz et al. (2016). Data at the subnational level is not available.

We also test the effect of international institutional frameworks. Far from discarding the autonomous policy development dynamics present at the country-level, membership of international organisations (such as the OECD or the EU) or international institutional frameworks (such as the Annex-I countries of the Kyoto Protocol) plays a significant role in the presence and development of carbon pricing policies. For example, the EU, a club of countries cooperating on a wide range of issues – including the environment, has implemented an organisation-wide emissions trading scheme. Several EU Member countries that are currently operating such a scheme were "dragged in" and did not willingly sign up for it. This is the case, for instance, of current EU Member States that joined the Union in 2004, i.e. a year before the start of the EU-ETS but a few months after Directive 2003/87/EC, which implemented the EU-ETS, was passed.[28] It is relatively clear that some Eastern European countries that joined the EU at the time had little (if any) say on the development of the legislation pertaining to the creation of the EU-ETS and implemented it only because it was part of the preexisting legislative *acquis* (Robinson and Stavins, 2015).

We also take a closer look at the Kyoto Protocol and the distinction between Annex I and non-Annex I countries. Having committed to a reduction of their GHG emissions, these countries may have had an additional incentive to develop climate mitigation strategies, including carbon pricing policies.

To capture such dynamics, we create two dummy variables. The first one takes value 1 whenever a country is a member of the EU in any given year, 0 otherwise. The second one takes value 1 for countries listed in Annex-I of the Kyoto Protocol from 1997 onward.[29]

[28]The Accession Agreement of the 10 countries meant to join the EU in 2004 was signed in April 2003. This agreement acknowledges compliance with the *acquis communautaire*.

[29]An Annex-II dummy, including all Annex-I countries except Economies in Transition, was used as well in preliminary analysis but turned out to be non significant.

4.2.4 Economic environment

Besides the political and institutional environment, we consider the role of the general economic environment in the development of carbon pricing policies. These general economic circumstances are captured by real GDP per capita and trade openness. GDP per capita is introduced to account for differences in the level of development of countries included in the panel. Pricing the environmental externality related to GHG emissions imposes an additional cost on GHG-intensive industries and, by extension, on the economy as a whole. For relatively poorer countries (i.e. countries with a low level of GDP per capita), such cost may be too much of a burden. Therefore, we expect the level of GDP per capita to have a positive impact on the odds of implementation of a carbon pricing policy and be positively correlated with the Effective Carbon Price. In other words, this can be interpreted as an Environmental Kuznets Curve hypothesis where countries with higher levels of GDP per capita are more inclined to bear the cost related to the internalization of the environmental externality. GDP per capita is taken from three different sources. Data for national jurisdictions is available from World Bank, World Development Indicators (2016); data for US jurisdictions (i.e. States) is taken from the U.S. Bureau of Economic Analysis, U.S. Department of Commerce (2016) whereas data for Canadian and Chinese provinces are retrieved from Statistics Canada (2016c) and Chinese Bureau of National Statistics (2016), respectively.

The second economic variable is the trade openness of the economy. It is computed as the sum of exports and imports (as a share of GDP). Data for national jurisdictions is taken from the World Bank, World Development Indicators (2016) whereas data for U.S. states and Canadian provinces are taken from U.S. Census Bureau (2016) and Statistics Canada (2016c). Two arguments relating trade openness to carbon pricing policies can be made. On the one hand, countries that are open to trade in general may be more receptive to "cap-and-trade" carbon pricing policies. On the other hand, the same countries may worry that the introduction of carbon pricing policies will put their economy at a competitive disadvantage. Given this theoretical ambiguity, we do not form any expectation about the direction of influence of trade openness on either the odds of implementation of a carbon pricing mechanism or the value of the ECP.

Table 3 summarizes the selected variables and the expected sign. Table 4 provides their summary statistics.

Table 3: Summary of variables

Category	Variable	Expected sign Carbon Price (Y/N)	Expected sign Carbon Price (Level)
Electricity sector & Industry	Elec. prod. - coal (% of total)	-	-
	Elec. prod. - oil (% of total)	-/0	-/0
	Elec. prod. gas (% of total)	-/0	-/0
	Industry, VA (% of GDP)	-	-/n.a.
Political envnt.	EU	+	+
	Annex-I	+	+
	Institutional capacity	+	n.a.
	Level of democracy	+	n.a.
	Left	+	+
Economic envnmt.	GDP per capita	+	+
	Trade Openness (% of GDP)	+/-	+/-

4.3 Preliminary analysis

Before proceeding with the estimation, we perform preliminary tests on the data to ensure that the assumptions required for statistical inference are satisfied. First, a rapid check of the cross correlation matrix (available in appendix D) reveals that the institutional capacity variable is highly correlated with GDP per capita (0.75), the group of Annex-I countries (0.79) and the level of democracy (0.63). In order to avoid multicollinearity issues, we shall therefore not include them in the same regression models.

Second, we analyse the stationarity of our dependent variable, the effective carbon price. We use the Harris-Tzavalis unit-root test, whose asymptotic properties best match the properties of our sample (i.e. large N, fixed number of periods), with no time trend. The test shows that the panels are stationary (statistic: 0.6605; p-value:0.000).

Table 4: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Pricing (1=yes,0=no)	0.069	0.254	0	1	5359
ECP (2014 $US/tCO2e)	0.65	3.98	0	70.79	5382
Elec. Prod - coal (% of total)	24.9	30.3	0	100	4290
Elec. Prod - gas (% of total)	20.4	27.7	0	100	4290
Elec. Prod - oil (% of total)	14.7	25	0	100	4290
Industry, value added (% of GDP)	30.5	11.076	6.3	78.5	4518
GDP per cap. (thousand 2011 $US)	25.327	20.386	0	134.117	4335
Trade Openness (% of GDP)	75	46.6	0.02	439.7	3494
EU	0.081	0.272	0	1	5359
Annex-I	0.392	0.488	0	1	5359
Institutional capacity	0.48	1.033	-2.282	2.174	3256
Level of Democracy	3.883	7.371	-10	10	5183
Left	0.506	0.5	0	1	1883

