

The political economy of carbon pricing: a panel analysis

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Abstract

In virtually all jurisdictions that explicitly price carbon, its average (emissions-weighted) price remains low. Our analysis focuses on the political economy of its introduction as well as its stringency in an international panel of national and North American subnational jurisdictions. Results suggest that political economy factors primarily affected the former and that policy stringency is a highly persistent process. This has two important policy implications. First, successful passage of carbon pricing legislation will either come with *contemporaneous* compensation of incumbent, CO₂-intensive, sectors or occur *after* their relative weakening. Second, if political economy constraints continue to prevail, climate change mitigation strategies will require multiple instruments.

JEL classifications: H23, Q58.

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

- 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%, range 9–30%) in 2025 and by 15.2 (10.1 to 21.1) Gt CO₂ eq (36%, range 24–60%) in 2030 ([United Nations/Framework Convention on Climate Change, 2016](#)).

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. This will, in turn, require the setting up of new (or the strengthening of existing) environmental policy tools. 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).² The focus of this article 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 (2018), 38 new carbon pricing mechanisms started operations between 2005 and 2018, including the California Cap-and-Trade Program and seven (sub-national) emissions trading schemes (ETS) in China. These new schemes added to a group of existing carbon pricing tools such as the European Union Emissions Trading System or a range of taxes explicitly based on the carbon content of fossil fuels.

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. 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. Furthermore, such studies often focus on policy outcomes as proxies for policy developments but do not directly study the policy tool itself (see, e.g. Gassebner *et al.*, 2011; or Cadoret and Padovano, 2016).

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. This allows us to address two fundamental questions pertaining to the design of climate mitigation strategies in the presence of such constraints. How should we adapt the policy design to a specific institutional and economic context? Do political economy constraints constitute a robust rationale in favour of a policy mix as opposed to a single instrument?

The article is organized as follows. Section 2 reviews the relevant strands of the literature. Section 3 briefly discusses carbon pricing (in theory and practice). Section 4 introduces the Emissions-weighted Carbon Price (ECP) and presents the hypotheses while Section 5 presents the data and discusses the empirical methodology used in the analysis. Section 6 discusses the results 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 rationalize them. Olson (1965) highlights the role played by

2 *Carbon per se* is not a greenhouse gas but carbon dioxide (CO₂) is. We refer to instruments putting a price on CO₂ emissions as carbon pricing instruments.

groups with shared interests in shaping policy outcomes and the factors that drive their behaviour. 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, 2006](#)). [Congleton \(1992\)](#) takes an institutional perspective to the issue; proposing 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.³ 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 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](#)), with only some of them 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; a possibility that [Joskow and Schmalensee \(1998\)](#) discuss in the case of the US SO_2 market.

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 globalization 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 \(2015\)](#), analysing data from 200 countries for the political determinants of fossil fuel pricing during the period 1991–2010, found that higher GDP levels lead to higher fuel prices (higher taxes or lower subsidy rates) and that a presidential system (unlike parliamentary or proportional representation systems) could lead to significantly lower gasoline and diesel prices.

Lastly, insights drawn from analyses of the liberalization of energy markets are also relevant to our investigation. [Pollitt \(2012\)](#) takes stock of the energy market liberalization processes to draw lessons about the role of policy in energy transitions and argues that liberalization *per se* will have little impact on the shift toward a low carbon energy mix. Rather, the willingness of societies to bear the cost of environmental policies will.

3 This argument runs against the standard view that political representatives are self-interested and focused on short-term electoral cycles.

Hence, liberalization is not necessarily *neutral* for carbon pricing policy formulation as it has made the cost of those policies increasingly apparent to consumers (Pollitt, 2012). Evidence from the USA (Jenkins, 2014) suggests that citizens are indeed 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. To our knowledge, only Del Rio and Labandeira (2009), Gawel *et al.* (2014) and Jenkins (2014) bring the issue to the fore. Shedding further empirical light on these dynamics is particularly important as we believe that they may differ in nature or in strength from those of: (i) excise duties, which in most occurrences constitute an indirect way to tax road transport; and (ii) other climate policies, whose cost is less visible to the final consumer. In the absence of more refined assessment, suggestions about a way forward for the implementation of carbon pricing when faced with *political economy* constraints are, at best, incomplete. Before turning to that analysis we briefly review the rationale and tools for a carbon price.

3. Carbon pricing policies: theory and practice

In theory, provided that the public authority can credibly commit to a state-contingent carbon price path and in the absence of transaction costs, the carbon price signal should be economy-wide (Tirole, 2012).⁴ Indeed, the externality associated with the release of GHGs into the atmosphere is the same regardless of its source (i.e. sector of origin) or type of use. Any departure from this situation will inevitably introduce distortions between sectors and/or types of users.

Two market-based mechanisms (and hybrid combinations⁵) have emerged: carbon taxes and ETSs. The former places a set price on each unit of CO₂ 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 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.⁶ The first view emphasizes the use of carbon pricing mechanisms to internalize 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 which case the price will follow the dynamically cost-effective price path (Rubin, 1996).

- 4 If transaction costs (i.e. costs of monitoring and verification) are positive, then optimal coverage may not be 100%. Additional emissions should then only be included if the marginal benefit in terms of enhanced cost efficiency outweighs the marginal cost of monitoring and verifying emissions.
- 5 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).
- 6 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 CO₂ but his conclusions were supported in theoretical settings closer to that of stock pollutants (Pizer, 2002; Hoel and Karp, 2002).

Table 1. Sectoral coverage (2015)—# of jurisdictions

	Carbon tax schemes (total: 16)	ETSS (total: 57)
Industry	14	47
Power	12	54
(Road) Transport	12	5
Aviation (domestic)	4	31
Buildings (residential and commercial)	12	8
Agriculture or Forestry	11	2
Waste	12	1

Source: World Bank (2018).

Note: The figures presented in this table count each jurisdiction participating in the EU-ETS as a separate scheme. 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 D](#).

Importantly for us, these schemes differ also in their practical implementations. On the one hand, most carbon taxes are based on the carbon content of fossil fuels. On the other hand, an ETS is based on actual verified emissions at covered (stationary) plants.⁷ Therefore, an ETS can in theory include fugitive and industrial processes emissions in addition to emissions from fuel combustion.

In 2015, the last year of our panel(s), 35 national and 21 subnational jurisdictions had an operating ETS while 15 national and one subnational jurisdiction had a carbon tax targeting at least one type of fossil fuel (i.e. coal, oil or natural gas). Among jurisdictions operating an ETS at the time, 47 covered industry and 54 covered the power sector while the same sectors were included in 14 and 12 carbon tax schemes, respectively. [Table 1](#) provides a summary of sectoral coverage per type of pricing mechanism.

4. Carbon pricing and its drivers

Following on the above discussion, we argue that introducing a carbon pricing mechanism involves two decisions. First, a decision on whether or not to enact a pricing scheme, regardless of the price level or the coverage. Second, a decision about the appropriate—or politically feasible—stringency (i.e. average price). The implementation of carbon pricing policy is recorded by a dummy variable taking value 1 if it is in force in a given country-year, 0 otherwise. The stringency is captured by the average (emissions-weighted) carbon price and is described in Section 4.1. The hypotheses formulated about the drivers of implementation and stringency are presented in Section 4.2.

