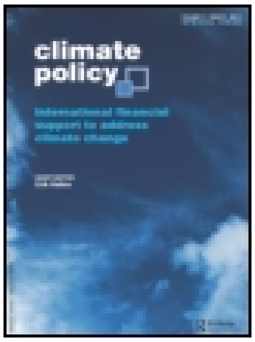

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Multi-level climate governance: examining impacts and interactions between national and sub-national emissions mitigation policy mixes in Canada

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ABSTRACT

Jurisdictions use an assortment of policies to reduce greenhouse gas emissions. Climate policy mixes have often evolved through the ad hoc layering of new policies onto an existing policy mix, rather than deliberate design of a complete policy portfolio. This can lead to unanticipated interactions between policies which can support or undermine policy objectives and is further complicated where climate policy is implemented at multiple jurisdictional levels. In the context of Canada and its four most populous provinces, we examine the development of climate policy mixes across jurisdictional levels between 2000 and 2020 and evaluate policy interactions. We develop an inventory of 184 climate policies, and examine each in terms of instrument type, implementation timing, technological specificity, and expected abatement. We evaluate interactions between overlapping policies both within jurisdictional levels (horizontal) and across jurisdictional levels (vertical) for their impact on emissions abatement using a policy coherence analysis framework. We find that subsidies and R&D funding were the most abundant policies (58%), although pricing and flexible regulation are expected to achieve the most abatement. Sub-national jurisdictions have often acted as policy pilots preceding federal policy implementation. We evaluate 356 policy interactions and find 74% are consistent in adding abatement. Less than 8% have a negative impact by reducing abatement, although vertical interactions between federal and provincial policies were more often negative (11%) than horizontal interactions at the federal (<3%) or provincial (<2%) levels. Although the impact of many interactions is unknown (13%), we generate interaction matrices as a foundational roadmap for future research, and for policy-makers to consider potential interactions when designing and assessing policy effectiveness.

Key policy insights:

- Climate policy mixes have expanded and diversified over the period 2000–2020 across jurisdictions in Canada.
- Sub-national jurisdictions have often acted as policy ‘pilots’ by implementing policy before the adoption of similar national level policy.
- Climate mitigation policy interactions are predominantly supportive toward achieving additional emissions abatement.
- Vertical interactions between federal and provincial policy can undermine the additionality of policy effort by sub-national jurisdictions.
- These findings emphasize the need for better coordination in climate policy mix design between national and sub-national jurisdictions.

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1. Introduction

To limit the impacts of climate change and achieve targets set out in the Paris Agreement (2015), the Intergovernmental Panel on Climate Change (IPCC) suggests greenhouse gas (GHG) emissions must be halved by 2030 and reach net-zero by 2050 (IPCC, 2018). In pursuit of this goal, national and sub-national jurisdictions are implementing a mix of policy instruments including technology mandates, performance standards, command-and-control regulations, carbon pricing, subsidies, information campaigns, and research and development (R&D) funding (Nascimento et al., 2021). While economists emphasize the economic efficiency of carbon pricing to reduce emissions, alternative instruments may be preferred by policymakers seeking to achieve multiple objectives, such as distributional equity, technological change, and political acceptability, in addition to reducing emissions (Axsen et al., 2020; Goulder & Parry, 2008). However, climate policy mixes have evolved over decades, often through the ad hoc layering of new policies onto an existing policy mix, rather than deliberate design of a comprehensive policy portfolio (Howlett & Rayner, 2013a).

The use of multiple overlapping policies can support or undermine policy objectives (Andonova et al., 2017; Fankhauser et al., 2010). Accounting for interactions is a particular challenge in cases of multi-level governance, including federations like Canada and the United States (US) where climate policy is implemented at both national and sub-national levels, known as *vertical policy interactions* (del Rio & Howlett, 2013; Howlett & del Rio, 2015). Interactions across (vertical) and within (horizontal) governance levels can affect the ability of a policy mix to achieve its objectives.

Considering the range of instruments used in a policy mix and how they interact is, therefore, critical to understanding their effectiveness in reducing emissions. Yet research tends to focus on individual instruments, with comparatively little research on the development and composition of policy mixes used in practice. While the area has received greater attention in recent years, policy mix literature is largely composed of conceptual analyses with limited empirical work (Howlett & del Rio, 2015; Schmidt & Sewerin, 2019).

As jurisdictions seek to ratchet-up measures in pursuit of deep decarbonization, it is important to understand the range of policy instruments used and how they interact to support or undermine policy objectives. This study contributes to the growing literature on climate policy mixes by providing empirical analysis examining the development and interaction effects of policy mixes across governance levels on emissions abatement. This was applied in the context of Canada and its four most populous provinces. Specifically, this study answers the following questions:

(i) How has the composition of instruments in climate policy mixes evolved over time?
(ii) What is the expected GHG abatement contribution of different elements of the policy mix?
(iii) Which policy interactions are expected to support or undermine emissions abatement?

