# The short-run household, industrial, and labour impacts of the Quebec carbon market

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**Abstract**

Resistance to the implementation of greenhouse gas pricing policies comes in part from fears about the concentrated impacts on certain industries, certain regions, and on less affluent households. These distributional concerns are valid, and fair policy may accommodate some transitional measures to soften the impact of sudden policy changes. On the other hand, the carbon pricing policy recently instituted in Quebec, in partnership with California under the Western Climate Initiative, is relatively modest in price targets, gradual in implementation, and has the capacity to spend revenues on transitional and impact-mediating programs for the labour market and households. We analyze the expected short-run impacts of the policy, focusing on equity in three domains — the household income distribution, labour in different industrial sectors, and regional effects across Quebec's 17 administrative regions. For reasonable prices and pass-through levels, and modelling direct and indirect emissions, we bracket these impacts, finding modest effects in all cases. Generous permit handouts to incumbents are likely to result in some windfall profits. Quebec would benefit from greater transparency in the intended allocation of the Green Fund revenues. Overall, the policy appears tuned to provide a balance of price predictability, steady decarbonisation, and manageable transition costs but could likely be even more aggressive.

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## 1 Introduction

In January 2013 the government of Quebec launched a carbon market for greenhouse gas (GHG) emissions in the industrial, transportation, and residential sectors. This policy, known as the "Système de plafonnement et d'échange de droits d'émission de gaz à effet de serre du Québec," (SPEDE) is a centerpiece in Quebec's plan for meeting its climate mitigation goal of GHG emissions at 20% below 1990 levels by 2020[1] (Government of Quebec, 2013). It operates by requiring companies to buy permits for the emission of $CO_2$ and other climate-changing gases, and gradually reducing the number of available permits over time. Since unused permits can be traded, the system creates an incentive for emissions to be reduced in the areas of production where it is least costly to do so. If Quebec's new carbon market is successful, it would make the province an exception to the dangerous global trend of ever-increasing GHG emissions, and could provide a model for the majority of jurisdictions that currently lack meaningful climate mitigation policies.

While carbon pricing systems, including both carbon markets like the SPEDE as well as carbon taxes, are widely regarded as the most efficient means of cutting emissions, they can have undesirable effects on industry and households in distributional terms. Production costs for carbon-intensive industries can increase substantially in the short-run before the adoption of GHG abatement technologies can occur, and, depending on market conditions, firms either bear these costs or pass them on to consumers by raising prices. These costs are an important part of the carbon market mechanism, as they send a price signal to consumers to favour less carbon-intensive goods, and to producers to adapt to cleaner technologies. However, poorer households spend a greater share of their income on carbon-intensive goods such as energy, transportation, food, and shelter, and as a result carbon pricing systems such as Quebec's are regressive in the absence of coinciding transfer payments to lower-income households.

Similarly, there can be disproportionate impacts on industries that are most reliant on GHG intensive processes, and certain regions where these industries may be clustered. This impact is what in the long run will help shift these industries and the economy as a whole towards fewer GHG emissions, but in the short run it is important to identify the specific industries or areas which will have the most difficulty adjusting. This makes it possible to minimize labour losses via temporary subsidies, retraining programs, or

[1] A target of 20 percent below the 1990 emissions of 83.9 $MtCO_2e$ is a reduction of only 15 percent from the 2012 level of 79 $MtCO_2e$.

other tools to ease the transition. Any regressiveness or overly costly concentration of impacts on certain industries or regions are not inherent to the SPEDE, and can be avoided if the distributional impacts of the market are well understood.

Having undesirable distributional impacts can also undermine the political support needed to ensure the SPEDE can achieve its targeted GHG emissions reductions. While there are many factors and nuances that have impacted the effectiveness and longevity of these policies in practice, equity is one possible point of influence that can have an effect. Once implemented, past climate pricing policies have often become politically infeasible, with some having been repealed, such as Australia's carbon tax, and others weakened to the point where they are not able to yield substantial levels of emissions reductions, as with the European Union's cap-and-trade system (Rootes, 2014; Jegou and Rubini, 2011). Furthermore, Quebec is one of the only jurisdictions in North America that has adopted a carbon pricing policy, and the success of the SPEDE could provide impetus for other jurisdictions to adopt similarly stringent economy-wide climate policies that are needed to avoid catastrophic climate change (Purdon, Houle, and Lachapelle, 2014). Indeed, the political sustainability of any substantial carbon pricing scheme rests on its spread and eventual adoption by trading partners. These wider political ramifications provide an additional impetus to ensure relatively equitable distribution of impacts from the carbon market.