4.1 Carbon price and coverage: an emissions-weighted carbon price

Following ‘first-best’ theoretical prescriptions, applied macroeconomic integrated assessment models often assume a single, economy-wide (100% coverage) carbon price. Yet,

7 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](#)).

experience with carbon pricing policies suggests that their implementation has rarely, if at all, followed such prescriptions. For example, most of the schemes under consideration entailed low coverage at time of introduction—due to, e.g. sectoral or fuel-based exemptions, or a combination of the two—and their coverage remained partial over their lifetime. Moreover, careful observation of policy developments shows little consistency between the stated environmental goals (and implied GHG budgets) and carbon prices. Therefore, the price tag alone cannot appropriately reflect the stringency 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 stringency, we introduce the concept of an ECP.⁸ This price, computed on a yearly basis, is a weighted average of all carbon price signals present in an economy at a point in time where the weights are the quantity of emissions covered as a share of that jurisdiction's total GHG emissions. To our knowledge, this is the first attempt at capturing the stringency of carbon pricing policies in a consistent and standardized way.⁹ Before turning to a discussion of the underlying methodology, 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 carbon taxes can be defined per fuel type too. The main difference between ETSs and carbon taxes lies in that the former sometimes cover multiple gases whereas the latter only apply to the carbon content of fossil fuels and, by extension, to CO₂ emissions. This article focuses exclusively on CO₂. Provided that accurate measurement of sectoral CO₂ emissions is available, sectoral coverage of a scheme can easily be translated into 'covered' CO₂ emissions as a share of total, CO₂ equivalent, GHG emissions. Based on this information, coverage figures were calculated for 135 national and 63 subnational (50 US States and 13 Canadian Provinces and Territories) jurisdictions as well as a hypothetical 'World' jurisdiction between 1990 and 2015.¹⁰ Figure 1 provides an overview of the

8 The methodology behind the computation of the ECP is similar to that suggested for the Effective Carbon Rate (OECD, 2015). However, the OECD methodology accounts for both explicit carbon prices and energy duties that indirectly price carbon, which we believe is misleading since, as we have emphasized and as the OECD itself acknowledges (OECD, 2015), the motivations behind their introduction are often unrelated to climate change concerns.

9 Measuring policy stringency is inherently difficult, even more so when the metric needs to be comparable across jurisdictions. Most studies rely on indirect measures of policy stringency such as private-sector cost measures, measures based on pollutant emissions and environmental policy enforcement expenditures (Brunel and Levinson, 2013). The OECD calculates an aggregated index of policy stringency at the country level based on information primarily related to climate and air pollution (Botta and Kozluk, 2014).

10 See Online Appendix B for a description of the methodology. At the national level, although our initial intention was to cover all jurisdictions, the cross-section dimension of our panel has been constrained by IEA emissions data availability while the time dimension has been constrained by CAIT data availability. At the subnational level, our focus on North America is driven by the fact that, up to 2015, that region concentrated most of the subnational carbon pricing schemes and that we were unable to gather robust data on the Chinese ETS pilot schemes or the Tokyo, Saitama, and Kyoto schemes.

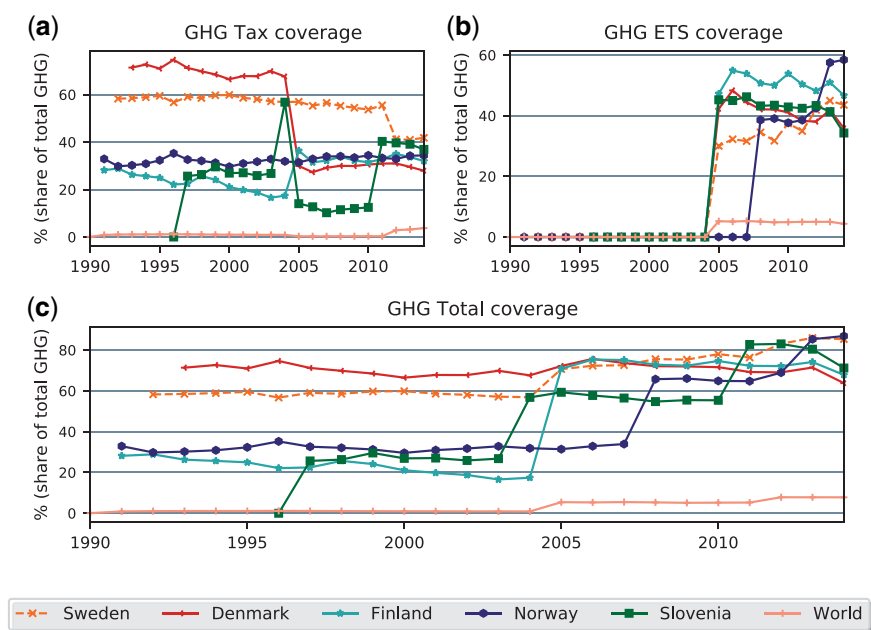


Fig. 1. Carbon pricing coverage—selected (national) jurisdictions

coverage of carbon pricing mechanisms in selected jurisdictions.¹¹ 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' coverage. 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. Yet, one notes that all countries that are part of the EU-ETS exhibit different coverage figures, despite the ETS being harmonized 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 Fig. 1 several others have introduced carbon pricing policies. Switzerland introduced a carbon tax in 2008 covering about 28% of its total emissions. The coverage remained relatively stable over time, with the scheme covering 27% 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,

11 Besides the 'World' jurisdiction, the jurisdictions for which information is presented in Figs 1–4 are among the earliest adopters of carbon pricing mechanisms—exclusive of the EU-ETS countries—and for which the information is therefore available for a meaningful number of years.

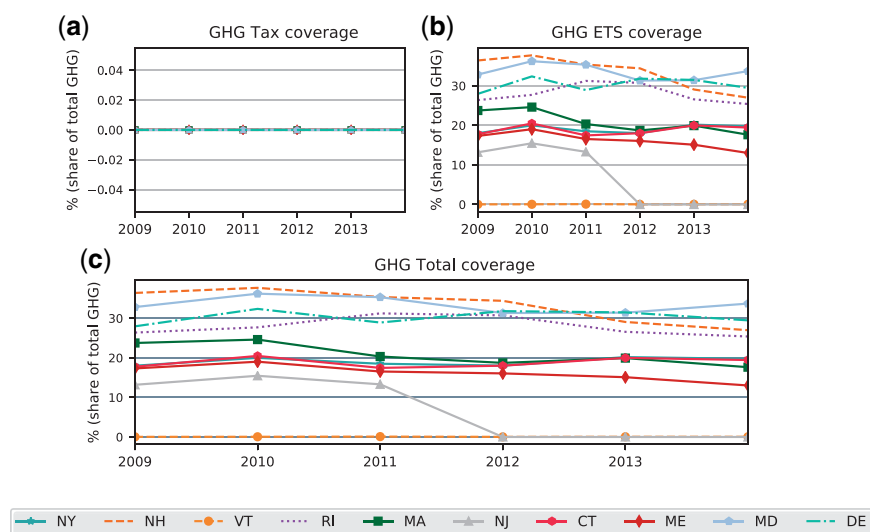


Fig. 2. Carbon pricing coverage—US Regional Greenhouse Gas Initiative

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 nine: the state of New Jersey pulled out of the scheme in 2012) North-eastern US States. Figure 2 shows the implied coverage of the scheme in the 10 participating states over the period 2009 (start year)–2014. 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 2014. 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.¹²

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, which varies mainly along three dimensions: time, jurisdiction, and sector(-fuel). 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 ETSs are only between covered and non-covered sectors (since the price signal is the same across all covered sectors and fuels) whereas a carbon tax scheme also introduces distortions at the sector-fuel level.

Figure 3 displays the total (i.e. the sum of the tax rate and the ETS allowance price, as applicable) price of CO₂ (in 2015 \$US/tCO₂e) in selected sectors of selected countries for

12 As of 1 January 2015, new activities were added to the California CaT, increasing coverage to about 85% of California's total GHG emissions.