2. Background

Over the last decade, climate governance discourse has shifted emphasis from top-down prescriptive policy to a more poly-centric approach across governance levels, including both state and non-state actors (Hale, 2016; Jordan et al., 2015; Rayner, 2010). The effectiveness of this multi-level governance approach to mitigation depends on the two-way exchange where sub-national action can help drive national policy and top-down policy can empower sub-national actors (Corfee-Morlot et al., 2009). In North America, sub-national jurisdictions have been early actors on climate policy, such that their effort has the potential to achieve large portions of national climate targets (Hultman et al., 2020; Kuramochi et al., 2020). Sub-national jurisdictions may also act as policy pilots where heterogenous climate policy across jurisdictions act as experiments to demonstrate the effectiveness of policy approaches. For example, California is recognized for pioneering climate policies that have subsequently driven US federal policy (Mazmanian et al., 2020; Shobe & Burtraw, 2012). The contributions of sub-national actors may therefore take forms other than direct abatement by supporting decarbonization through scaling and entrenchment of sub-national efforts (Bernstein & Hoffmann, 2018; van der Ven et al., 2017). This has contributed to a complex policy mix across governance levels working to mitigate climate change.

Among the limited empirical literature on climate policy mixes, most research has focused on *policy output* (i.e. the number and design of policies) rather than *policy outcomes* (i.e. emissions abatement). This has led to the evaluation of policy mixes using simple metrics such as *policy density*, the number of policy instruments in place (Kern et al., 2017).

However, more policies do not necessarily translate into greater emissions reductions due to differences in compulsoriness of policy types (e.g. information campaigns versus regulations), coverage, stringency (magnitude of change required), and exemptions (Lieu et al., 2018). A recent study by Nascimento et al. (2021) examined climate policy mixes across G20 countries from 2000 to 2019 to identify sectoral coverage and gaps, however it does not consider important dimensions of the policy mix such as stringency, sub-national efforts, or interactions between policies.

The layering of additional policies onto an existing policy mix can support or undermine achievement of the same objective (i.e. emissions abatement) known as *policy consistency,* or alternative policy objectives known as *policy coherence* (Howlett et al., 2006; Nilsson et al., 2012). For instance, policy interactions can also impact energy security, employment, economic competitiveness, health, food security, water quality, and biodiversity conservation (Somanathan et al., 2014).

Emerging research on policy interactions tends to focus on the optimal design of a policy package to maximize synergies and avoid trade-offs (van den Bergh et al., 2021). However, policy mixes in practice are rarely conceptualized and implemented as a package but rather evolve over time as policies are added in light of new information or priorities, known as *policy patching* (Howlett & Rayner, 2013b; Kern et al., 2017). For instance, policy patching can be used by sub-national jurisdictions to address emissions pathways that national jurisdictions have failed to regulate.

Empirical examination of the outcomes of interactions within complex policy mixes is further complicated in federations where multiple jurisdictional levels seek to reduce emissions. While interactions are generally expected to be supportive, they can also undermine policy objectives (Hale et al., 2021; Hsu et al., 2020) Previous research has highlighted important vertical climate and energy policy interactions within the European Union and its member states as well as between US state and federal policies (Antonioli et al., 2014; del Río González, 2007; Goulder et al., 2012; Sijm, 2005). For example, Goulder et al. (2012) demonstrate how emissions reductions from stringent vehicle emissions standards imposed by California and other states are effectively undermined by federal fuel economy standards. Whether the sub-national climate policy effort acts as complement or substitute to federal action remains under debate (Andonova et al., 2017). This added dynamic of *vertical interactions* where the same problem – and in some cases the same emissions pathways – are regulated at multiple levels can pose a particular challenge when governance levels prioritize alternative policy objectives (del Rio, 2011). In contrast, *horizontal interactions* refer to interactions between policies at the same governance level. For example, a clean electricity standard that reduces emissions intensity of the electricity sector can increase the effectiveness of a zero-emission vehicle (ZEV) sales mandate, which incentivizes the adoption of electric vehicles. This multi-level governance approach to climate mitigation highlights the need to better understand policy dynamics across governance levels and the extent to which interactions may support or undermine policy goals (Andonova et al., 2017; Hale et al., 2021; Hsu et al., 2019; Rogge et al., 2017)

This study contributes to this gap in the literature by examining the temporal development of sub-national climate policy mixes in parallel with national policy, to better understand the extent of policy overlap, the role of policy diffusion, and the expected interaction effects between national and sub-national policy to identify whether they act as complements or substitutes. For the purposes of this study, we focus on how each interaction affects emissions abatement as the primary goal of climate mitigation policy (i.e. policy consistency). However, climate policies may be chosen based on how they contribute to other objectives (i.e. policy coherence). Considering interactions across a range of objectives represents an important area for further research.

3. Context: climate change mitigation policy in Canada

As an illustrative example of multi-level climate governance, this study focuses on climate policy in Canada, both at the federal level and among the four most populous provinces. Canada represents a compelling jurisdiction to study climate policy mixes across governance levels as a high-emitting country where heterogenous sub-national effort has preceded increased federal climate policy ambition. Canada is an emissions intensive country with the 7th highest emissions per capita globally in 2018 (World Bank, 2022). The country is a federation of provinces in which jurisdiction for environmental policy is divided between both the federal and provincial levels (Becklumb, 2019). This study focuses on the federal level and the provinces of Alberta, British Columbia, Ontario, and Quebec, which are the largest in terms of population and economic activity and together account for over 80% of the country's emissions (ECCC, 2020).