5 The model

5.1 To price or not to price?

5.1.1 Econometric specification

We model the logit specification as follows:

$$\mathbb{I}_{it} = \phi_i + \boldsymbol{\psi}'\boldsymbol{X_{it}} + \boldsymbol{\gamma}'\boldsymbol{Z_{it}} + \boldsymbol{\eta}'\boldsymbol{W_{it}} + \epsilon_{it} \tag{1}$$

where $\mathbb{I}_{it}$ is an indicator variable capturing the existence of a carbon pricing scheme; $\boldsymbol{X_{it}}$ is the m-dimensional vector of industry-specific variables, $\boldsymbol{Z_{it}}$ is the n-dimensional vector of political and institutional variables and $\boldsymbol{X_{it}}$ is the p-dimensional vector of economic variables. $\boldsymbol{\psi}'$, $\boldsymbol{\gamma}'$ and $\boldsymbol{\eta}'$ are vectors of dimensions m, n and p, respectively, each element of which corresponds to the estimated parameter of the associated explanatory variable. The error term is denoted by ϵ_{it}.

5.1.2 Results

Table 5 shows that the estimated effect of the energy mix on the implementation of carbon pricing policies is in line with our expectations: shares of electricity generation from fossil fuels negatively affect the odds of implementation. All coefficients are negative except that of the share of electricity generated from natural gas in specification (1). This coefficient, however, is not statistically significant. The effect of the share of electricity production from coal is statistically significant across all estimations except one. The share of electricity produced from oil significantly decreases the odds of introduction of carbon pricing policies. For instance, in the first specification, a rise of one percent in the share of electricity produced from oil decreases the odds by 33%.[30] This effect is nonetheless consistent across all specifications, with only minor variation in its magnitude. As far as gas is concerned, the evidence is much weaker. The effect is negatively significant in one out of three regressions. This, however, is not entirely surprising given that natural gas is the fossil fuel with the lowest carbon content and that carbon pricing policies alter the relative price of fossil fuels in favor of gas-fired power plants.

Similarly, as suggested by the negative relationship between the value added of industry and the existence of carbon pricing mechanisms, the presence of large (potentially CO_2-intensive) industrial sectors in a jurisdiction's economy decreases the odds of implementation of such mechanisms. The effect is particularly strong: a 1% increase in a country's share of industry

[30] $\exp(-0.396) = 0.673$. The decrease in the odds is 1-0.673 = 0.327.

value added in GDP leads to a 67% decrease in the odds of introduction of a carbon pricing policy.

The general level of development (as measured by the level of GDP per capita), on the contrary, has a positive effect on the odds of introduction of a carbon pricing mechanism. A $1000 increase in GDP per capita results, on average, in a multiplication of the odds by 2.44 (regression 1). Although the magnitude of this effect changes depending on the econometric specification, the direction of the induced change is stable across all estimated models. As carbon pricing policies induce additional (private) costs, economic agents are more likely to support the introduction of such policies if they are relatively better off.

Similarly, trade openness has a positive effect on the odds of implementation (specification 1), which suggests that more open economies are more likely to introduce carbon pricing mechanisms. However, it is possible that this result is partly driven by EU countries which all have a (common) carbon pricing policy and, at the same time, trade heavily with each other.

The results also highlight the (international) institutional dynamics at play in the development of carbon pricing policies. Since many jurisdictions that currently have carbon pricing policies are members of the European Union, the variable capturing EU membership is, unsurprisingly, found to have a significant impact on the odds of instituting a carbon pricing mechanism.[31]

International institutional dynamics form one part of the story but do not explain it all. The local political environment also plays a pivotal role. The level of democracy is found to significantly influence the odds of implementation: as suggested by Congleton (1992), jurisdictions experiencing a higher level of democracy are more likely to implement a form of carbon pricing mechanism. On the contrary, the variable capturing government ideology shows no significance across all estimated models, suggesting that the introduction of carbon pricing policies are not necessarily associated with one political ideology in particular. This does not mean, however, that, in a given jurisdiction, all parties support the introduction of carbon pricing policies. It only means that, in the sample currently considered, such policies have received support from parties across the political spectrum.

Finally, since the institutional capacity is strongly correlated with the level of GDP per capita ($\rho = 0.75$), we test its effect on the odds of pricing in a separate regression (specification

[31] Note, however, that some countries that introduced carbon pricing mechanisms did so before joining the EU. For instance, this is the case of Norway and Sweden, which introduced their respective schemes in the early 1990s and became members of the European Union in 1995.

3). There is no evidence that it significantly influences the odds of implementation.

Table 5: Panel logistic regression – estimation results

Pricing (1=yes,0=no)	(1)	(2)	(3)	(4)
Elec. Prod - coal (% of total)	-0.134***	-0.171***	-0.115***	-0.128***
	(0.0269)	(0.0308)	(0.0320)	(0.0347)
Elec. Prod - gas (% of total)	-0.000160	-0.0250	0.0548*	0.0419
	(0.0287)	(0.0540)	(0.0238)	(0.0395)
Elec. Prod - oil (% of total)	-0.246**	-0.305**	-0.270***	-0.248***
	(0.0797)	(0.100)	(0.0560)	(0.0268)
GDP per cap. (thousand 2011 $US)	0.355***	0.683***		0.547***
	(0.0439)	(0.0861)		(0.0573)
Industry, value added (% of GDP)	-0.604***	-0.711***	-0.809***	-0.648***
	(0.0846)	(0.188)	(0.0789)	(0.105)
Trade Openness (% of GDP)	0.0716***	0.0539**	0.0928***	0.135***
	(0.0111)	(0.0191)	(0.00953)	(0.0153)
EU	14.17***	5.570**	20.79***	
	(1.932)	(1.896)	(1.805)	
Level of Democracy	1.381***	1.203*		1.833***
	(0.337)	(0.569)		(0.452)
Left		-0.546		
		(0.584)		
Institutional capacity			0.478	
			(0.775)	
Annex-I				8.581***
				(2.606)
Constant	-25.18***	-18.84*	-0.701	-50.44***
	(4.409)	(7.812)	(2.107)	(5.971)
Constant	5.008***	5.454***	5.172***	5.879***
	(0.185)	(0.240)	(0.180)	(0.189)
Observations	2938	1615	2163	2938