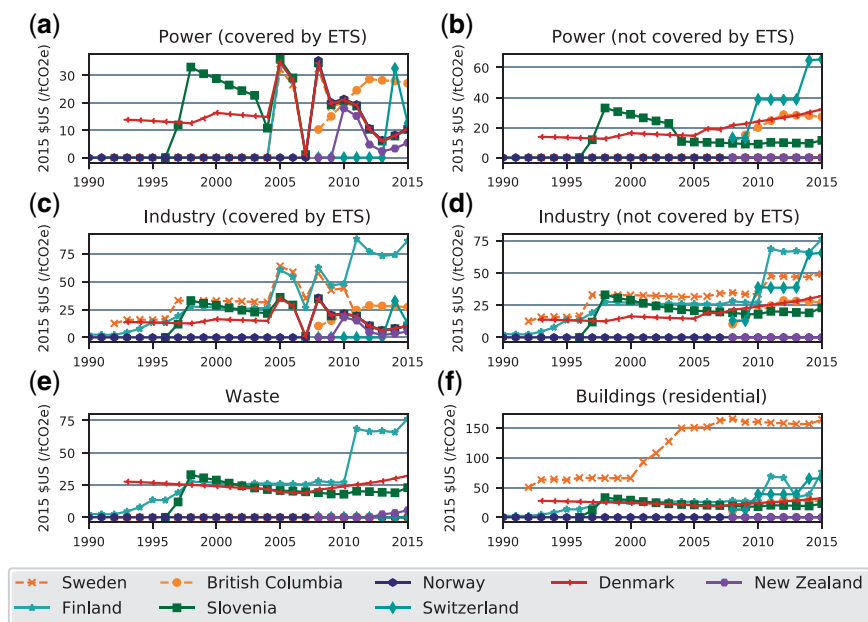


Fig. 3. Total carbon price over time—coal/peat

coal.¹³ The carbon price does not vary much across fuels, suggesting that 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.

4.1.3 The emissions-weighted carbon price (ECP) Combining sector- or sector-fuel-level coverage and price information allows for the calculation of an economy-wide ECP. To compute the ECP each emitted ton of GHGs is attributed the corresponding total price signal. That is, emissions covered by either a tax or an ETS receive the associated tax rate or permit price as price tag whereas emissions of a sector covered by both schemes receive the sum of the tax rate and the permit price.¹⁴

The evolution of the ECP in selected countries over the period 1990–2015 is presented in Fig. 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 partly due to the presence of carbon taxes in some—but not all—countries, which create an additional price signal for some emissions. It is also, perhaps more importantly, due to differences in the relative size of

13 Figures A.1 and A.2, available in Online Appendix A, show the total price for oil and natural gas, respectively.

14 Note that the ECP can be computed using time-varying or fixed weights. In the former case, weights (i.e. sector-fuel emissions share) are the year-specific emissions share; in the latter, we use 2013 emissions share. The latter is used in the empirical analysis as it is not subject to changes in emissions shares (i.e. weights) that might have been the result of the policy itself. See Appendix C for a formal presentation.

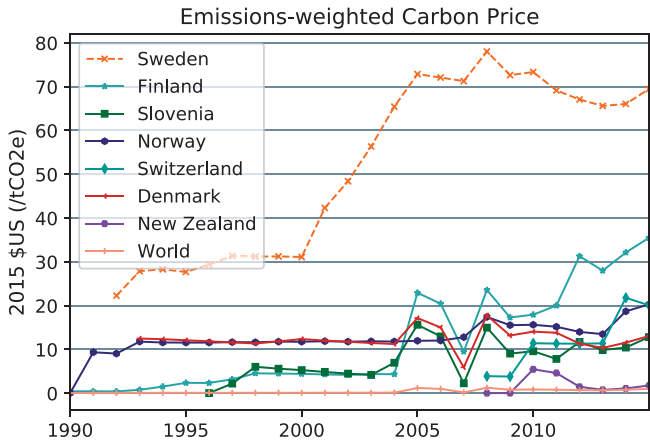


Fig. 4. ECP—selected jurisdictions

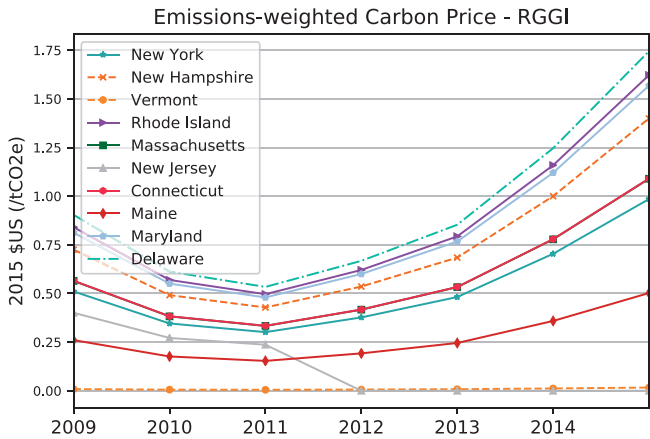


Fig. 5. ECP—RGGI

sectors and their respective CO₂ intensity, as mentioned in Section 4.1.1. This feature is particularly well illustrated by the ECP of states participating in the US RGGI (Fig. 5).

Lastly, note that some countries' ECPs 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 over the sample period.

4.2 Hypotheses

We now formulate hypotheses about the determinants of policy implementation and stringency. These are grouped as follows: (i) regulatory capture; (ii) political institutions; and (iii) macroeconomic determinants. A summary is presented in Table 2.

Table 2. Summary of hypotheses

Category	Variable	Expected sign Carbon Price (Y/N)	Expected sign Carbon Price (Level)
Regulatory capture	Power-coal	–	–
	Power-oil	–/0	–/0
	Power-gas	–/0	–/0
	Industry	–	–/n.a.
	International competitiveness	+/–	+/–
Political institutions	EU	+	+
	Annex-I	+	+
	Institutional capacity	+	n.a.
	Level of democracy	+	n.a.
	Left	+	+
Macro determinants	GDP <i>per capita</i> (WTP)	+	+
	CO ₂ emissions <i>per capita</i>	–	–

4.2.1 Regulatory capture

Power sector Any form of carbon pricing that includes the power sector might impose costs (e.g. reduced profits or capital losses) on those electricity producers that produce electricity from fossil fuels. We expect these costs to be higher the larger the share of electricity produced from fossil-fuelled power plants which, following [Olson \(1965\)](#), would weaken the political feasibility of carbon pricing regulation. 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. In aggregate, under perfect competition and 100% pass through, electricity producing firms' profits will remain largely unaffected.¹⁵ With less than 100% pass through the change in equilibrium market price will not entirely reflect the increase in cost and firms' 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. Such a possibility 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 CO₂-intensive) sectors were successful in influencing the design of GHG trading systems. In fact, except for the US RGGI, all ETSs have been introduced with close to 100% free allocation of emission permits ([World Bank, 2014](#)). It is difficult to explicitly account for such effects in an econometric investigation but we note at this stage that it is likely to reduce the magnitude of the

15 There is still, however, the possibility that the profits of coal fired power plants will fall relative to gas and non-fossil generators. Hence carbon pricing policies will affect individual firms differently depending on the composition of their generation portfolio.

coefficients on the variables accounting for the role of CO₂-intensive sectors, including the power sector.