In addition, they reflect a range of economic structures, access to energy resources, political ideologies, and climate policy effort. For example, Alberta is home to significant oil and gas reserves on which it relied for nearly 25% of GDP and 10% of government revenue in 2019 (Cosbey et al., 2021). In contrast, both British Columbia and Quebec are endowed with extensive hydro resources which allow for near zero-emission generation of electricity (Government of Canada, 2021). This results in a wide range of per capita emissions, with Alberta accounting for 63 tonnes of carbon dioxide equivalent (t CO_2e) per person annually compared to 5.7 t CO_2e in Quebec, 12.8 t CO_2e in British Columbia, and 19.1 t CO_2e in Ontario (ECCC, 2020).

As a large country with diverse sub-national regions, action on climate has historically been characterized by a fragmented regional approach with varying degrees of effort and stringency. Harrison (2023) identifies three distinct phases of climate policy development in Canada: (i) from 1990 to 2006, a 'joint decision trap' where consensus was sought and the provinces with the least climate ambition vetoed any stringent national policy; (ii) from 2007 to 2015, a period of provincial innovation and diffusion where certain provinces filled a climate leadership vacuum at the federal level with ambitious and novel climate policy, while other provinces lagged; and (iii) from 2016-present, where federal climate policy prevailed. In recent years, the federal government has sought to advance and harmonize climate policy across the country. For example, in 2018 the federal government mandated carbon pricing, with a back-stop carbon price to be imposed on provinces who failed to implement their own policies to meet the national benchmark stringency level. The constitutionality of the federal government's ability to impose a carbon price on provinces was challenged by multiple politically opposed provinces, including Alberta and Ontario, and was upheld in a ruling by the Supreme Court of Canada (2021).

Institutions to improve coordination between federal and provincial climate policy have been developed. Notably, the Pan-Canadian Framework on Clean Growth and Climate Change was developed between the federal and provincial and territorial governments, and nine federal-provincial-territorial ministerial tables were established to deliver and report on the framework's measures as well as through the Canadian Council of Ministers of the Environment (Government of Canada, 2016). However, a report by Canada's auditor general found insufficient coordination within and between levels of government on climate action, concluding that it may contribute to inefficient and ad-hoc policy implementation (Canada, 2018).

Despite recent efforts, Canada has failed to achieve the country's mitigation targets, most recently failing to reduce emissions 17% below 2005 levels by 2020 (ECCC, 2021). In the Paris Agreement (2015), Canada committed to reduce emissions 30% below 2005 levels by 2030 and announced a more ambitious target in 2021 of 40–45% below 2005 levels by 2030 (Canada, 2021a). However, emissions trajectories have differed across regions and sectors, where Ontario has seen the greatest proportional decrease in emissions as a result of a phase-out of coal-fired electricity (falling 22% between 2000 and 2020) while Alberta has experienced continued emissions growth driven by expansion of the oil and gas sector (increasing 21% from 2000 to 2020) (ECCC, 2020). As the nation seeks to increase efforts to reduce GHG emissions, it is important to take stock of the development of climate policy mixes to date and to evaluate the ways in which overlapping policies may support or undermine emissions abatement.

4. Methods

To examine climate policy mix development across jurisdictional levels and understand how interactions support or undermine emissions abatement, this study adopts a policy coherence analysis framework adapted from Nilsson et al. (2012). Our analysis proceeds in three stages. First, we develop an inventory of policies in each jurisdiction between 2000 and 2020. Second, we examine policies across a range of attributes using policy content analysis to understand their design and implementation. Third, we evaluate interactions between overlapping policies, both within jurisdictional levels (horizontal interactions) and across jurisdictional levels (vertical interactions), for their impact on emissions abatement using policy coherence screening matrices.

4.1. Policy inventory

Although climate change is impacted by a myriad of policies across sectors, our study limits consideration to policies self-identified by governments, with the main objective of mitigating GHG emissions. Notably, this excludes policies that directly contradict this objective, such as subsidies for oil and gas development, as well as those that indirectly support the objective, such as gasoline taxes which represent fairly well understood interactions (Goulder, 2013). We also limit the analysis to policies implemented during the period 2000–2020, as this period represents the most significant climate policy development efforts.

We obtained basic policy data (e.g. name, description, sector, and instrument type) from national biennial reports to the United Nations Framework Convention on Climate Change (UNFCCC). We identified 184 policies across the five jurisdictions after removing duplicates and policies that were never implemented, but included policies that were implemented and later cancelled.

4.2. Individual policy evaluation

We used content analysis to characterize individual policies in terms of their design and expected impact on reducing GHG emissions according to four main attributes: instrument type, implementation timing, technological specificity, and expected abatement.

4.2.1. Policy instrument types

Policies were classified as one of five types of instruments: (i) economic (which include subsidies for R&D, production, and consumption), (ii) information, (iii) carbon pricing, (iv) performance standards, and (v) command-and-control regulations. These categories were adapted from the IPCC (Somanathan et al., 2014), with two modifications: we distinguish the category of performance standards from ‘regulations’ to reflect the hybrid instrument design of *flexible regulation*s that combine attributes of command-and-control regulations and carbon pricing by including tradeable compliance credits (Rhodes et al., 2021), and we distinguish carbon pricing (including both carbon taxes and cap-and-trade) from subsidies as economic support instruments that are applied as ‘sticks’ rather than ‘carrots’.

4.2.2. Implementation timing

When policies were implemented and for how long provides insight into first movers and trends in climate policy adoption. We used UNFCCC and supplementary government policy documents to identify implementation timing for mandatory policies. This allowed us to generate a timeline of the mandatory policy mix in each region, similar to the approach taken by Kern et al. (2017) (see Figure 1).