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2 Policy stringency

5.2.1 Econometric specification

In this second step, our empirical model aims at testing the relationship between the ECP and the set of variables identified in section 4.2. Hence these estimations focus on the stringency of the pricing mechanism that is implemented. We use a panel analysis with fixed effects.[32] The standard equation can be modelled as

[32]The Hausman test comparing the RE and FE estimator strongly supports the use of the fixed-effects estimators. Moreover, estimates are consistent across both fixed- and random-effects estimations.

$$ECP_{it} = \phi_i + \boldsymbol{\psi'} \boldsymbol{X_{it}} + \boldsymbol{\gamma'} \boldsymbol{Z_{it}} + \boldsymbol{\eta'} \boldsymbol{W_{it}} + \epsilon_{it} \tag{2}$$

where ECP_{it} is the Effective Carbon Price; $\boldsymbol{\psi'}, \boldsymbol{\gamma'}, \boldsymbol{\eta'}$ and $\boldsymbol{X_{it}} \boldsymbol{Z_{it}}, \boldsymbol{W_{it}}$ as well as ϵ_{it} are as before.

5.2.2 Results

We start by analyzing the influence of the energy mix. Results suggest that an electricity generation system biased towards the use of fossil fuels reduces the stringency of a carbon pricing mechanism. All variables pertaining to the electricity production mix have a negative effect on the stringency of the implemented tool, although only the effect of the share of electricity produced from coal is found to be statistically significant. More precisely, an increase of 1% of that share is associated with a $0.04 decrease in the Effective Carbon Price (specification 1).

The magnitude of this effect is very close to that of the share of industry value added in GDP. A larger industrial sector will, on average, decrease the stringency of carbon pricing policies. More precisely, a 1% increase in the share of industry value added in GDP is associated with a $0.05 decrease in the ECP, which suggests that jurisdictions with larger (CO_2-intensive) industrial sectors will either reduce the coverage of their legislation or decrease the level of the price tag associated with a tonne of CO_2 emissions. The evidence on the role played by the electricity generating sector and the industry broadly supports the assumptions made about them in the section (4.2).

Turning to the general economic environment, we observe that the effect of GDP per capita on stringency is positive. A $1000 increase in GDP per capita is associated with a $0.13 increase in the Effective Carbon Price (specification 1). Trade openness, however, does no longer exhibit a statistically significant effect.

Unsurprisingly, jurisdictions that were part of the European Union had, on average, an ECP that was roughly $5 higher than other jurisdictions. Slightly more surprising, however, the level of democracy does not seem to have any significant influence. That is, although it appeared determinant for the introduction of a carbon pricing policy, there is no evidence of an effect on the stringency of the policy, a result that is partially at odds with the argument of Congleton (1992). Eventually, in specification 3, we test the effect of institutional capacity. As expected, institutional capacity does not significantly affect the stringency of a carbon pricing mechanism.

Table 6: Panel (fixed-effects) regression – estimation results

ECP (2014 $US/tCO2e)	(1)	(2)	(3)	(4)
Elec. Prod - coal (% of total)	-0.0463**	-0.0715*	-0.0495	-0.0458*
	(0.0170)	(0.0341)	(0.0256)	(0.0177)
Elec. Prod - gas (% of total)	-0.00893	-0.00720	0.0104	-0.0196
	(0.0147)	(0.0249)	(0.0145)	(0.0162)
Elec. Prod - oil (% of total)	0.00249	-0.0104	-0.0122	0.00322
	(0.00946)	(0.0145)	(0.0121)	(0.00977)
GDP per cap. (thousand 2011 $US)	0.238**	0.392**		0.312**
	(0.0789)	(0.137)		(0.0974)
Industry, value added (% of GDP)	-0.0446**	-0.0574*	-0.0809***	-0.0486**
	(0.0154)	(0.0266)	(0.0241)	(0.0164)
Trade Openness (% of GDP)	0.00112	-0.00475	0.0164*	0.00770
	(0.00456)	(0.00750)	(0.00806)	(0.00577)
EU	5.411**	4.964*	5.313***	
	(1.649)	(2.044)	(1.443)	
Level of Democracy	-0.0141	-0.106**		-0.0120
	(0.0148)	(0.0393)		(0.0171)
Left		-0.624		
		(0.498)		
Institutional capacity			-0.153	
			(0.560)	
Annex-I				2.728
				(1.505)
Constant	-2.190	-1.042	2.872**	-4.283
	(1.472)	(2.138)	(0.968)	(2.266)
Observations	2938	1615	2163	2938
R^2	0.203	0.245	0.110	0.149

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6 Discussion

The results presented above support the relevance of a political economy explanation to the implementation of second- (rather than first-) best policies. These results call for some clarifications. First, one may be tempted to attribute much – if not all – of the carbon pricing developments to EU-leadership and dismiss the relevance of other factors. This temptation should be avoided. Both economic and institutional variables retain significant explanatory power, even after controlling for EU membership. Moreover, if the membership of the EU is a powerful explanation for the emergence of ETSs, it is much less so for national or subnational carbon taxes: Sweden and Finland were not part of the EU when they launched their respective carbon tax schemes and Norway has one but, although it has adopted most of its Directives, is still not part of the EU.

Second, the fact that in many jurisdictions the Effective Price of Carbon falls short of the Social Cost of Carbon should not be interpreted as evidence that those jurisdictions are failing to tackle climate change. Many of them have supplementary policies in place that implicitly price GHG emissions and reduce the level of the socially optimal explicit price of carbon. A central question for those jurisdictions is therefore that of the nature of the tradeoff between carbon pricing and other climate change mitigation policies.

Third, carbon pricing policies face their own internal tradeoff. Suppose that the *stringency* of a given carbon pricing scheme needs to be increased. Should the regulator favour an increase in the price signal in currently covered sectors or aim at widening the scope of the scheme by including more sectors? Or is the choice neutral for social welfare?

Fourth, absent from the present analysis is an explicit discussion of the role of revenue recycling in the political acceptability of carbon pricing policies. Introducing such consideration in a panel analysis like this one is relatively difficult due to the heterogeneity of schemes and policies and, as such, would deserve a separate discussion. However, it is to be noted that most – if not all – of the carbon pricing schemes mentioned in the paper were introduced with some form of revenue recycling.