The objective of this paper is to analyze the short-run distributional consequences of Quebec's cap-and-trade program. While medium-to-long run assessments are also important for assessing the policy, the short-run is most relevant to distributional impacts because it is in this period, before substitutions to less GHG-intensive products and processes are available, that costs can be expected to be the highest. While some basic analyses of the distribution of the carbon market's impact have been conducted, no study with detailed information on the household, industrial, or geographic consequences has yet been performed for Quebec's SPEDE.

## 2 Literature Review

While economic analyses of carbon markets have typically focused on the relative efficiency of market mechanisms in reducing emissions, an increasing number of studies have focused their attention on the equity of GHG abatement policies. They assess the distribution of costs of these regulations across timescales, industrial sectors, regions, or household income levels in order to discern what groups in society might become vulnerable under new carbon pricing. In the absence of revenue recycling, these studies have found that lower income households are disproportionately affected by carbon pricing policies in the short run because they spend a larger share of their income on fossil fuels.

Carbon markets can have an equally distorted impact on industrial output and employment in the short run. In this respect, carbon intensive industries such as petroleum refineries, primary metal manufacturing or cement production usually face the largest costs and labour reductions. Finally, where there are regions in which these industrial facilities are concentrated, there can be a strong geographical gradient to the impacts. The objective of this section is to provide an overview of the methodologies and findings of past household and industry carbon pricing impact studies. While some of these analyses are theoretical, many address the distributional impacts of well-established GHG abatement programs like British Columbia's carbon tax or the European Union Emissions Trading System (EU ETS).

### 2.1 Model Design

A crucial aspect of determining the equity of effects from the carbon market are the assumptions made about the time scale under consideration. Many previous analyses have divided the effects into short-and long-run, with some also adding 'very-short run' and 'medium-run' categories. Ho, Morgenstern, and Shih, (2008) used all four timescale categories, and the framework describing their general assumptions and their effects is summarized in Table 1.

In their conception of the very-short run time scale for an analysis of the industrial impacts of a hypothetical pricing policy for the United States, Ho, Morgenstern, and Shih, (2008) assumed no behavioural responses to the new costs imposed by carbon charges. Thus, in this period before firms can adjust their prices, their profits fall by the total cost of the emissions used in production. As a result, none of the costs are passed through to consumers or downstream firms. In the next-longest time frame, the short-run, a variety of behavioural effects occur concurrently, as producers raise prices and as a reaction to this, households switch to less carbon-intensive goods or imports not affected by the policy. This reduces the overall demand for carbon-intensive goods, in turn reducing firm output and labour in those industries.

Various analyses have made different assumptions about the magnitude and timing of these short-run behavioural effects, and have employed different methodologies to calculate them. For example, Ho, Morgenstern, and

| | Very Short-Run | Short-run | Medium Run | Long Run |
|---|---|---|---|---|
| General Assumptions | No behavioural responses, & partial equilibrium | Behavioural reponses, & partial equilibrium | Behavioural responses, adjustable input mixes for firms, & some general equilibrium effects considered | Capital substitution & full general equilibrium effects considered |
| Firms Effects | Costs of inputs increase, cannot raise prices | Increase prices to account for higher production cost | Inputs shift towards less GHG intensive mixes where possible, reduces marginal cost | Capital reallocated within and between industries |
| | Reduced profits | Output falls due to decreased demand | Output changes according to relative effects of price change from input shifting and adjusted consumer demand | Output reduced in some industries, increased in others |
| | No labour changes | Labour reduction proportional to decrease in revenue | Possible labour rebound due to cheaper wages from previous reduced labour demand and relatively cheaper input mix | Possible labour rebound due to capital substitution |
| Consumer Effects | No change in prices | Reduced demand for carbon intensive products, shift towards substitutes and imports | Adjust demand for carbon intensive products relative to any further price changes | Household 'capital' adjustments such as a closer home or more energy efficient appliances |