4.2.3. Technological specificity

Climate policies vary in the specificity with which they are applied, ranging from broad-based policies that cover the entire economy to those targeting specific projects. Economists typically favor economy-wide policies, such as carbon pricing, to allow for equal marginal compliance costs across sectors to maximize economic efficiency (i.e. polluters in each sector face the same cost to emit an additional ton). More specific policies alter the incidence of costs across sectors and technologies; however, some have argued that more specific policies are easier to implement for political economy reasons (Cullenward & Victor, 2020; Fox et al., 2017; Long et al., 2020). We classify policies according to five degrees of specificity:

(1) Project – target a specific project (e.g. funding for the Boundary Dam Carbon Capture and Storage facility).
(2) Technology – target a specific technology as a solution (e.g. electric vehicle rebates).
(3) Class – target a class of solutions capable of achieving the desired outcome (e.g. support for renewable electricity which may be solar, hydro, or wind).
(4) Sector – target a specific sector to achieve a level of performance but are neutral in terms of the technology used to achieve the outcome (e.g. low carbon fuel standard in transportation).
(5) Multi-sector – apply across technologies and sectors (e.g. carbon taxes).

4.2.4. Expected abatement

Evaluating the expected emissions reductions of individual policies in a robust and comparable way across policies and jurisdictions remains a challenge. There is inevitably a high degree of uncertainty due to a range of

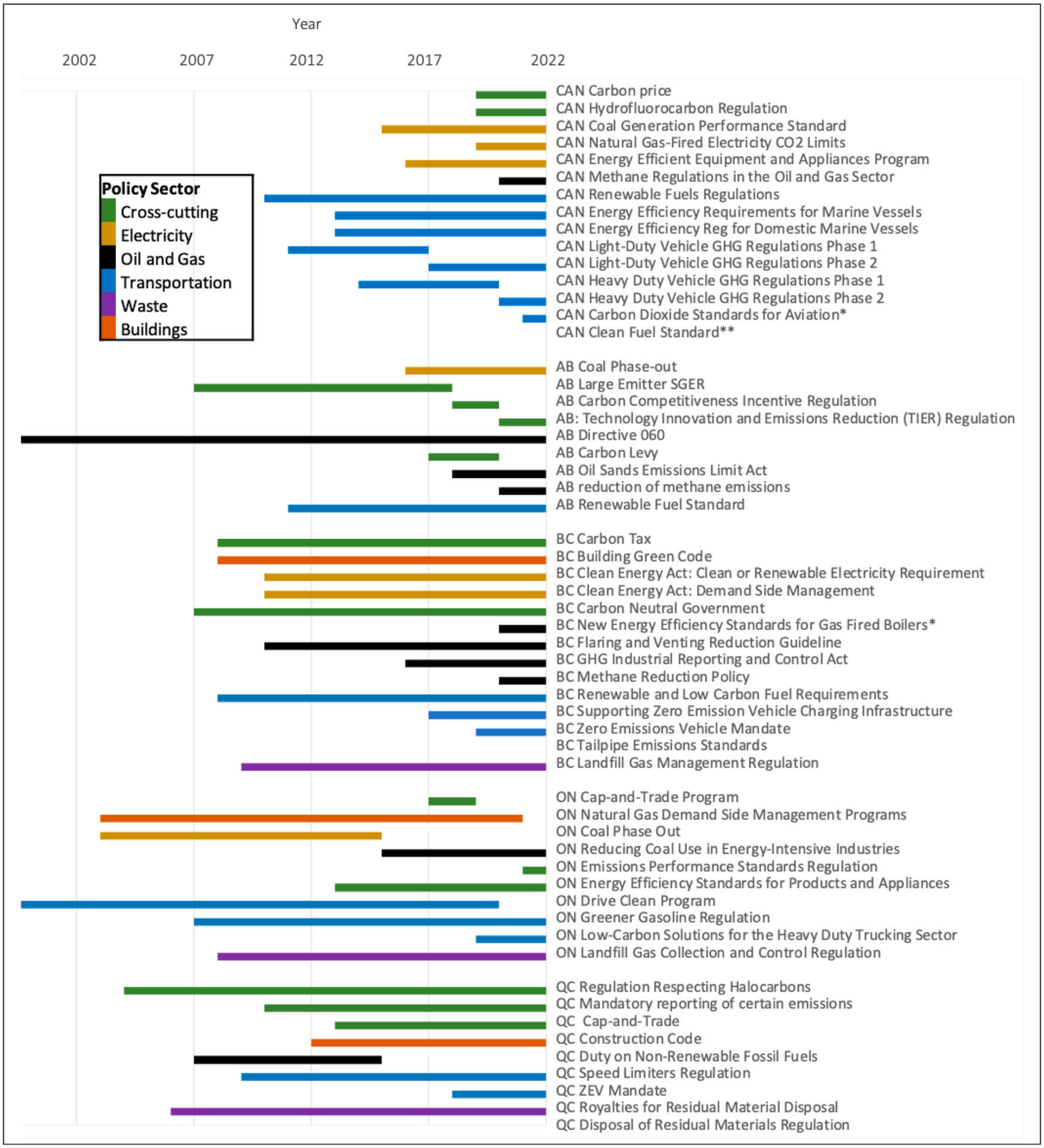


Figure 1. Timeline of mandatory policy implementation.

assumptions, including macro-economic fluctuations, resource price shocks, and rates of technological change in different modelling tools. Therefore, to apply a consistent approach, we compare modelled estimates of emissions abatement by policy in 2020 and 2030 relative to business-as-usual according to Canada's biennial reports to the UNFCCC which apply the E3MC model by Environment and Climate Change Canada[1] (ECCC, 2019).