Lastly, the present analysis is based on data up to 2012. This is due to the limited availability of total GHG emissions from the World Resources Institute. Several developments took place after that year, including, as noted earlier, the launch of seven pilot ETSs in China (five in 2013, two in 2014). Despite being centrally led, further analysis of their development could provide additional insights into the political economy dynamics leading to carbon pricing: the design and scope of each of those schemes differ and it is likely that those differences are the consequence of different economic structures of the regions (provinces or municipalities) in which they are implemented. Outside China, Quebec launched an ETS in 2013 and linked it with that of California in 2014 while France and Portugal introduced a carbon tax in 2014 and 2016, respectively.

7 Conclusion

Carbon pricing policies have (re-)emerged in the policy making arena as credible tools to achieve (some) reductions in GHG emissions. Extending such tools to new jurisdictions or strengthening existing ones will require in-depth knowledge of the political economy dynamics governing their development. The present work is a contribution toward that goal. First, it emphasises the importance of looking at both the coverage and the price level to assess the stringency of a given carbon pricing scheme and provides data about the Effective Carbon Price for a large panel of jurisdictions over the period 1990-2012.

Second, it sheds light on the development of carbon pricing policies, looking successively at the drivers behind their implementation and their intensity in the hope of providing both a retrospective explanation of past developments and inform prospective policy discussion. We believe that this objective has been met. Firstly, we have shown that the dynamics driving the implementation of carbon pricing policies differ from those determining the stringency. Institutional and political variables play a significant role in the decision to implement – or not – a carbon pricing mechanism but much less so in the actual stringency of the scheme. This is the case, for example, of the level of democracy. This partially supports the hypothesis formulated by Congleton (1992) that democratic institutions are conducive to more stringent environmental regulations (*a* carbon price, regardless of its level, is a more stringent policy than *no* price at all) and lends support to Hahn's conclusions (1990) that environmental regulation is a balancing act between a variety of interests (the actual stringency is determined by the relative weight of each interest group and not by the 'democratic' nature of a political system). However, we were unable to detect any significant effect from the institutional capacity of a jurisdiction either on the odds of implementation or the stringency of a carbon pricing mechanism, suggesting that it is not one of the most determining factors of either of those decisions. Similarly, the political orientation of a government does not significantly affect the odds of the implementation nor the stringency of a carbon pricing policy. This result is in line with the findings in Fankhauser et al. (2015).

Secondly, GDP per capita positively affects both the odds of the implementation of carbon pricing mechanisms as well as their intensity, supporting the idea that richer jurisdictions are more inclined to bear the cost associated with the internalisation of the environmental externality.

Eventually, we hypothesised that an electricity generation sector biased toward fossil fuels and a large relative share of industry in value added would weaken both the odds of the implementation of a carbon pricing mechanism as well as the intensity of the scheme. This was confirmed by our empirical analysis: larger shares of electricity produced from fossil fuels, and coal in particular, lead to a decrease in both the likelihood of implementation of carbon pricing mechanisms and the stringency of the introduced tool; similar conclusions are drawn about the share of industry in total value added.

From a policy making perspective, such results highlight the existence of political economy constraints that bind the Effective Price of Carbon below optimal levels and suggest that it would be easier to introduce carbon pricing policies once the electricity sector (and the economy in a broader sense) has already been partially "de-carbonised", possibly by means of other policies. Hence it provides a rationale for the development of climate mitigation strategies with multiple GHGs abatement tools and, more crucially, emphasises the importance of the sequence of introduction of different climate policies (Meckling et al., 2015).

References

Aldy, J. and Pizer, W. (2012). The competitiveness impacts of climate change mitigation policies. *Duke Environmental Economics Working Paper Series*, (EE 12-01).

Barbier, E. and Pearce, D. (1990). Thinking economically about climate change. *Energy Policy*, 18(1):11–18.

Bennear, L. and Stavins, R. (2007). Second-best theory and the use of multiple instruments. *Environmental and Resource Economics*, 37(1):111–129.

Bowen, A. (2011). The case for pricing carbon. *Policy brief – Grantham Research Institute on Climate Change and the Environment.*

Bowen, A. (2015). Carbon pricing: how best to use the revenue? *Policy brief – Grantham Research Institute on Climate Change and the Environment.*

Cadoret, I. and Padovano, F. (2016). The political drivers of renewable energies policies. *Energy Economics*, 56:261–269.

Chang, C. P. and Berdiev, A. (2011). The political economy of energy regulation in OECD countries. *Energy Economics*, 33:816–825.

Congleton, R. (1992). Political institutions and pollution control. *The Review of Economics and Statistics*, 74(3):412–421.

Del Rio, P. and Labandeira, X. (2009). Barriers to the introduction of market-based instruments in climate policies: an integrated framework. *Environmental economics and policy studies*, 10:41–60.

European Commission (2012). *COMMISSION REGULATION (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.*

Fankhauser, S., Gennaioli, C., and Collins, M. (2015). The political economy of passing climate change legislation: Evidence from a survey. *Global Environmental Change*, 35:52–61.

Gawel, E., Strunz, S., and Lehmann, P. (2014). A public choice view on the climate and energy policy mix in the EU - how do the emissions trading scheme and support for renewable energies interact? *Energy Policy*, 64:175–182.

Grainger, C. and Kolstad, C. (2010). Who pays a price on carbon. *Environmental and Resource Economics*, 46:359–376.

Hahn, R. (1990). The political economy of environmental regulation: Towards a unifying framework. *Public Choice*, 65:21–47.

Hoel, M. and Karp, L. (2002). Taxes versus quotas for a tax pollutant. *Resource and Energy Economics*, 24:367–384.

IEA (2016). IPCC fuel combustion emissions (2006 guidelines).

Interagency Working Group on Social Cost of Carbon (2013). Technical support document: Technical update of the social cost of carbon for regulatory impact analysis under executive order 12866. Technical report, United States Government.

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* IGES, Japan.