Industry Besides the power sector, other energy-intensive sectors, broadly defined as ‘industry’ are likely to oppose a carbon pricing scheme on the grounds that it holds the potential to increase production costs. There are two channels via which costs to industry could be pushed upward by a carbon pricing policy. A direct channel whereby CO₂-intensive industries that fall within the scope of a carbon pricing scheme will have to pay for their own CO₂ emissions; and an indirect channel whereby the introduction of carbon pricing policies covering the electricity generating sector leads 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, might raise the production cost of electricity-intensive industries. This argument closely follows Cadoret and Padovano (2016).

International competitiveness As emphasized by Aldy and Pizer (2012), sectors of the economy that are export-oriented should be more resistant to the introduction of a carbon price as it risks putting them at a competitive disadvantage in international markets. Care is usually taken to design the schemes in ways that minimize the international competitive disadvantage that domestic firms may suffer from but jurisdictions that are very exposed to international markets may nonetheless be less inclined to implement carbon pricing policies.

4.2.2 Political institutions

Political regime Congleton (1992) argues that autocrats’ time horizon is shorter than that of democratic planners and they therefore set weaker environmental targets. Yet, Hahn (1990) also argues that liberal democracies offer the possibility for different interest groups to express their views and ‘weigh’ on the legislative process, in which case regulatory outcomes will be a balancing act that reflects the relative bargaining power of the different interest groups. This could work both in favour or against the introduction of carbon pricing policies, depending on interest groups’ relative lobbying strengths.

Government ideology Prior studies have found left wing governments implement 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. We test whether the orientation of the executive branch of government with regard to economic policy affects the implementation and/or stringency of carbon pricing schemes.

Institutional capacity 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. 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, irrespective of the level of the price associated with it.

International dynamics Membership of international organizations (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 EU-wide emissions trading system. Several EU Member countries currently part of the system were ‘dragged in’ and implemented it only because it was part of the preexisting legislative *acquis* (Ranson and Stavins, 2015). 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. 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.

4.2.3 Macro(economic) determinants of environmental policy Finally, besides the sector-specific stance towards carbon pricing and the political institutions of a jurisdiction, we note two further factors potentially affecting implementation and stringency of a carbon pricing scheme. First, under the assumption that environmental quality is a normal good, the willingness to pay for CO₂ emissions abatement rises with income. Therefore, we expect the income level (*per capita*) to be positively associated with the probability of implementation of a carbon pricing policy as well as the ECP. Second, given the direct economic cost that pricing carbon entails, larger emitters (*per capita*) may be less prone to introduce pricing policies.

5. Data and identification strategy

5.1 The data set

The analysis is performed on three different panels: 124 national jurisdictions—panel A; 50 US States—panel B; and 13 Canadian Provinces—panel C.¹⁶ Panel A runs over the period 1990–2015; panel B starts in 2008 and ends in 2015; panel C covers the years 2005–2015. This represents (a maximum of) 3,224 country-year observations, 400 (US) State-year observations and 143 (Canadian) Province-year observations. The actual ECP is only observed for those jurisdictions that have selected into a pricing mechanism (either ETS or tax, or both). In 2015, 35 national jurisdictions, 11 US States and two Canadian Provinces had had a carbon pricing mechanism in force in at least one year. That is, the ECP is observed for 420 country-year, 70 (US) State-year and 11 (Canadian) Province-year pairs. This particular structure of the data has implications for our empirical analysis—see Section 5.3.

5.2 Covariates

This section introduces the variables used to investigate the hypotheses presented in Section 4.2. The corresponding summary statistics are presented in Table 3.

5.2.1 Regulatory capture Previous literature has proxied the strength of the lobbying exercised by the power/energy sector in at least two ways. First, Fredriksson *et al.* (2004) and

16 Although the ECP is calculated for 135 national jurisdictions, data availability for some of our covariates constrains the panel dimension of our sample to 124—models (I) and (III)—and 110 units—models (II) and (IV). For panel A, each estimator is therefore presented for two alternative specifications because the *Left* variable is not available for all panel units. In addition, panel A is unbalanced.

Table 3. Variable sources and summary statistics

Variable	Jurisdiction	Source	Mean	Std. Dev.	Min.	Max.	N
Pricing	National	Author (see appendix)	0.12	0.33	0	1	3,510
	US States	Author (see appendix)	0.17	0.37	0	1	400
	Can. Prov./Terr.	Author (see appendix)	0.12	0.32	0	1	143
ECP ^c (time-invariant weights)	National	Author (see appendix)	12.84	16.67	0.002	95.21	420
	US States	Author (see appendix)	0.88	1.38	0.01	9.66	70
	Can. Prov./Terr.	Author (see appendix)	16.24	10.18	2.19	29.48	11
Elec. generation-coal, % of total	National	World Bank, WDI (2016)	16.78	25.87	0	100	3,477
	US States	U.S. EIA (2015)	39.61	28.87	0	97.79	400
	Can. Prov./Terr.	Statistics Canada (2016a)	15.88	24.77	0	69.93	143
Elec. generation-gas, % of total	National	World Bank, WDI (2016)	22.63	30.12	0	100	3,477
	US States	U.S. EIA (2015)	24.5	23.48	0	98.51	400
	Can. Prov./Terr.	Statistics Canada (2016a)	6.82	9.52	0	38.37	143
Elec. generation-oil, % of total	National	World Bank, WDI (2016)	19	27.96	0	100	3,477
	US States	U.S. EIA (2015)	2.28	10.24	0	76.21	400
	Can. Prov./Terr.	Statistics Canada (2016a)	3.25	7.46	0	34.65	143
Industry VA, % of GDP	National	UN data	32.11	11.67	6.3	84.55	3,452
	US States	US BEA (2016)	21.5	7.25	0	46.5	400
	Can. Prov./Terr.	Statistics Canada (2016b)	29.83	11.26	15.37	58.56	143
EU	National	Author-created	0.15	0.35	0	1	3,510
Institutional capacity	National	World Bank, WGI (2016)	0.1	0.98	-2.19	2.26	2,538
Democracy	National	Polity IV project	3.7	6.74	-10	10	3,247
Left	National	Varieties of Democracy (2018)	0.33	0.47	0	1	2,894
Ideology	US States	Shor and McCarty (2011)	0.09	0.72	-1.47	1.23	346 ^a

(continued)

Table 3. Continued

Variable	Jurisdiction	Source	Mean	Std. Dev.	Min.	Max.	N
GDP per capita, PPP \$2011 USD	National	World Bank, WDI (2016)	17,810.61	19,575.93	354.28	129,349.9	3,338
	US States	US BEA (2016)	47,576.53	9047.45	31,565.52	74,417.54	400
	Can. Prov./Terr.	Statistics Canada (2016c)	44,510.85	13,280	28,806.69	95,355.49	143
Trade openness, % of GDP	National	World Bank, WDI (2016)	83.14	49.01	0.02	441.60	3,348
	US States	U.S. Census Bureau (2016)	18.99	9.64	4.04	59.05	350 ^b
	Can. Prov./Terr.	Statistics Canada (2016c)	57.56	18.55	15.78	111.71	143
CO ₂ emissions, <i>tcap</i>	National	World Bank, WDI (2016)	5.62	7.24	0.017	70.14	3,283
	US States	WRI, CAIT Climate Data Explorer (2015)	23.6	19.35	8.47	130.7	350 ^b
	Can. Prov./Terr.	Statistics Canada (2018)	20.14	13.23	6.47	52.81	143
Polyarchy	National	Varieties of Democracy (2018)	0.45	0.28	0.01	0.916	3176
Libdem	National	Varieties of Democracy (2018)	0.56	0.27	0.017	0.95	3,176
Corruption	National	World Bank, WGI (2016)	0.02	1.05	-2.06	2.59	3,150

Source: Authors' calculations.