We focus our analysis on the 61 policies identified as mandatory policies which include carbon prices, performance standards, and command-and-control regulations, for which modelled contributions to emissions

[1]Additional detail on Canada's modelling approach can be found in BR4 Annex II (A2.7.2), available from https://unfccc.int/documents/209928.

abatement are reported. Subsidies, information programmes, and R&D funding were excluded due to their non-compulsory nature and the lack of quantitative assessments of expected emissions reductions.

4.3. Assessment of policy interactions

To examine interactions between policies, we apply a policy-analytical framework to evaluate interactions through a screening matrix of all potential pairwise interactions (Nilsson et al., 2012). We build on the approach of Nilsson et al. (2012) to score each interaction according to the expected impact of one policy on the emissions abatement performance of another based on a review of available literature. This allows us to identify expected interactions across existing policy mixes and highlight less understood interactions for future research.

Using the policy inventory described in Section 4.1, screening matrices were constructed for each province with the identified mandatory policies active in the jurisdiction across both axes, including sub-national and national policies (see Figure 3). We limit the analysis of interactions to mandatory policies (carbon prices, performance standards, and command-and-control regulations) that are currently implemented or have a scheduled start date to maintain a feasible scope.

In each cell, interactions were classified by the authors according to how the implementation of the row policy is expected to impact the performance of the column policy in terms of emissions abatement, following an interaction evaluation approach similar to Howlett and del Rio (2015) (see Figure 3). This allows for examination of both horizontal interactions within a jurisdictional level and vertical interactions between national and sub-national jurisdictions. This scoring approach builds on the work of Howlett and del Rio (2015) by expanding their four classifications to include 'redundant' interactions. Their classifications of strong conflict, weak conflict, complementarity, and synergy align closely with our definitions of counter-acting, constraining, consistent, and reinforcing, respectively (see Figure 3 legend). We introduce 'redundant' interactions to reflect how a policy may not contribute additional abatement, but may be desirable as a 'back-stop' in case another policy is removed or fails (Levinson, 2012).

We classified interaction based on a review of 84 studies of climate policy interactions from a focused literature review. The review was conducted using the policy instrument types and 'interaction' as keywords in Scopus. Initially, 498 studies were identified and screened for those that evaluate the abatement of each policy alone and two policies in combination. There were limited examples where interactions within the jurisdictions of interest were explicitly examined (Axsen et al., 2020; Bhardwaj et al., 2020; Rivers & Wigle, 2018). We therefore performed scoring based on empirical or theoretical research focused on similar policy interactions in other jurisdictions which were deemed applicable based on the authors' judgement. For example, Jenn et al. (2019) demonstrate how US vehicle emissions standards overvalue the emissions intensity reduction from electric vehicles such that the implementation of ZEV sales mandates at the state level can lead to an increase in emissions by reducing the stringency of the vehicle emissions standard on the rest of the vehicle fleet. This translates directly to the Canadian context where federal vehicle emissions standards and provincial ZEV sales mandates in British Columbia and Quebec are harmonized with the design of US policies.

While individually modelling all 1371 pairwise interactions could more robustly assess the mitigation impact of policy interactions, this represents an enormous undertaking. The screening matrix approach employed in this study, although far from comprehensive, provides a qualitative overview of expected interactions and highlights key trends and interactions that merit further research.

5. Results and discussion

5.1. Policy inventory

In total, 184 climate policies were identified across jurisdictions between 2000 and 2020. The federal government implemented the greatest number of policies with 67 (36% of the total). The distribution of policies by jurisdiction and type can be seen in Table 1. Among provinces, Quebec had the most policies followed by British Columbia and Ontario, while Alberta had the fewest.