Table 1: Framework for carbon market behaviour by firms and households across time-scales from Ho, Morgenstern, and Shih, (2008)

Shih, (2008) use input-output tables and price elasticities of demand for final outputs to calculate a partial equilibrium which considers how all four effects balance out. In order to estimate changes in output, they calculate demand elasticities by simulating an aggregate economic model under constrained conditions. Multiplying these elasticities by the percentage increase in production costs (which is assumed to be passed on fully to consumers) yields the percentage decline in output. A similar approach is taken by Morgenstern and Moore, (2011) for an analysis of California's carbon pricing policy, and by Choi, Bakshi, and Haab, (2010) for a hypothetical analysis of a U.S. wide policy. In a study on the industrial impacts of EU's Emissions Trading Scheme (ETS), Reinaud, (2005) creates two pricing scenarios for firms in response to the ETS rather than assuming all costs will be passed on, and estimates the corresponding changes in consumer demand and output based on price elasticities of demand. In terms of household analyses, Grainger and Kolstad, (2010) also make similar assumptions and use both input-output tables and price elasticities of demand for their hypothetical U.S.-wide analysis, while Congressional Budget Office, (2009), in an analysis of a previously proposed U.S.-wide policy and Siriwardana, Meng, and McNeill, (2011), in an analysis of Australia's carbon tax, have similar assumptions but use pre-established models rather than primary analysis of input-output tables to calculate effects.

However, many studies consider only a subset of the short-run effects. For example, in their study on the EU ETS European Commission, McKinsey, and Ecofys, (2006) estimate firms' price increases in reaction to cost increases, but not the corresponding changes in demand and firm output, as they consider final demand to be relatively inelastic. In an analysis of the EU ETS within Belgium, Gonne, (2010) makes similar assumptions. European Commission, McKinsey, and Ecofys, (2006) estimate the prices changes through a literature review of industry characteristics and the amount of free allocation given in the EU ETS, while Gonne, (2010) uses input-output tables. Alternate short-run assumptions are also seen in household analyses. In a study of BC's carbon tax for the Canadian Centre for Policy Alternatives, Lee, (2011) estimates price increase effects on household income without considering changes in household demand, as does Blonz, Burtraw, and Walls, (2010) in their analysis of a previously proposed U.S.-wide pricing policy. In these household-analysis cases, the assumption of static household demand in the short-run is justified as a means to estimate the maximum possible effects in the case that demand is relatively inelastic or that there is a significant lag between firms raising costs and households being able to alter their purchasing patterns.

In the medium term, firms are assumed to adjust their input mixes towards less carbon-intensive inputs and that consumers continue to reduce their demands for carbon-intensive goods. Finally, in the long-run, full general equilibrium effects are considered, meaning that both firms and consumers make capital adjustments, and while some industries will have lower outputs than before, these reductions are met with increases in industries that are relatively more efficient. These effects are not considered in most of the analyses reviewed, but are important in understanding how distributional impacts may change over time. For example, it should be noted that competitiveness concerns for firms arise in the very-short, short, and medium run, due to limited substitution possibilities in the production structure, but not in the long run when technological progress and structural changes have occurred (Gonne, 2010).

### 2.2 Distribution of Household Impacts

Over the past decade a number of academic and policy papers have attempted to address the distributional consequences of cap-and-trade programs and carbon taxes on household income. Despite important methodological differences that have been described above, each of these studies found carbon prices to be regressive with respect to annual income without a compensation scheme in place. Nevertheless, the studies that do consider compensation schemes clearly establish that the policies can be made progressive with redistribution of some of the revenues generated from auctions or taxes. The degree by which their regressive nature is mitigated depends on the way revenues are allocated.

The Congressional Budget Office, (2009) released a series of policy briefs in 2009 addressing the potential household costs of the American Clean Energy and Security Act (H.R 2454). The CBO's analysis focuses on the effects of the legislation in the year 2020, when forecasted allowance prices reach $28 per tonne of CO2 equivalent. In an effort to estimate household impacts, the agency calculated the net loss in purchasing power by subtracting the overall compensation received by households from their dollar loss due to price increases. Assuming 30 per cent of the allowance value is allocated to households to compensate them from increased expenditures, the CBO estimates a net annual cost of about $175 per household. Nevertheless, the agency finds net costs to vary greatly across income levels. As a result of the proposed government recycling strategy, they find the lowest income quintile would actually see a net benefit of about $40 while the richest quintile would face average costs of $235.