Notes: ^aThe *Ideology* covariate is unavailable for the state of Nebraska and is not available for all years of each panel unit.

^bThe *Trade openness* and CO₂ *emissions* are unavailable for 2015.

^cIncludes only jurisdiction-year observations for which a pricing scheme was in operation, i.e. excludes '0' entries which reflect the absence of a pricing scheme rather than a truly zero price.

Fredriksson and Vollebergh (2009) use the share of value added of the energy industry in total GDP. Second, Marques *et al.* (2010) and Marques and Fuinhas (2011) disentangled the specific role played by different fossil fuel sources using the contribution of each of them to total electricity production. Since coal, gas and oil electricity generation would not be similarly affected by the introduction of a carbon pricing scheme, we follow this last approach and use their share in total electricity generation as proxies for their influence on policy developments. To capture the lobbying activity of CO₂/energy-intensive industries, we follow Cadoret and Padovano (2016) and use the value added of industry (as a share of GDP). Finally, the effect of trade openness is captured by the sum of a jurisdiction's exports and imports (as a share of GDP).

5.2.2 Political institutions We introduce an institutional capacity indicator, constructed as the simple average of the World Bank's 'Government Effectiveness' and 'Regulatory Quality' indicators (World Bank, WGI, 2016). This follows Steves *et al.* (2011).¹⁷ The first year of these series is 1997 but they only became available on an annual basis in 2002. Therefore, years 1998 and 2000 are filled using a linear interpolation method. Our main proxy for the state of democracy (*Dem*) comes from the Marshall *et al.* (2018). As a robustness check, we also perform the analysis with two variables taken from the Varieties of Democracy Database. The first (*Polyarchy*) measures to what extent the ideal of electoral democracy is achieved whereas the second (*Libdem*) measures performance regarding the achievement of principles of liberal democracy (Varieties of Democracy, 2018).¹⁸

To investigate the effect of the political orientation of the executive with respect to economic policy in national jurisdictions we create, based on Cruz *et al.* (2018) in Varieties of Democracy (2018), a variable (*Left*) which takes value 1 whenever the ruling party is identified as left wing party and 0 otherwise. The '0' therefore lumps together right-wing and centre parties as well as parties whose political platform does not take a clear stance regarding economic policy. For panel B, the variable used (*Ideology*) captures the median ideology in the state's house of representatives, as defined in Shor and McCarty (2011). No such variable is available for subnational Canadian jurisdictions. Finally, the effect of EU membership (*EU*) is tested with the use of a dummy variable that takes value 1 whenever a country is a member of the EU, and 0 otherwise.¹⁹

5.2.3 Macro determinants To control for general economic and environmental conditions, we use GDP (PPP, \$US 2011) and CO₂ emissions (metric tonnes), both *per capita*.

5.3 Model and identification strategy

Our objective is to identify some of the determinants of carbon pricing policy implementation as well as stringency. To that end we introduce two (sets of) models. One that relates our covariates to a binary outcome variable recording the presence of a carbon pricing

17 Correlation with the World Bank *Control of Corruption* estimate is also investigated, see Section 6.3.

18 Such variables are not available for subnational jurisdictions but their inclusion would most likely add little to the model as there would be little cross-section and/or time variability.

19 Earlier work tested the role of being listed in Annex-I and Annex-II of the Kyoto Protocol. Both institutional features turned out to have negligible impact on our outcome variables.

scheme for a given jurisdiction-year entry, another relating some of these same covariates to the stringency of the scheme. A general representation of each of them is

$$\mathbb{1}_{it} = \alpha + \psi'X_{it} + \gamma'Z_{it} + \eta'W_{it} + d_t + u_{it} \quad (1)$$

$$ECP_{it} = \eta + \delta ECP_{it-1} + \psi'X_{it} + \gamma'Z_{it} + \eta'W_{it} + d_t + \phi_i + \epsilon_{it} \quad (2)$$

where $\mathbb{1}_{it}$ is an indicator variable capturing the operation of a carbon pricing scheme, ECP_{it} is the Emissions-weighted Carbon Price, X_{it} is the vector of regulatory capture variables, Z_{it} is the vector of political and institutional variables and W_{it} is the vector of macro(-economic) variables. ϕ_i is the unobserved jurisdiction fixed-effect while d_t is the vector of time dummy variables; ψ' , γ' and η' are vectors of dimensions m , n and p , respectively, each element of which corresponds to the estimated parameter of the associated explanatory variable. u_{it} and ϵ_{it} are the observation specific error terms.

In estimating (1) and (2), two potential problems may arise. First, as much as economic structure and electricity generation mix may affect policy implementation and stringency, the latter can also affect the former, creating a reverse causality problem and causing standard estimation approaches to fail. Second, there may be endogenous selection into the policy, which would bias the coefficient estimates in eq. (2).²⁰

5.3.1 Reverse causality The potential presence of simultaneity bias prompts us to: (i) note the features of the data that make our analysis less prone to it; (ii) describe the steps taken to minimize and subsequently address this issue. First, note that $\mathbb{1}_{it}$ records *implementation*, not *passage* of the legislation. In most cases, the year of implementation differs from the year the legislation is passed, the former following the latter by a lag of one (in the case of the EU-ETS) to three years (in the case of, for example, Chile's carbon tax). This provides a rationale for the use of lagged values of all the variables included as regressors in eq. (1)—see Table 4—and prevents the possibility that its outcome variable would determine the covariates—at least in a contemporaneous manner. That is, some regressors may only be pre-determined.

Second, an endogeneity problem only arises if the policy, once implemented, works as intended. Carbon pricing policies were primarily designed to affect jurisdictions' CO₂ emissions through altered technological choices or structural changes in the composition of the economy. While it cannot be ruled out that some of these policies (especially the most stringent ones) did have the intended effects, it is worth noting that: (i) these policies affect the economy only slowly; (ii) technological advances in abatement technology may reduce structural shifts in economic composition; (iii) except for a few jurisdictions, most carbon pricing policies introduced over the period covered in the sample have been relatively weak; and (iv) several jurisdictions introduced said schemes towards the end of our sample period. All this suggests that it is unlikely that the value added of industry, which we use to proxy for the lobbying intensity of energy-intensive sectors, will be determined by policy implementation or stringency. However, the same argument does not hold as strongly for the electricity mix variables or CO₂ emissions, which tend to be more sensitive to carbon prices.

20 Note, however, that a selection bias would only be present insofar as the population of interest is the entire set of jurisdictions initially present in our panels.

Table 4. Implementation—Outcome: ¶

Panel	Category	Variable	RE Logit		RE Probit	
			(I)	(II)	(III)	(IV)
A—National	Regulatory capture—X	Power-Coal _{t-2}	−0.014 (0.0355)	−0.016 (0.0358)	0.01 (0.0165)	0.043 (0.0184)
		Power-Gas _{t-2}	−0.065* (0.0467)	−0.096 (0.0616)	−0.029 (0.0207)	−0.063* (0.0359)
		Power-Oil _{t-2}	−0.286*** (0.0812)	−0.188*** (0.0775)	−0.109*** (0.0332)	−0.132*** (0.0434)
	Political institutions—Z	Industry, VA _{t-2}	−0.141 (0.1319)	−0.114 (0.2163)	−0.06 (0.0706)	−0.054 (0.0943)
		Trade Openness _{t-2}	0.023 (0.0198)	0.008 (0.023)	0.01 (0.0087)	0.01 (0.0147)
		Level of Democracy _{t-2}	1.756*** (0.2229)	0.82*** (0.4216)	0.759*** (0.0972)	0.834*** (0.2363)
	Macro(economic) environment—W	EU _{t-2}	14.449*** (4.1656)	17.9*** (3.2755)	5.643*** (1.5721)	11.249*** (2.095)
		Left _{t-2}		−1.209 (1.4653)		−0.564 (0.8598)
		Institutional capacity _{t-2}		7.423** (3.0055)		5.925*** (1.6916)
	Observations	GDP per cap _{t-2}	0.397*** (0.0489)	0.093 (0.1014)	0.167*** (0.0306)	0.125** (0.0599)
		CO ₂ Em _{t-2}	0.153 (0.1575)	0.199 (0.2003)	0.045 (0.0812)	0.036 (0.1103)
		Constant	−46.352*** (7.3768)	−42.879*** (9.8192)	−20.257*** (3.7665)	−33.924*** (4.8143)
	Observations	Year dummies	Yes	Yes	Yes	Yes
			2726	1793	2726	1793

Source: Authors' calculations.