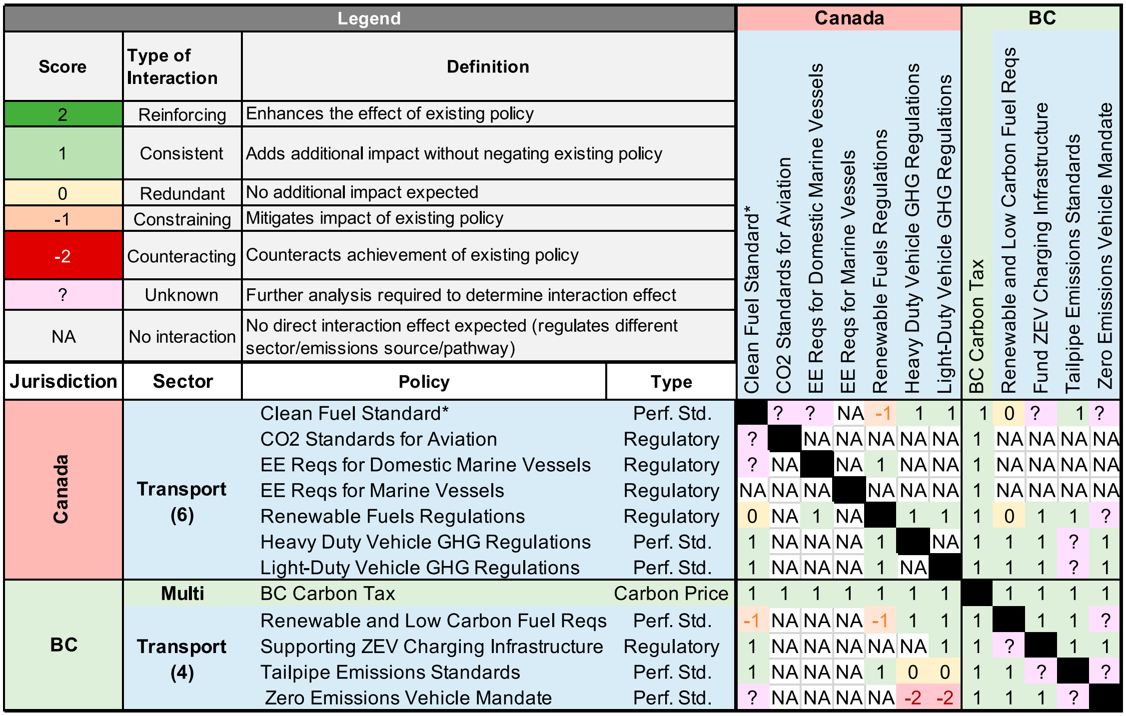


Figure 3. Subset of policy interaction matrix for emissions abatement through British Columbia and Canadian federal climate policies targeting transportation.

Economic policies, including subsidies and R&D funding, were the most abundant with 106 policies (58%). This is likely due to the political popularity of economic support policies and that they often have pre-determined end dates (Rhodes et al., 2017; Tobler et al., 2012). The finding that command-and-control regulatory policies were more common than tradeable performance standards and carbon pricing also supports previous findings by Rabe (2008), which suggested that market-based policies preferred by economists may be less politically feasible than other policy types. However, our findings in Section 5.2 suggest that these market-based policies are expected to contribute the most to abatement, despite their relatively small number.

Importantly, these totals reflect the number of policies that have been enacted, but not all policies are maintained in perpetuity. Figure 1 shows a policy timeline, including the start and end periods for mandatory policies. This figure demonstrates how sub-national climate policy has often preceded national policy. Alberta was an early actor regulating flaring and venting in the upstream oil and gas sector from 1999, as well as the nation's first carbon price in the form of the *Specified Gas Emitter Regulation* in 2007.

Evidence from Canada's experience with carbon pricing, low-carbon fuel standards, and methane regulations finds that the successful implementation of sub-national policies often precedes uptake of policies at the national level. This supports previous research highlighting the important role of sub-national jurisdictions as policy pilots and the opportunity for policy scaling (Bernstein & Hoffmann, 2018).

Table 1. Description of policy inventory (2000–2020).

Instrument type	AB	BC	Canada	ON	QC	Type total
Carbon price	4	1	1	1	2	9
Economic	5	17	43	15	26	106
Tradeable Perf. Std.	1	6	5	1	1	14
Information	0	0	5	0	2	7
Regulatory	5	11	13	12	7	48
Jurisdiction total	15	35	67	29	38	184

While provincial policy preceding federal action is the norm, the reverse can also be seen with British Columbia developing its own vehicle emissions standards despite the existence of a federal policy. This may be due to the province seeking to push federal policy to be more stringent, as with California in the US (Mazmanian et al., 2020).

The timeline also highlights inconsistency in mandatory climate policy, with cancellations and alterations particularly common in Alberta and Ontario following changes in government. This lack of policy predictability can impede the ability of businesses and consumers to make informed investments and reduce the effectiveness and economic efficiency of the policy mix (Brunner et al., 2012).

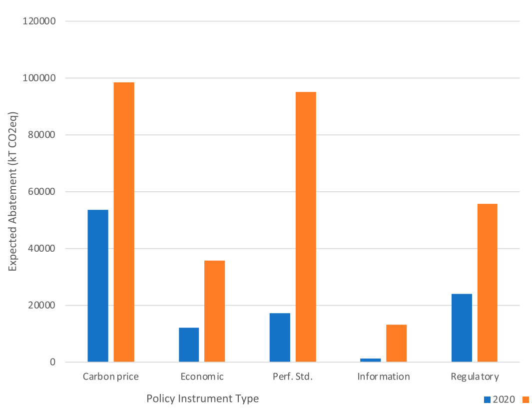
5.2. Abatement potential of individual policies

Based on our calculations from Canada's reporting to the UNFCCC, an increasing share of emissions reductions are expected to come from non-pricing policies, with tradeable performance standards increasing from 15% in 2020 to 31% in 2030 (see Figure 2(a)). The increased reliance on performance standards may be due to the relative popularity of the policy instrument in comparison to carbon pricing (Rhodes et al., 2017).

We find an increasing reliance on policies implemented at the sectoral level, with expected abatement from sector-level policies to increase by more than 3.5 times between 2020 and 2030 and exceed multi-sector policies (see Figure 2(b)). This might reflect a policy strategy that seeks to minimize opposition through more targeted intervention, despite the economic efficiency benefits of broad-based policy (Cullenward & Victor, 2020). However, since these abatement estimates were reported in 2019 (ECCC, 2019), the Canadian federal government announced intentions to increase the national carbon pricing benchmark to C$170/t CO_2e by 2030, which may significantly alter the estimated abatement by policy type and specificity for 2030 (Canada, 2021b).