IPCC (2014). Summary for policymakers. In Field, C., Barros, V., Dokken, D., Mach, K., Mastrandrea, M., Bilir, T., Chatterjee, M., Ebi, K., Estrada, Y., Genova, R., Girma, B., Kissel, E., Levy, A., MacCracken, S., Mastrandrea, P., and White, L., editors, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pages 1–32, Cambridge, United Kingdom and New York, NY, USA. Cambridge University Press.

Jenkins, J. (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.

Joskow, P. and Schmalesee, R. (1998). The political economy of market-based environmental policy: The u.s. acid rain program. *Journal of Law and Economics*, 41(1):37–83.

Markussen, P. and Svendsen, G. (2005). Industry lobbying and the political economy of ghg trade in the european union. *Energy Policy*, 33:245–255.

Marques, A., Fuinhas, J., and Pires Manso, J. (2010). Motivations driving renewable energy in european countries: A panel data approach. *Energy Policy*, 38:6877–6885.

Meckling, J., Kelsey, N., Biber, E., and Zysman, J. (2015). Winning coalitions for climate policy. *Science*, 349(6253):1170–1171.

Nordhaus, W. (1989). The global commons i: costs and climatic effects. *American Economic Review*, 72:242–246.

OECD (2015). Effective carbon rates on energy. Technical report, OECD.

Olson, M. (1965). *The Logic of Collective Action*. Harvard Univeristy Press, Cambridge, Massachussetts.

Pearce, D. (2005). The political economy of an energy tax: The united kingdom's climate change levy. *Energy Economics*, 28:149–158.

Pizer, W. (2002). Combining price and quantity controls to mitigate global climate change. *Journal of Public Economics*, 85(3):409–434.

Pollitt, M. (2012). The role of policy in energy transitions: Lessons from the energy liberalisation era. *Energy Policy*, 50:128–137.

Roberts, M. and Spence, M. (1976). Effluent charges and licenses under uncertainty. *Journal of Public Economics*, 5:193–208.

Robinson, A. and Stavins, R. (2015). Linkage of greenhouse gas emissions trading systems: learning from experience. *Climate Policy*, pages 1–17.

Rode, A. (2013). Rent seeking over tradable emissions pemits: theory and evidence. *University of California Santa Barbara Working Paper*.

Rubin, J. (1996). A model of intertemporal emission trading, banking and borrowing. *Journal of Environmental Economics and Management*, 31:269–286.

Shammin, R. and Bullard, W. (2009). Impact of cap-and-trade policies for reducing greenhouse gas emissions on u.s. households. *Ecological Economics*, 68:2432–2438.

Sijm, J., Hers, S., Lise, W., and Wetzelaer, B. (2008). The impact of the eu ets on electricity prices.

Steves, F., Treisman, D., and Teytelboym, A. (2011). *The Low Carbon Transition*, chapter four, Political economy of climate change policy in the transition region. European Bank for Reconstruction and Development, London.

Stigler, G. (1971). The theory of economic regulation. *The Bell Journal of Economics and Management*, 2(1).

Tirole, J. (2012). Some political economy of global warming. *Economics of Energy and Environmental Policy*, 1(1):121–132.

United Nations/Framework Convention on Climate Change (2015). Adoption of the paris agreement. 21st Conference of the Parties, Paris.

United Nations/Framework Convention on Climate Change (2016). Aggregate effect of the intended nationally determined contributions: an update. 22nd Conference of the Parties - Item X of the provisional agenda.

van Beers, C. and Strand, J. (2015). *Political determinants of Fossil fuel pricing*, chapter 5. The MIT Press, Cambridge, Massachussetts and London, England.

Weitzman, M. (1974). Price vs. quantities. *The Review of Economic Studies*, 41(4):477–491.

Weitzman, M. (1978). Optimal rewards for economic regulation. *American Economic Review*, 68(4):683–691.

Wier, M., Birr-Pedersen, K., Jacobsen, H., and Klok, J. (2005). Are CO_2 taxes regressive? evidence from the danish experience. *Ecological Economics*, 52:239–251.

World Bank (2014). *State and trends of carbon pricing.* Washington, DC.

World Bank (2015). *State and trends of carbon pricing.* Washington, DC.

Data sources

Bureau of Economic Analysis, U.S. Department of Commerce (2016). Regional economic accounts.

CAIT Climate Data Explorer (2015). World Resources Institute, Washington, DC.

California Air Resource Board (2016). Available at: http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm.

Center for Systemic Peace, Polity IV project (2015).

Chinese Bureau of National Statistics (2016). GDP - expenditure approach.

Cruz, C., Keefer, P., and Scartascini, C. (2016). *Database of Political Institutions, 2015 Update.*

European Union Transaction Log (2016). Available at: http://www.ec.europa.eu/environment/ets.

IEA (2016a). *Energy prices and taxes*, volume 2015/4. OECD Publishing, Paris.

IEA (2016b). IPCC fuel combustion emissions (2006 guidelines).

OECD (2016). Database on instruments used for environmental policy.

Statistics Canada (2016a). Table 128-0014 Electricity generated from fossil fuels, annual. CANSIM (database).

Statistics Canada (2016b). Table 379-0028 Gross Domestic Product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories, annual (percentage share). CANSIM (database).

Statistics Canada (2016c). Table 384 - 0038 Gross Domestic Product, expenditure-based, provincial and territorial, annual. CANSIM (database).

The Global Climate Legislation Database (2015). Grantham Research Institute, London School of Economics, London, UK.

U.S. Census Bureau (2016). State Export and Import Data, by North American Industrial Classification (USA Trade Online).

U.S. Energy Information Administration (2015). State-level generation and fuel-consumption data.

World Bank, World Development Indicators (2016).

World Bank, World Governance Indicators (2016).

World Resources Institute (2015). *GHG Protocol tool for stationary combustion. Version 4.1.*

A Carbon prices - data sources and details

For each jurisdiction and each year we collect carbon price data in nominal local currency. Most jurisdictions quote the price of carbon as per tonne of CO2e; others (essentially those with carbon taxes) express the carbon price as per natural unit of the fuel. In the latter case, we transform the price in per tCO2e using conversion factors from the World Resource Institute (World Resources Institute, 2015). We then convert those values into 2014 $US using the Official Exchange Rate (Local Currency Unit/$US) and inflation rate from the World Bank, World Development Indicators (2016).