Notes: (i) The institutional capacity variable is observed for the first time in 1997, shortening the time dimension of models (II) and (IV). Together with the lower number of panel units available for *Left*, it explains the lower number of observations; and (ii) all time dummies from 2005 onwards were statistically significant at the 1% level in models (I) to (IV). We also took a different approach and introduced a time trend. It did not, however, exhibit any significance.

100.0 > *p****10.0 > *p***5.0 > *p**—*test*s reported in some paragraphs

5.3.2 Selection We only observe the stringency for the jurisdictions that have a scheme in operation in any given year. If there is correlation between the selection/participation and level/stringency decision, then the process is best modelled as a model with incidental truncation (or selection) where both a level and a selection equation are specified and a correction for the selection bias is applied (Gronau, 1974; Heckman, 1976). That is, eq. (2) should be complemented with the introduction of a latent variable (see e.g. Semykina and Wooldridge, 2010):

$$s_{it} = 1[z_{it}\delta_t + \phi_{i2} + v_{it} > 0] \quad (3)$$

where $1[\cdot]$ is an indicator function and s_{it} is a selection indicator that equals 1 if ECP_{it} is observed and 0 otherwise.

Given the above, we implement the following econometric approach, applied to each panel separately. First, we estimate (1) with random effect logit and probit models. All regressors in estimations of eq. (1) are introduced with a two-period lagged value to account for the lag between passage of legislation and policy implementation. Second, we provide results of (FE) OLS and system GMM estimations for eq. (2). In addition to controlling for unobservable time-invariant fixed effects, the GMM estimator allows us to account for potential endogeneity of the regressors and model the persistence of the stringency variable. The GMM approach has been taken in Marques and Fuinhas (2011) to study the relationship between a very similar set of covariates and renewable energy deployment.

We correct for the selection bias by introducing a sample selection correction term. This term is calculated for each ECP observation using a Heckit approach adapted from Semykina and Wooldridge (2010). In a first step, a probability of occurrence of that observation is obtained by estimating, for each t , eq. (3) using a probit regression on the entire cross-section of jurisdictions. In a second step, this term is then included in the estimation of eq. (2) as a regressor. For panel A, the set of regressors for the selection equation includes the electricity generation mix variables, the value added of industry, CO₂ emissions and GDP *per capita*, trade openness, and EU.²¹ All variables are introduced with a two-year lag to reflect our theoretical assumption that operation of a carbon pricing scheme ($s_{it} = 1$) is dictated by past economic and institutional structure. For panel B, the same variables are included, except EU.²²

6. Estimation results

We comment separately on the estimation of eqs (1) and (2). The results are presented for panels A, B and C. All estimations include year fixed-effects, and all estimations of eq. (2) include country fixed-effects.

6.1 Implementation

6.1.1 Panel A—national jurisdictions Table 4 presents the results of both RE logit and RE probit estimations, which lead to convergent conclusions about the effects of the covariates

21 Institutional capacity and *Left* are not part of the selection equation since the former is not available until 1997 and the latter further reduces the panel dimension.

22 Given the paucity of ECP observations for Canadian Provinces & Territories (2 panel units, for a total of nine observations) no estimation is presented.

on the decision to implement a carbon pricing scheme. First, estimates suggest that a larger share of electricity generated from gas and oil fired power plants lowers the probability of subsequent introduction of a carbon pricing scheme. This is in line with our expectation that jurisdictions whose electricity generation system relies more heavily on fossil fuels would face greater opposition to the introduction of such schemes. The estimates of the coefficient on the share of coal in the electricity system, however, do not indicate a consistent pattern of influence on the implementation of carbon pricing mechanisms, which runs against the understanding that jurisdictions with coal fired electricity systems would fiercely oppose the introduction of carbon pricing policies. One potential explanation for this is that 'dirty' electricity producers have been granted significant compensation in the schemes introduced so far. For example, in the case of the EU-ETS, CO₂-intensive electricity producers and heavy industries were 'bought in' by grandfathering emissions allowances in the first two phases of the operation of the system. Second, within the sample of national jurisdictions, we find little evidence supporting the hypothesis that larger industry or manufacturing sectors hindered the introduction of carbon pricing policies. Although coefficient estimates are negative across all estimations, they are only weakly statistically different from zero. One potential explanation for this observation is that the set of panel units includes both strongly industrialized and less industrialized jurisdictions, with most carbon pricing policies having been introduced within the former group. Lastly, trade openness does not seem to have played a determining role in the introduction of carbon pricing policies. Again, one can plausibly suggest that it is related to the fact that existing schemes have: (i) covered non-traded sectors; (ii) provided sectoral exemptions/compensation for industries exposed to international competition. Third, the institutional environment does play a role in the adoption of carbon pricing policies. Results suggest a consistent pattern of introduction of carbon pricing policies among jurisdictions that rank higher on the Polity IV democracy index and have a stronger institutional capacity as calculated in this article. 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 (1990) conclusions 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). This might also suggest that the 'green' lobby is effectively given some weight in the policy-making process. The economic orientation of the executive does not seem, on the contrary, to play a significant role in the adoption of carbon pricing policies, suggesting that, in the sample currently considered, such policies have received support from parties across the political spectrum. This result is in line with Fankhauser *et al.* (2015). The results also highlight the (international) institutional dynamics at play in the development of carbon pricing policies as EU membership is found to strongly affect the probability of introduction of a carbon pricing scheme, a result that is likely to be mainly driven by the introduction of the EU-ETS in 2005. The results also indicate that, all else equal, larger emitters (*per capita*) have been more likely to introduce carbon pricing mechanisms, reflecting the fact that, until now, carbon pricing mechanisms have been introduced in more economically advanced jurisdictions with large CO₂/capita emissions, possibly following international commitments. Finally, GDP *per capita* has a positive effect on the introduction of a carbon pricing mechanism ([II] and [III]), although the statistical significance of this effect vanishes when institutional capacity is accounted for ([III] and [IV]). Its magnitude changes depending on the econometric

specification but the direction of the induced change is stable across all estimated models, strongly suggesting that economic agents are more likely to support the introduction of such policies if they are relatively better off.

6.1.2 Panels B & C—US states & Canadian provinces The results for the subnational jurisdictions (Table 5) considered are broadly consistent with those based on panel A, although we note some interesting differences.²³ In the USA, results indicate that electricity generation from fossil fuels negatively impacted the development of carbon pricing mechanisms, with the largest absolute effect associated with electricity generation from oil. The results also suggest that carbon pricing mechanisms were less likely to be introduced in states with high CO₂ emissions *per capita* as well as states for which (CO₂-intensive) industry represents a large share of total economic activity—consistent across models (V) and (VI). Conversely, states with relatively higher income *per capita* were more likely to introduce carbon pricing. The insights obtained from panel C need to be interpreted with caution as only two Canadian Provinces introduced a carbon pricing mechanism over our sample period. Nonetheless, results suggest that richer (*per capita*) jurisdictions were more likely to introduce carbon pricing mechanisms whereas larger CO₂ emitters (*per capita*) or jurisdictions with relatively larger industry were less likely to do so. In that regard, it is interesting to note the contrasted dynamics between national and subnational jurisdictions. For example, national jurisdictions with large CO₂ emissions (*per capita*) seem to have taken the lead in pricing carbon (perhaps due to international commitments) whereas large (*per capita*) subnational emitters have not.