We also note a decrease in expected abatement from policies at the level of class (i.e. renewables) which may reflect a trend to move toward performance-based policies. For example, there are clear benefits in terms of efficiency and innovation in the shift from a renewable fuel standard, which mandates a quantity of biofuel to be blended in transportation fuels, to a low carbon fuel standard, which requires the fuel supply achieve a specified emissions intensity (Holland et al., 2009).

Evidence across jurisdictional levels shows a greater variety of instrument types and increased reliance on sectoral level policies for emissions abatement. Corresponding to the increasing urgency to reduce emissions, this represents an 'all-hands-on-deck' approach to mitigation where policies are applied across multiple sectors and jurisdictional levels and may involve strategic *policy patching* to identify additional opportunities for abatement (Hale, 2016).



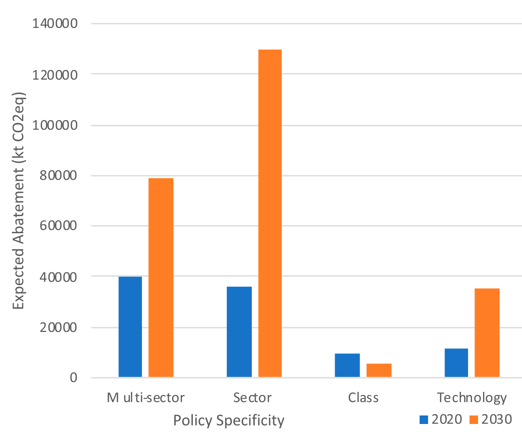


Figure 2. (a) Expected emissions abatement by policy type across all jurisdictions; (b) Expected abatement by policy specificity. Source: Authors calculation based on Canada's biennial reporting to the UNFCCC (ECCC, 2019).

5.3. Policy interactions

The screening matrix approach allows us to generate a map of expected climate policy interactions across jurisdictional levels. Considering only mandatory climate policies in place or with a starting date, we identify 1371 potential policy interactions. From this, we exclude interactions where one policy is not expected to directly alter the outcome of another policy in terms of emissions abatement, for example, by regulating different emissions pathways in different sectors (e.g. a ZEV sales mandate is unlikely to interact with methane flaring regulations). This leaves 356 identified interactions, which are analyzed here. Figure 3 provides a sample interaction matrix reflecting transportation policies in British Columbia. The complete matrices can be found in the Supplementary Material.

Of the analyzed interactions, 74% are expected to be consistent, meaning that they add additional abatement without negating the impact of the other policy. Only 26 interactions, less than 8% of those considered, are expected to have a negative impact (redundant, constraining, or counteracting) which largely occur through vertical interactions and interactions with Quebec's cap-and-trade programme. However, the literature on many policy interactions remains scant, and 13% are classified as unknown and require additional policy detail or modelling to understand the nature of the interaction. This supports previous work that suggests policies at the national and sub-national level are expected to be largely complementary (Hale et al., 2021; Hsu et al., 2020). However, it highlights a need to better understand the cases in which negative interactions occur.

Across jurisdictional levels, vertical interactions between federal and provincial policies are more often found to be redundant, constraining, or counteracting (11%) than horizontal policy interactions at the federal (<3%) or provincial (<2%) levels (see Figure 4). This highlights the existing gap in considering interactions during the design and implementation of climate policy and the importance of working across governance levels to ensure policies are mutually supportive.

Provincially, Quebec had the highest proportion of negative interactions (19%) due to how policies interact with the province's cap-and-trade programme. Additional policies interact differently with quantity-based instruments (i.e. cap-and-trade) than with price-based instruments (i.e. carbon tax). In theory, a cap sets a limit on the total emissions from regulated sectors and allows firms to trade emissions allowances so that the least expensive abatement options can be realized (OECD, 2011). When an additional policy is applied to a sector covered by the cap, it is unlikely to generate additional abatement because the total limit on emissions set by the cap is unchanged. Instead, it may either be redundant if less stringent, or increase total policy costs while artificially depressing cap-and-trade allowance prices if more stringent (Levinson, 2012; Rosendahl, 2019). This has important implications for policy equivalence across jurisdictions such as in comparing how provincial carbon pricing policies stack up against the federal benchmark.

In contrast, additional policy is expected to be complementary with a price-based instrument such as the federal carbon levy in Alberta and Ontario or British Columbia's carbon tax, since the price incentive for abatement at the margin remains, regardless of the other policies put in place. For example, gasoline supplied in British Columbia faces cumulative compliance costs imposed by both the carbon tax and the low carbon fuel standard, creating a greater incentive for emissions reduction than either policy alone (Axsen et al., 2020).

Interactions classified as synergistic, where the addition of a policy enhances the effect of existing policy, occurred primarily through policies that decarbonize electricity generation and policies that encourage electrification or reduce electricity demand. For example, in British Columbia, a clean electricity standard is in place to reduce the emissions intensity of electricity production, which further enhances the impact of the province's ZEV sales mandate and which incentivizes the electrification of road transportation. This highlights an important avenue for decarbonization effort where policies can have an outsized benefit when used in combination.