A.1 Emissions Trading Schemes

Table A.1: ETSs prices – details

Jurisdiction	*Price information*
EU-ETS	The price of European Union emissions Allowances (EUA) quoted in this study is the EUA futures price. This is the annual average of daily prices. Source: Bloomberg
Korea, Rep.	The market for Korean Allowance Units (KAUs) has been characterised by high illiquidity due to the absence of sellers amid concerns that the market is under-allocated. The last trade took place on March 15, 2016 at a price of $15.53.
New Zealand	Annual average of daily spot prices of New Zealand Allowances (NZU). Source: Bloomberg.
Switzerland	As of today, no transaction of Swiss emissions allowances (CHU) has taken place over a centralised platform. Transactions have either not taken place or occurred over-the-counter outside of that transaction platform. Hence, no secondary market data is available. Consequently, the price quoted in this study is the volume-weighted average price at auction. Source: Swiss Emissions Registry
California(-Quebec)	Annual average of daily California Carbon Allowances (CCA) futures contract price. Source: California Carbon Dashboard
RGGI	Volume-weighted annual average of spot transactions. Source: RGGI CO2 Allowance Tracking System (COATS).

A.2 CO_2 taxes

Information on sectoral fuel tax rates has been retrieved from a wide range of sources. A full list of sources is available upon request. These sources include (but are not limited to): OECD Database on Instruments used for Environmental Policy (OECD, 2016), International Energy Agency Energy Price and Taxes publication (IEA, 2016a), jurisdictions' budget proposals (as in the case of, e.g., Norway or Denmark), customs' agencies documentation, academic journal articles, policy assessment reports.

A.3 Total CO_2 price (oil, natural gas)

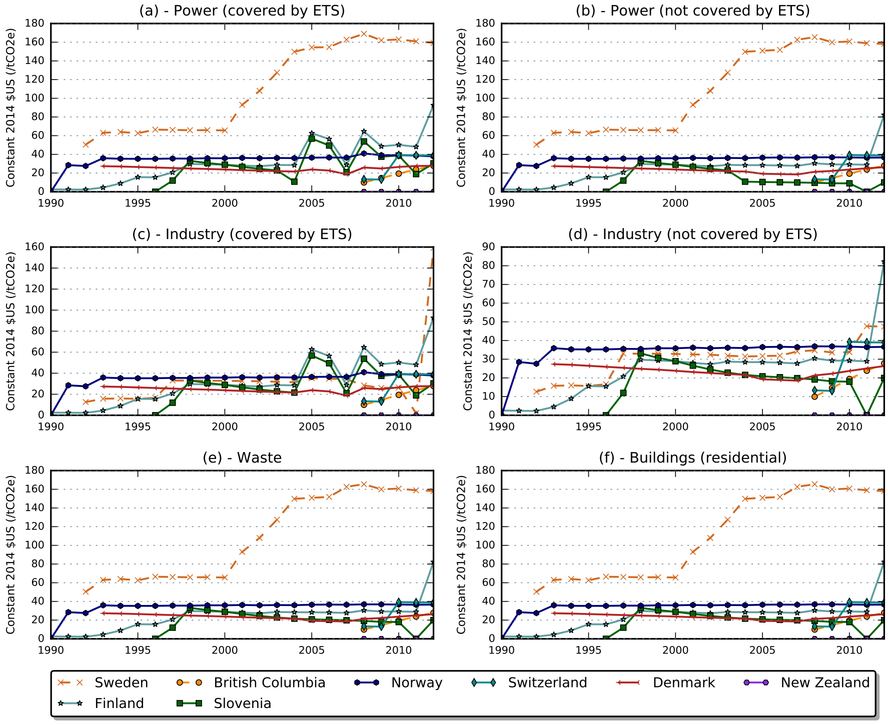

Figure A.1: Total carbon price over time – oil

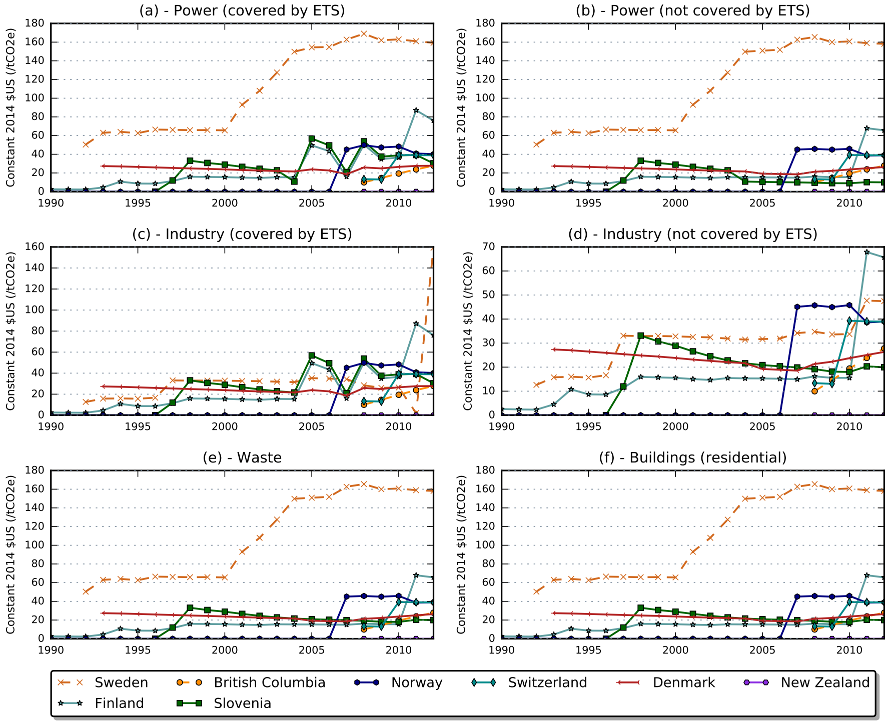

Figure A.2: Total carbon price over time – natural gas

B Scheme's coverage

This methodological appendix further details the steps involved in the computation of the coverage figures. As for the carbon prices, a complete list of sources used to create the data points is available upon request.