6.2 Stringency

This section discusses the estimation results of eq. (2). Tables 6 and 7 present the results for national jurisdictions and US States, respectively. Models (VII) and (IX) do not account for potential sample selection bias whereas models (VIII) and (X) do. The results clearly demonstrate a very high persistency of policy stringency. This effect is present across all panels, consistent across estimators and of the order of 0.8–0.9, indicating that carbon pricing policy stringency changes very slowly over time. The evidence regarding the role of the electricity generation portfolio is mixed. In panel A, electricity generation from coal is found to have a negative impact on the stringency of implemented schemes only in models (IX) and (X). The associated estimated coefficients suggest that an increase of 10% in the share of electricity generated from coal would lead to a 0.6–1.2USD/tCO₂e decrease in the average carbon price. Similar mechanisms are identified for the share of gas in the electricity generation mix, which weighs negatively on the stringency of the carbon pricing policy. A 10% increase in this share would reduce the average carbon price by between 0.9USD/tCO₂e and 1.8USD/tCO₂e. Next, coefficient estimates of all models except model (IX) point at a negative effect of the relative strength of industry on the policy stringency. The magnitude of this negative effect varies from -0.17USD/tCO₂e in model (X) to -0.04USD/tCO₂e in model (VIII) for each 1% increase in the share of industry in total GDP. Results do not support the existence of a clear relationship between trade openness and policy stringency, most likely for the same reasons that it did not seem to decisively affect implementation. Interestingly, results indicate that being part of the EU had a positive yet not statistically significant impact on stringency. The magnitude of the

23 Panel B contains only *Ideology* as political variable and panel C contains no variable reflecting the state of political institutions.

Table 5. Implementation—Outcome: 1.

Panel	Category	Variable	RE Logit (V)	RE Probit (VI)
B—US States	Regulatory capture—X	Power-Coal _{t-2}	−0.225 (0.1489)	−0.086 (0.1041)
		Power-Gas _{t-2}	−0.082 (0.0706)	−0.014 (0.05)
		Power-Oil _{t-2}	−0.308 (0.4222)	−0.222 (0.2352)
		Industry, VA _{t-2}	−1.71 ** (0.7826)	−1.111 * (0.6487)
		Trade Openness _{t-2}	0.305 (0.1866)	0.206 (0.1341)
		Ideology _{t-2}	−0.031 (3.1119)	0.004 (1.9761)
	Political institutions—Z			
	Macro(economic) environment—W	GDP per cap. _{t-2}	0.738 ** (0.3176)	0.386 ** (0.176)
		CO ₂ per cap. _{t-2}	−1.509 ** (1.3175)	−1.154 * (0.6273)
		Constant	14.929 (37.9157)	13.891 (16.2831)
		Year dummies	Yes	Yes
	Observations ^a		255	255
C—Canadian Prov. & Territories	Regulatory capture—X	Power-Coal _{t-2}	0.544 (0.8818)	0.208 (0.4137)
		Power-Gas _{t-2}	1.093 (0.6613)	0.481 (0.3694)
		Power-Oil _{t-2}	−5.5328 (4.0517)	−1.918 (1.8411)
		Industry, VA _{t-2}	−0.193 (1.1889)	−0.092 (0.3729)
		Trade Openness _{t-2}	−0.405 (0.3713)	−0.159 (0.1843)
		Ideology _{t-2}		
	Macro(economic) environment—W	GDP per cap. _{t-2}	0.556 (0.748)	0.271 (0.3140)
		CO ₂ per cap. _{t-2}	−0.994 (2.0007)	−0.338 (0.9613)
		Constant	−14.086 (19.9356)	−4.699 (10.8357)
		Year dummies	Yes	Yes
	Observations ^a		117	117

Source: Authors' calculations.

Notes: ^aPanel A: from a number of observations of 400, we lose 2 × 50 observations given that we use two-years lag. Panel B: 2 × 13 observations are lost. Year dummies from 2012 onwards are significant in Panel B estimations. None of the year dummies for panel C were significant.

Standard errors in parentheses; *P < 0.05, **P < 0.01, ***P < 0.001.

Table 6. Stringency—ECP (2015 \$US/tCO₂e).

Panel	Category	Variable	FE OLS (VII)	FE OLS, Heck (VIII)	Syst GMM (IX)	Syst GMM, Heck (X)
A—National	Regulatory capture—X	ECP _{t-1}	0.875*** (0.0438)	0.879*** (0.052)	0.824*** (0.1126)	0.824*** (0.1402)
		Power-Coal _t	0.068** (0.0261)	0.064* (0.0324)	−0.054 (0.0773)	−0.123 (0.1106)
		Power-Gas _t	0.022 (0.0274)	0.03 (0.0268)	−0.088* (0.0508)	−0.181* (0.0911)
		Power-Oil _t	−0.016 (0.1084)	−0.013 (0.1089)	0.095 (0.1265)	0.061 (0.1609)
		Industry, VA _t	−0.084 (0.1021)	−0.041 (0.0918)	0.068 (0.2857)	−0.173 (0.4142)
	Political institutions—Z Macro(economic) environment—W	Trade Openness _t	−0.014 (0.0239)	−0.021 (0.0242)	0.02 (0.026)	0.028 (0.0427)
		EU _t	0.621 (1.0813)	0.127 (0.8366)	3.801 (6.101)	10.412 (7.9493)
		CO ₂ Em _t	−0.533*** (0.2058)	−0.473** (0.199)	0.458 (0.5451)	0.453 (0.6637)
		Constant	6.186 (4.0966)	7.861 (3.6756)	5.499 (16.577)	9.1 (20.9732)
		Year dummy	Yes	Yes	Yes	Yes
		Sample selection term	No	Yes	No	Yes
	Instruments	Observations	349	349	GMM-sys 349	GMM-sys 349
		AR(1) test			−3.38***	−2.79***
		AR(2) test			0.64	0.16
		Sargan (χ^2)			10.12	3.95

Source: Authors' calculations.

Notes: Time dummies for years 2005 and 2007 to 2010 were significant in models (VII) and (VIII) but not in models (IX) and (X). Including GDP in the stringency equation does not qualitatively nor quantitatively change the results. The sample selection terms are significant in regressions (VIII) and (X). Standard errors in parentheses. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 7. Stringency—ECP (2015 \$US/tCO₂e).