In response to the CBO's analysis, Blonz, Burtraw, and Walls, (2010) from Resources for the Future (RFF) carried out a more detailed assessment of H.R. 2454's household impact, analyzing the differences not only between income groups but also across age groups and geographical regions. It is important to note that although both agencies assess the same legislation, their methodologies, assumptions, and time frames differ. The more recent RFF study introduces two possible scenarios, an 'optimistic' one with an allowance price set at $12.82 per tonne of CO2e and a 'pessimistic' one with a higher allowance price, set at $23.32 per tonne. Assuming that 15 per cent of the allowance value is used to compensate poorer households, the authors forecast household costs to rise by $138 for the lower price scenario and $438 for the higher price one. Nevertheless, because an energy rebate program is in place, net impacts differ widely across income groups. In the higher priced scenario the lowest income quintile has a $15 net benefit while the highest income quintile faces an $820 cost. Like the CBO, Blonz, Burtraw, and Walls, (2010) find the overall impact of the American Clean Energy and Security Act to be progressive. That is, the government's revenue recycling strategy successfully offsets the burden on poorer families.

In North America, only a handful of jurisdictions have implemented carbon taxes, and these have typically had limited geographical or sectoral coverage and have assigned only modest price to emissions (Resources for the Future, 2014). An exception to this rule is the carbon tax levied by the Canadian province of British Columbia in 2008. Initially set at a modest $10 per tonne of CO2e, the tax increased $5 per year, reaching $30 per tonne of CO2e in July 2012. The BC government has adopted an 'upstream' approach, aiming to cover all fossil fuels consumed in the province (roughly 70 per cent of BC's GHG emissions) by taxing refineries and importers of petroleum products based on the carbon content of their gasoline, diesel fuel or heating oil (Lee, 2011). The government has aimed for the tax to be revenue neutral, meaning all of the revenue raised is refunded via personal and corporate tax cuts and low income credit. Seeking to assess the extent of its fairness, the Canadian Centre for Policy Alternatives (CCPA) released a set of papers calculating the net costs on BC households across income levels. In stark contrast to the CBO and RFF, the CCPA finds that while the overall costs to families are small, tax cuts disproportionately benefit high income families, those with the highest carbon footprints. The CCPA calculates that in 2010 the poorest quintile faced a net burden of $12 from the policy while richer households saw a net benefit of $229 primarily as a result of higher corporate tax cuts.

Finally, in 2010, Grainger and Kolstad conducted an analysis of a hypothetical U.S-wide carbon pricing policy. They do not distinguish between tradable carbon permits and a carbon tax. Similar to the other three analyses, they found the hypothetical policy to be regressive in the absence of a revenue recycling scheme.

### 2.3 Distribution of Industrial Impacts

When assessing the distributional effects of a carbon price on industries, the most common approach has been to focus on the medium to long run impacts described above: i.e., when factor inputs are mobile and new import patterns are established. However, the very short and short-run costs on industrial output and employment also have important implications as they have the potential to cause labour reductions and firm closures in the interim before structural changes occur. Of the short-run industrial impact studies mentioned above, Reinaud, (2005), European Commission, McKinsey, and Ecofys, (2006), Ho, Morgenstern, and Shih, (2008), and Gonne, (2010) provide particularly useful insight into understanding the distribution and extent of these short run costs. Note that the exact magnitude and distribution of short-run costs for various industries are not directly comparable across studies as they have assessed industries at different levels of aggregation and scope based on their economy of focus. Furthermore, the magnitude of costs are also not always comparable due to the use of different policy and carbon price level scenarios. However, their methodologies and their findings of which industries bear the highest costs still provide useful context.