Computing coverage figures requires defining a sectoral disaggregation of the economy. For the sake of consistency with IEA (2016) and CAIT Climate Data Explorer (2015) data, we adopt the sectoral disaggregation recommended by the IPCC (2006) Guidelines for National Greenhouse Gases Inventories.[33] Table B.1 summarises the sectoral disaggregation.

Table B.1: Sectors

IPCC	This study
Manufacturing industries and construction*	Industry
Electricity and Heat generation*	Power
Road Transportation	Transport
Domestic Aviation	Aviation
Residential	Buildings - Residential
Commercial and public services	Commercial and public services
Agriculture/forestry	Agriculture/forestry
Waste	Waste

*As highlighted in Appendix B, those sectors are, in some countries and in some years, covered by a tax and an emissions trading scheme. Therefore, some of our calculations distinguish between that part of emissions of these sectors that are covered by the tax scheme and that that is covered by an ETS. The Industry and Power sectors are therefore each broken down into two "sub-sectors": ETS and nETS.

Next, differences in design that exist between carbon taxes and emissions trading schemes matter. The scope of a GHG emissions trading scheme is defined at the sectoral level regardless of the fuel from which CO_2 – and other GHG – emissions originate. Therefore, an emissions trading scheme requires the measurement of GHG emissions at the point of emission. The case of carbon (or any other GHG)-taxes is slightly different. Existing carbon taxes are first defined according to the type of fuel. The sectors to which the tax applies are defined in a second step. The relevant physical unit to be measured in the case of a carbon tax is therefore the fuel consumption (per economic sector). A carbon tax is then applied to the consumption of each type of fuel in each sector by converting a set price for the tonne of CO_2 into price per physical unit of each fuel in each sector using appropriate conversion factors (which are based on the carbon content of each fuel).

In order to record the information described above, we create a panel which records whether a given sector (and, for carbon taxes, a given fuel) was covered by a carbon pricing scheme in

[33]This sectoral disaggregation is itself based on the United Nations International Standards Industrial Classification (ISIC), Revision 4.

a given country, in a given year. That information is coded as a binary variable (0 if the sector is not covered, 1 if it is) and is retrieved from various sources, which vary from one country to the other. Table B.2 summarises the information recorded.

Table B.2: Institutional design

	Carbon Tax	Emissions Trading Scheme
Price signal	Tax rate (nominal - local currency)	(Spot/Futures) Allowance price (nominal - local currency)
Sectoral coverage	✓	✓
Fuel coverage	✓	n.a.
GHG-gas coverage	*	✓
(Price) exemptions	✓	n.a.

*The only GHG covered by carbon taxes is obviously CO_2.
Note: For each jurisdiction and year, except price, all information is coded as a binary entry.

B.1 CO_2 taxes

The last step before the actual calculation of coverage combines IEA (2016), verified emissions and CAIT Climate Data Explorer (2015) data to compute sectoral emissions as shares of a jurisdiction's total greenhouse gases emissions.[34] The data is disaggregated at the user-fuel level and the main fuel categories are: Coal/peat, Oil, Natural Gas. The economy-wide coverage figure is computed according to the following formula

$$Coverage_{i,t} = \frac{\sum_j \sum_k E_{i,j,k,t} \times \mathbb{1}_{i,j,k,t}}{Etot_{i,t}}$$

where $E_{i,j,k,t}$ represents jurisdiction i's emissions from sector k arising from the combustion of fuel j in year t; $\mathbb{1}_{i,j,k,t}$ is an indicator variable taking value 1 if fuel k in sector j of country i in year t is covered by the scheme, 0 otherwise; $Etot_{i,t}$ is the total greenhouse gases emissions in jurisdiction i in year t.

B.2 Emissions Trading Schemes

Unlike for a carbon tax, aggregation across fuels is irrelevant for coverage of Emissions Trading Schemes. Hence, the calculation of coverage of an Emissions Trading Scheme entails one fewer aggregation than that of a carbon tax. Formally,

$$Coverage_{i,t} = \frac{\sum_j E_{i,j,t} \times \mathbb{1}_{i,j,t}}{Etot_{i,t}}$$

[34]For subnational jurisdictions, tax coverage is computed using jurisdiction-specific sources and sometimes relies on secondary data (i.e. not own computation). This is because IEA CO2 emissions data is available at the country-level only.

where $E_{i,j,t}$ represents jurisdiction i's (combustion and fugitive) emissions from sector j in year t; $\mathbb{1}_{i,j,t}$ is an indicator variable taking value 1 if sector j of country i in year t is covered by the scheme, 0 otherwise; $Etot_{i,t}$ is as above.

Note, however, that a sectoral disaggregation is obviously not a necessary condition for the calculation of the "aggregate" (i.e. economy-wide) coverage of an ETS scheme. If one is interested in the aggregate coverage, total (i.e. all sectors) (verified) emissions suffice for the calculation. For instance, in the case of the California-Quebec CaP or the EU-ETS, we used total verified emissions data from the California Air Resource Board (2016) and the European Union Transaction Log (2016), respectively.

The following table provides information about the respective ETSs registries:

Table B.3: Emissions Registries

Scheme	Registry name	Available at
EU-ETS	EU Transaction Log	http://ec.europa.eu/environment/ets/
Switzerland ETS	Swiss Emissions Trading Registry	https://www.emissionsregistry.admin.ch/...
New Zealand ETS	NZ Emission Unit Register	http://www.epa.govt.nz/e-m-t/reports/...
RGGI	CO_2 Allowance Tracking System	https://rggi-coats.org/eats/rggi/
California CaT	California Air Resource Board	http://www.arb.ca.gov/cc/reporting/...
Quebec CaT	GHG Emissions Registry	http://www.mddelcc.gouv.qc.ca/...

B.3 Overlapping coverage

In a few jurisdictions both a carbon tax and an Emissions Trading Scheme co-exist. In some jurisdictions (and years), the schemes are expressly designed not to cover the same emissions. In some specific cases, schemes overlap. This is the case in the European Union where some emissions are covered by the EU-ETS and by national carbon tax schemes. World Bank (2015) estimates that approximately 4% of EU emissions are "double-covered". To avoid double counting emissions that are covered by both an ETS and a tax scheme in our coverage figures, our calculations distinguish, within each sector, tax scheme-covered and ETS-covered emissions.