Panel	Category	Variable	FE OLS (XI)	FE OLS, Heck (XII)	Syst GMM (XIII)	Syst GMM, Heck (XIV)
B—US States	Regulatory capture—X	ECP_{t-1}	1.042*** (0.0815)	1.038*** (0.0907)	0.88*** (0.0462)	0.903*** (0.0728)
		Power-Coal _t	−0.014* (0.0076)	−0.014* (0.0076)	−0.004 (0.0051)	−0.005 (0.0046)
		Power-Gas _t	−0.001 (0.0037)	−0.0014 (0.0037)	0 (0.0045)	0.001 (0.0066)
		Power-Oil _t	0.025 (0.0316)	0.027 (0.0349)	0.142*** (0.045)	0.137*** (0.0488)
		Industry, VA _t	0.018*** (0.0057)	0.018** (0.006)	0.011 (0.0072)	0.014 (0.0149)
		Trade Openness _t	0.032*** (0.0077)	0.032*** (0.0077)	0.006 (0.0132)	0.011 (0.0177)
	Macro(economic) environment—W	CO ₂ Em(Mt) _t	−0.025 (0.0254)	−0.024 (0.0265)	0.074 (0.0585)	0.079 (0.069)
		Constant	−0.573 (0.4375)	−0.577 (0.39)	—	—
		Time dummies	Yes	Yes	Yes	Yes
		Sample selection	No	Yes	No	Yes
		Instruments			GMM-sys	GMM-sys
		Observations	49	49	49	49
		AR(1) test			1.51	0.09
		AR(2) test			1.27	0.23
		Sargan (χ^2)			39.47***	18.62***

Source: Authors’ calculations.
Note: All year dummies are statistically significant at (at least) the 5% level in models (XI) and (XII). In models (XIII) and (XIV), year dummies 2010 and 2011 are not significant; all others are.
Standard errors in parentheses: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

estimated effect varies greatly across models (VII)–(X), with the largest effect is estimated in model (X), at about 10USD/tCO₂e. Finally, the effect of CO₂ emissions *per capita* is not clearly identified, being negative in models (VII) and (VIII) where estimates may suffer from simultaneity bias, and positive yet with weak statistical significance in models (IX) and (X).

Insights from panel B point to a similarly persistent stringency process, with a coefficient estimate for ECP_{t-1} of 0.90 in model (XIV). Estimates in models (XI) and (XII) are most likely severely biased due to the short time dimension of Panel B. The results also suggest that larger CO₂ emitters and more industrious (CO₂-intensive) US States had more stringent carbon pricing mechanisms. These effects are, however, not statistically significant when estimated with the GMM estimator.

6.3 Robustness checks and discussion

To test the robustness of our results, we perform a series of additional estimations. First, to address concerns that the coefficient estimates of eq. (1) may be biased due to correlation

between past residuals and current regressors, we repeat its estimation with a sample where, for each panel unit, the time dimension is (right)-curtailed at the year of policy adoption. That is, for each panel unit in which a carbon pricing scheme was introduced, we keep only one observation for which $\mathbb{1} = 1$. The results are qualitatively similar, although statistical significance of the estimated coefficients decreases. Second, we note that for eq. (1), i.e. regression models (I) to (VI), the results do not change qualitatively if we choose a different (meaningful) lag structure. In particular, they are robust to the use of one-period lagged values of the regressors. Third, it can be argued that, over the period considered, there exists a structural break in carbon pricing policy developments as many national jurisdictions introduced such policies after 2005. To test whether the dynamics presiding over these developments differ prior and after 2005, we re-estimate models (II) and (IV) over two different time periods: 1990–2004 and 2005–2015. For the period 1990–2004, the share of electricity generated from gas and oil is negatively associated with the probability of implementation of carbon pricing policies. Surprisingly, the share of electricity produced from coal seems to have a small positive—albeit statistically insignificant—impact. This may be driven by the fact that Denmark, which was in 1990 heavily reliant on coal for its electricity generation, managed to introduce a carbon pricing mechanism in 1992 (albeit with substantial sectoral exemptions and rebates). The more general observation that electricity generation from fossil fuels weighted negatively on carbon pricing policy developments may reflect the fact that until 2004, only northern European jurisdictions, which have achieved a lower share of electricity generated from fossil fuel over time, had introduced a carbon pricing scheme. In addition to this, the coefficient of *EU* is an order of magnitude smaller than in the full sample models. This is likely explained by the fact that carbon pricing activity took place in jurisdictions that were not EU members at the start of the scheme. Over the period 2005–2015, the results for these models indicate that EU membership was a much more significant determinant of the introduction of carbon pricing mechanisms. This echoes the fact that a lot of these jurisdictions' first carbon pricing mechanism was the EU-ETS. GDP *per capita*, institutional capacity and the level of democracy are both found to positively affect implementation over the period whereas the share of industry, CO₂ emissions *per capita* and the orientation of the executive with respect to economic policy have a negative impact on implementation. All coefficient estimates except those associated with GDP and the level of democracy exhibit, however, weak statistical significance.

We also checked whether the results were robust to the use of different indicators of democratic institutions, namely *Polyarchy* and *Libdem*, as well as with another indicator of governance, *Corruption*. Estimations of models (I) to (IV) with these variables provided very similar results, which is somewhat unsurprising given that these are highly positively correlated with our main indicator of democratic institutions ($\rho = 0.9$ and $\rho = 0.85$, respectively). Estimations with the (control of) corruption variable suggested that implementation of carbon pricing policies was more likely to occur in less corrupt jurisdictions. Finally, we repeated the estimation of regressions (VII) to (X) with a different version of our outcome variable in eq. (2), one where the weights are varying year-to-year. The results are, for all models considered, qualitatively similar.

7. Conclusion

Carbon pricing policies have re-emerged in the policy-making arena as potential tools to achieve (some) reductions in GHG emissions. This renewed political appetite for carbon

pricing mechanisms is apparent in the number of new schemes brought online over the last decade. However welcome these developments are, they should not be understood to mean that carbon pricing policies are on track to expand quickly to new jurisdictions nor to reach the stringency that achieving the Paris Agreement target requires. Indeed, this article shows that, when weighted for the share of covered emissions, these policies are, in most jurisdictions, much weaker than typically assumed. Moreover, because the jurisdictions with carbon pricing policies represent a small share of world emissions, the world average price of emissions remains extremely low, at about 1USD/tCO₂e in 2015. In light of the statistical results discussed in this study, this is an uncomfortable state of affairs. First, because structural political and economic forces continue to hinder the introduction of new schemes beyond jurisdictions for which the political and economic cost of pricing carbon is comparatively low. For example, carbon pricing is unlikely to appeal to jurisdictions with low GDP *per capita* and/or, oil-fuelled electricity generation, for which other domestic policies, possibly complemented by international technology and financial transfers would prove more palatable. Second, because all implemented schemes exhibit strong persistency in their stringency, which is particularly problematic given that most of the schemes introduced so far are associated with weak (average) price signals.

The present analysis does, however, also offer lessons—and cautious optimism—for future policy developments. First, even if such developments are hindered by political economy factors, their effect is not as strong as one might have initially expected and suitable policy designs have been found to overcome them. Nonetheless, the difficulty with which carbon pricing schemes can be introduced, together with the weakness of most existing ones continues to provide a rationale for the development of climate mitigation strategies with multiple GHGs abatement tools and stresses the need to carefully consider the private and public cost of (early) retirement of the existing capital stock. This also highlights the importance of the sequence of introduction of the climate change mitigation policy package. One way to weaken incumbents' lobbying power is to weaken their relative influence *prior* to the introduction of carbon pricing policies.

Second, even in the presence of other climate policies, this analysis suggests that there is room for further strengthening of carbon pricing mechanisms. This can be done through extension of coverage or a price increase in currently covered sectors. But when considering implementation or strengthening of carbon pricing schemes, jurisdictions ought to pay close attention to the factors discussed here as it may save them from spending time and political capital on policy proposals bound to be met by fierce opposition.

Supplementary material

[Supplementary material](#) is available on the OUP website. These are the data and replication files and the [online appendix](#).

Funding

This work was supported by the UK Economic and Social Research Council [grant number: 1621415].

Acknowledgements

The authors are grateful to the editor and two anonymous referees for their comments on an earlier version of this manuscript. All remaining errors remain the responsibility of the authors.

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