There are two important industry-specific considerations in predicting industrial impacts that are discussed in most of the analyses. The first is the extent to which firms pass through their increased costs to consumers and downstream firms. In the chronology of impacts presented in Table 1, it is suggested that firms merely pass through all increases in cost to consumers and then react to the resulting decrease in demand and input, but it is important to note that in actuality firms try to assess what these impacts will be. As a result, the amount firms raise prices is not only dependent on a facility's cost increases from its carbon-intensity of production, but also on the degree of import competition and on the price elasticity of demand for its goods. Firms in industries that face high levels of competition from imports or whose products are easily substitutable will be more likely to bear costs in the short-run rather than pass them on to consumers in order to avoid substantial anticipated decreases in demand (Reinaud, 2005). Ho, Morgenstern, and Shih, (2008) and Choi, Bakshi, and Haab, (2010) make the assumption that firms will pass through all cost increases resulting from a carbon pricing policy. However, a variety of studies did consider the limited tendency to pass costs on in certain industries. European Commission, McKinsey, and Ecofys, (2006) estimate the proportion of pass through for different industries based on a literature review of industry characteristics, and Gonne, (2010) models it as a function of trade exposure. Reinaud, (2005) makes no quantitative estimates of the proportion of pass through, presenting instead a range of maximum and minimum costs to industry corresponding to 0% and 100% pass-through, giving qualitative estimates about how certain industries are likely to behave.

The second consideration is the amount of free allocation that is granted to firms within an industry. Free allocation is when firms are given a certain portion of their emissions permits for free in order to lessen the costs of a carbon market. Theoretically, freely-allocated permits still hold an opportunity cost as a firm is able sell one at market price if it can reduce emissions for a lower marginal cost. However, in practice there are many nuances in policy design that prevent the opportunity cost of freely allocated permits from being considered as a margin with which to curb emissions, and there is a tendency for firms to pass through opportunity costs to consumers instead (Jegou and Rubini, 2011). For example, analyses of the EU ETS have shown substantial rents to firms from passing through carbon costs to consumers when there is free allocation (Jegou and Rubini, 2011). Despite these reduced environmental gains, free allocation does reduce the costs for the industries that receive them, and where implemented, they alter what would otherwise be the distribution of impacts across industries.

Reinaud, (2005) and European Commission, McKinsey, and Ecofys, (2006) both estimate industrial impacts in the context of the EU ETS. Both estimate net cost impacts by calculating the extent to which short run costs due to carbon-intensity may be mitigated with a free allocation of emission permits. Without any free allocation, both studies find basic oxygen furnace (BOF) steel and cement to be among the industries incurring the greatest costs, with differences in production costs in this case purely dependent on variations in combustion and process emissions across industrial categories. It is therefore not surprising for very carbon intensive firms like steel to incur the greatest initial costs. In European Commission, McKinsey, and Ecofys, (2006), BOF steel faces an initial cost increase of 17.3% at €20 per $tCO_2e$. The initial impact on cement is found to be even greater, with costs rising 36.5% relative to the pre-cap scenario. When the scenario with 95% free allocation of allowance permits for direct emissions is considered, industries with low indirect emissions like BOF steel are able to counter their initial costs by as much as 90%.[2] Contrastingly, sectors like mechanical pulp which are highly dependent on indirect emissions, for which they receive no free allocation,would only witness a modest cost decline in costs. Gonne, (2010) considers the effects of a hypothetical carbon tax for Belgium alone. His findings are similar to the EU ETS analyses, finding refined petroleum, coke manufacturing, and iron and steel manufacturing to be the industries facing the highest cost increases.

In contrast to the three European papers, Ho, Morgenstern, and Shih, (2008) calculate the impact of a $CO_2$ pricing policy in the United States not only in cost terms but also in terms of output and employment, at the very-short, short, medium, and long run scales shown in Table 1. The output and employment estimates are possible due to the inclusion of an input–output framework and price elasticity of demand considerations as explained in Section 2.1. Ho, Morgenstern, and Shih, (2008) assume a unilateral \$10 per $tCO_2e$ with no free allocation. The authors find those industries facing the highest production costs and price elasticities of demand suffer the greatest fall in output in the short-run. For example, at \$10 per $tCO_2e$ petrochemical manufacturers face a 4.2% increase in costs leading to a 7.7% decline in sales. Compared to petrochemical manufacturing, inelastic industries like cement face a greater rise in costs (5%) than they do a decline in output (4.1%). Overall, coal mining followed by gas mining and petrochemical manufacturing are found to face the highest reductions in output in the short-run. Choi, Bakshi, and Haab, (2010) also assess a U.S. wide policy and include output loss estimates. They find that output is likely to be most reduced in coal fired electricity generation, followed by coal mining and petroleum fired electricity generation.