C Effective Carbon Price

Formally, the ECP of sector i can be expressed as

$$ECP_i = \frac{[\tau_i \times q_{tax,i}] + [p \times q_{ets,i}] + [(\tau_i + p) \times q_{tax,ets,i}]}{q_i^{GHGs}} \quad (3)$$

where τ_i is the carbon tax rate applicable to sector i, $q_{tax,i}$ is the amount of GHG emissions of sector i covered by a tax only, p is the price of an emission permit, $q_{ets,i}$ is the amount of GHGs emissions of sector i that are covered by an ETS, $q_{tax,ets,i}$ is the amount of GHG emissions of sector i that are covered by both an ETS and a tax and q_i^{GHGs} is the quantity of GHGs emitted by sector i. Should a sector be covered by only one of those two instruments and all emissions of the sector be covered, the ECP_i would collapse to either τ_i or p.[35]

An economy-wide ECP is then computed as a weighted average of the effective carbon rates across sectors, where the weights are the quantity of emissions subject to each individual carbon rate:

$$ECP_{eco} = \sum_i (ECP_i \times \gamma_i) \quad (5)$$

$$= \sum_i \left(ECP_i \times \frac{q_i^{GHGs}}{q^{GHGs}} \right) \quad (6)$$

where γ_i represents the GHGs emissions of sector i as a share of the economy's (jurisdiction's) total GHG emissions. For the purpose of the present study, only the economy-wide ECP is computed.

D Cross-correlation matrix

Table D.1: Cross-correlation table

Variables	Elec. Prod - coal	Elec. Prod - gas	Elec. Prod - oil	Industry, VA	GDP per cap.	Trade Openness	EU	Annex-I	Inst. cap.	Level of Dem.	Left
Elec. Prod - coal	1.000										
Elec. Prod - gas	-0.301	1.000									
Elec. Prod - oil	-0.329	-0.170	1.000								
Industry, VA	-0.054	0.315	-0.061	1.000							
GDP per cap.	0.204	0.219	-0.249	-0.017	1.000						
Trade Openness	-0.158	0.204	0.123	0.214	0.085	1.000					
EU	0.034	0.006	-0.063	-0.079	0.146	0.192	1.000				
Annex-I	0.351	-0.117	-0.298	-0.305	0.565	-0.084	0.335	1.000			
Institutional capacity	0.370	-0.077	-0.307	-0.295	0.748	-0.019	0.261	0.782	1.000		
Level of Democracy	0.359	-0.305	-0.254	-0.391	0.315	-0.128	0.239	0.624	0.673	1.000	
Left	-0.044	0.042	-0.027	0.054	-0.204	-0.070	-0.131	-0.169	-0.291	-0.331	1.000

[35] Note that the quantity of GHG emissions is expressed in tonnes of CO_2 equivalent. In addition, this equation can equivalently be written as

$$ECP_i = \frac{[\tau_i \times (q_{tax,i} + q_{tax,ets,i})] + [p \times (q_{ets,i} + q_{tax,ets,i})]}{q_i} \quad (4)$$

It makes clear that calculating the ECP does not require that one identifies overlapping emissions separately.

E Jurisdictions with carbon pricing

Table E.1: Jurisdictions with carbon pricing schemes as of 2015

Jurisdiction	Emissions Trading	Carbon tax	ECP - 2012 (const. 2014 $US)
Australia	2012	(2012)	7.89
Austria	2005	-	3.9
Belgium	2005	-	3.71
Bulgaria	2007	-	3.12
Cyprus	2005	-	6.35
Czech Republic	2005	-	0.21
Denmark	2005	1992	8.76
Estonia	2005	2000	7.08
Finland	2005	1990	32.79
France	2005	2014	2.54
Germany	2005	-	5.44
Greece	2005	-	6.25
Hungary	2005	-	4.03
Iceland	2008	2010	4.2
Ireland	2005	2010	10.76
Italy	2005	-	4.07
Japan	-	2012	0.63
Kazakhstan	2013	-	n.a.
Korea, Rep.	2015		n.a.
Latvia	2005	1995	2.58
Liechtenstein	2008	-	
Lithuania	2005	-	0.82
Luxembourg	2005	-	3.36
Malta	2005	-	7.58
Mexico	-	2014	n.a.
Netherlands	2005	-	4.1
New Zealand	2008	-	2.55
Norway	2007	1991	11.95
Poland	2005	1990	1.34
Portugal	2005	2015	4.01
Romania	2007	-	0.98
Slovak Republic	2005	-	5.45
Slovenia	2005	1996	1.27
Spain	2005	-	4.27
Sweden	2005	1991	63.72
Switzerland	2008	2008	10.79
United Kingdom	2005	2013	5.81
Alberta* (Canada)	2007	-	
Beijing (China)	2013	-	n.a.
British Columbia (Canada)	-	2008	19.45
California (US)	2009	-	5.48
Chongqing (China)	2014	-	n.a.
Connecticut (US)	2009	-	0.45
Delaware (US)	2009	-	0.79
Guangdong (China)	2013	-	n.a.
Hubei (China)	2013	-	n.a.
Kyoto (Japan)	2011	-	†
Maine (US)	2009	-	0.10
Maryland (US)	2009	-	0.78
Massachusetts (US)	2009	-	1.9
Mexico	2014	-	n.a
New Hampshire (US)	2009	-	0.85
New York (US)	2009	-	0.44
Quebec (Canada)	2013	-	n.a.
Rhode Island (US)	2009	-	0.76
Saitama (Japan)	2011	-	†
Shanghai (China)	2013	-	n.a.
Shenzhen (China)	2013	-	n.a.
Tianjin (China)	2013	-	n.a.
Tokyo (Japan)	2010	-	†
Vermont (US)	2009	-	0.00

†: missing information at the time of writing – Chile: 2017; South Africa: 2016; New Jersey's scheme was discontinued in 2011, Australia's in 2012.