There are 16 policy interactions identified as redundant overall, which largely occurs through vertical interactions between federal and provincial policies. Several policies such as renewable fuel standards, low carbon fuel standards, and vehicle emissions standards exist in similar forms at both the federal and provincial levels. When these policies are quantity- or intensity-based, the provincial policy is unlikely to create any additional emissions reductions at the national level, but simply shift emissions and costs between provinces. This occurs because more stringent provincial policies effectively relax the standard applied to the rest of the country by the federal policy (Goulder & Stavins, 2011). This has been shown to be the case in the US where

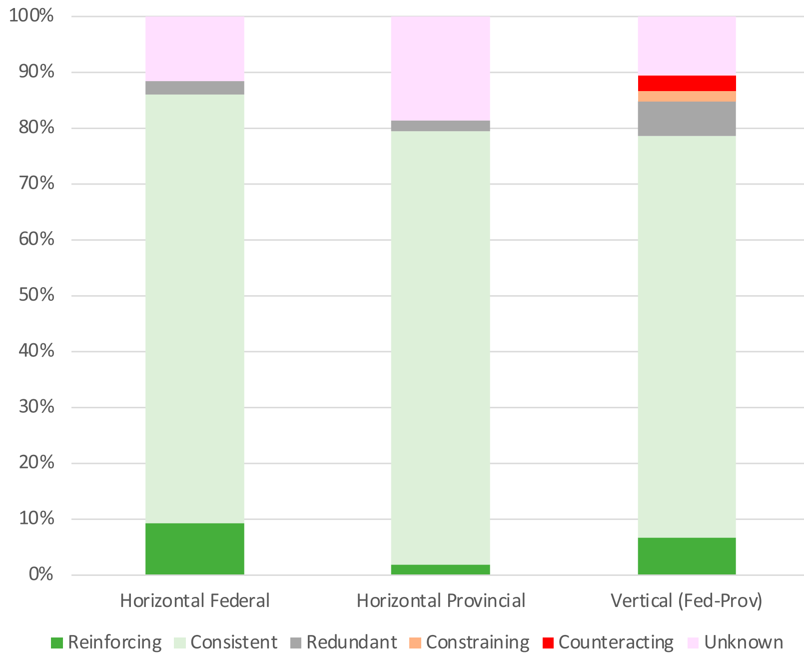


Figure 4. Interaction scores by jurisdictional level.

stringent vehicle emissions standards in California allow more emissions-intensive vehicles to be sold in other states while still meeting the federal standard (Goulder et al., 2012). In this way, federal policy may undermine sub-national effort by netting out any additional mitigation from stringent provincial policy and simply shifting emissions and costs between sub-national jurisdictions. This may represent a trade-off between the potential for provincial policy to catalyze national efforts with the potential for national policy to undermine the additionality of provincial policy. This also presents a challenge in attributing mitigation effort between jurisdictions where overlapping policy occurs.

5.4. Limitations

Many types of policy can impact the ability of a jurisdiction to achieve their climate goals which are not considered in this study. For example, gasoline excise taxes can support abatement while fossil fuel subsidies can undermine abatement. We also do not consider the extent to which policy interactions may impact objectives other than emissions abatement (i.e. efficiency, equity, innovation). This study does not examine interactions across other jurisdictional levels such as municipal policy, which can have significant impact on emissions through interventions such as land-use planning, public transportation systems, and building codes (Jaccard et al., 2019).

6. Conclusion

This study examines the development of policy mixes across governance levels to evaluate the extent of policy transfer and overlap; it also evaluates the potential synergies and trade-offs that may arise from policy interactions. We develop an inventory of climate mitigation policies in Canada at the federal level and among the four largest provinces to examine the types of instruments, technological specificity, implementation timing, and expected abatement of policy mixes, and evaluate potential interactions between overlapping policies within and across jurisdictions using a policy coherence screening matrix.

Results show that climate policy mixes have expanded and diversified in terms of the policy instruments used across jurisdictional levels. While the frequency of economic and command-and-control policies correspond to previous research on their relative popularity, the majority of emissions reductions are expected to come from flexible regulations and carbon pricing policies. We develop a temporal map of climate policy mix development across jurisdictional levels and sectoral scope (see Figure 1). Evidence on implementation timing supports previous research that sub-national jurisdictions have often acted as policy pilots, allowing for successful policies to be scaled up to the national level. Our analysis of the interactions between climate policies suggests they are predominantly supportive (74%). Vertical interactions between national and sub-national policy are the most likely to be negative (11%), emphasizing the need for better coordination between jurisdictions in policy design. This may represent a trade-off between sub-national jurisdictions catalyzing national-level policy ambition with the potential for overarching national policy to undermine the additionality of provincial policy. Consideration of complementarity with the rest of the climate policy mix and coordination between the national and sub-national level is therefore critical to policy design.

This study produced novel screening matrices for expected policy interactions across jurisdictional levels. Future research could build on this work to evaluate unknown policy interactions identified in the policy matrices or could use energy-economic modelling to quantitatively assess policy interactions. This analytical approach could also be applied in other domains, such as looking at other types of policy or their impact on additional objectives such as air pollution, equity, or economic efficiency. Comparing policy mixes between jurisdictions with varying designs and stringency levels remains a challenge. This represents another priority area for future research, particularly as jurisdictions seek to impose border carbon policies to avoid inter-regional leakage and in evaluating requirements to meet benchmark policy levels, such as with Canada's approach to carbon pricing. Additionally, research on how actors and stakeholders interact within and across national and sub-national policymaking efforts could provide greater insights on the barriers to more complementary policy design. Finally, despite the expansion and diversification of climate policy mixes observed in this study, emissions in Canada continue to rise. Further examination of the role of different policies in achieving emissions reductions and the gaps that allow for continued emissions growth would be a valuable contribution.

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