## 3 An Overview of Quebec's Carbon Market

Quebec's carbon market was developed as a part of the Western Climate Initiative (WCI), a partnership started in 2007 between 7 American states and 4 Canadian provinces to implement a coordinated cap-and-trade system (Western Climate Initiative, 2013). However, since its initiation, the changing political climate has led to some jurisdictions leaving the WCI, and only Quebec and California have committed to emissions trading programs. In

[2]For industries, indirect emissions are those associated with the production of inputs, typically electricity and raw materials. Direct emissions are those associated with processes that occur within an industry, such as combustion of fuel or those released from land-use change.

December 2011, the government of Quebec released a regulatory document setting the rules and regulations of the Province's cap-and-trade system for GHG emission allowances. While its objective and scope of coverage have been largely unaltered, two regulatory amendments to this preliminary document have been made. The final version of the document was published by Quebec's Ministry of Sustainable Development, Environment and Parks (MDDEP) on November 13, 2013. As of January 2014, the Californian carbon market was linked to the Quebecois one, and while this has interesting implications for efficiency in the long-run, it will not have a significant impact on the short-run distributional effects this analysis is concerned with, aside from the fact that the larger market means the market's price for carbon is more likely to remain at or near the price floor in the short run (Goldstein, 2014; Purdon, Houle, and Lachapelle, 2014).

This section describes the system's objectives, scope and implementation as well as a brief discussion of the underlying equity and efficiency concerns. Unless otherwise noted, all information pertaining to the system's design has been either taken from the final regulatory documents or the MDDEP's website. Quebec's Carbon Market came into force on January 1st, 2013 as the primary tool to meet the province's GHG emissions target of 20 percent below their 1990 level by 2020. Its enforcement is divided into three compliance periods and covers seven greenhouse gases: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3). The market's scope is summarized in Table 2.

The first period of the carbon market began in 2013 and covers the 79 emitters in the industrial and electricity generation sectors whose annual greenhouse gas emissions exceed 25 kt$CO_2$e. The electricity generation sector also includes all operators or facilities acquiring electricity produced outside Quebec and whose generation exceeds the annual threshold of 25 kt$CO_2$e During this initial phase, the market covers approximately 28% of the province's emissions.

The second period will begin in January 2015, and it will expand the market to include roughly 45 distributors of fossil fuels which distribute fuel whose emissions *when consumed* will exceed the 25 kt$CO_2$e level, not including any fuel sold to firms already included in the carbon market in period one. That is, industries already included in period one of the market are still responsible for securing permits for their combustion emissions, and they are not included in the permits needed for the company who distributed that fuel. This includes all fuels except fuel for aviation and marine bunkers, hydrocarbons used as raw materials for non-fuel products, and biomass. There

| Industrial Sector | Compliance Period | Free Allocation |
|---|---|---|
| Manufacturing | 1st | 80% combustion, 100% process and 'other' |
| Mining, quarrying, and oil and gas extraction | 1st | 80% combustion, 100% process and 'other' |
| Electric power generation, transmission and distribution | 1st | 80% combustion, 100% process and 'other' |
| Steam and airconditioning production for industrial purposes | 1st | 80% combustion, 100% process and 'other' |
| Fuel distribution | 2nd | 0% |
| Pipeline Transportation of fuel | 2nd | 0% |

Table 2: Summary of SPEDE Scope and Implementation. Note: Fuel includes gasoline, diesel fuel, propane, natural gas, and heating oil. Source: Government of Quebec, (2014a)

is an existing carbon levy on fuels that will end once the second compliance period begins in 2015, based on a carbon price of \$4.26/t$CO_2$e that is roughly one-third of the minimum that will be enforced under SPEDE at this time. With gasoline as an example, this will result in a relatively small increase of about 1.84 cents on the existing overall fuel tax of 20.2 cents, meaning there will be no large price shock to fuels as the second period of the market begins. The third compliance period is thus far slated to have identical regulations to the second and will run from 2018-2020.

During the second and third periods, the carbon market will cover about 85% of the province's total emissions. The remainder is mostly the 14% of emissions from agriculture, waste, and deforestation, leaving only 1% made up of emitting companies below the 25 kt$CO_2$e level from the intended sectors of coverage, industry and transportation. These remaining sectors are covered to some extent by the offsets available, which currently include approved protocols for agricultural methane destruction, small landfill site methane destruction, and ozone depleting substance destruction. Importantly, all emitters will remain covered until the 3rd consecutive annual report in which their GHG emissions fall below the annual 25 kt$CO_2$e threshold.

The cap, and thus the number of GHG permits available for purchase, will decrease at an average annual rate of 4% from 2015-2020. Emission units will be auctioned by the MDDEP at most four times a year, and the price will be determined by demand at these auctions. However, there

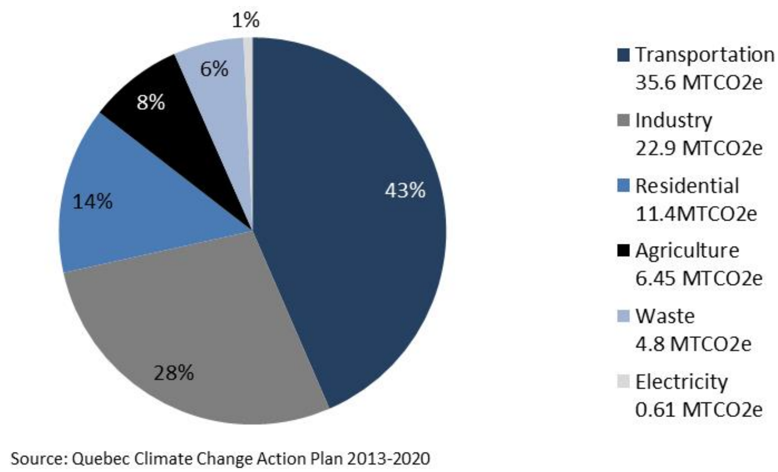


Figure 1: Quebec Emissions by Sector, 2009.

is a price floor, i.e., a minimum auction price per tonne of $CO_2$e set at \$10.75/t$CO_2$e for 2013, that is scheduled to increase at an annual rate of 5 percent plus inflation thereafter. Similarly, there is a reserve of credits called the 'Allowance Price Containment Reserve', which act as a guaranteed maximum auction price to prevent the cost of mitigation from reaching a level too prohibitive for Quebec's businesses and consumers. This was set in three equally sized 'baskets' of \$40, \$45, and \$50 permits in 2013 which are scheduled to increase annually in price by 5% plus inflation until 2020. Both the price floor and the maximum price reserve play the important role of minimizing price volatility, thus providing some certainty for industry regarding the need for substitutions away from carbon-emitting processes, and for the government with respect to revenue for the Green Fund. In order to promote cost effectiveness, the market allows for the banking of allowance permits. With banking, allowances that are saved from one year to the next may be sold or used for future compliance, although provisions have been taken to avoid any one entity gaining too large a market share. A maximum holding limit has also been put in place, with the maximum number of emission units held determined by equation 32-1 in the final regulation.

Another measure that will help reduce the economic impacts of the regulation and that has helped make the market politically feasible, is the generous level of free allocation for the industrial and electricity generation sectors who face competition from markets outside of Quebec. Free allocations are given in order to prevent emission leakage, whereby emissions are merely outsourced to jurisdictions without climate regulation, resulting in no net reduction and reducing the competitiveness of the local industry covered by climate regulation. Emissions are divided into three categories: process emissions, the emissions from fixed chemical processes that have no known alternatives, combustion emissions, those related to the exothermic reaction of a fuel, and 'other' emissions which do not fit in the first two categories. Under Quebec's free allocation rules, these companies are given 100% of their process emissions for free, 80% of their combustion emissions for free, and 100% of any other emissions free in the first period based on average historic emissions intensity of these different categories. There is less free allocation for combustion emissions as they are generally the easiest to reduce in the short term. In the second and third compliance periods these levels will fall based on an annually decreasing industry-specific emissions target, on average 1-2% each year.

The market is expected to raise an estimated revenue of $2.7 billion between 2013–2020, which as stipulated in section 46.16 of the Environmental Quality Act (R.S.Q., c. Q-2) will go to the province's Green Fund which is broadly used to "finance GHG reductions, limitation or avoidance measures, the mitigation of the economic and social impact of emission reduction efforts, public awareness campaigns, adaptation to global warming and climate change, or to finance the development of Quebec's participation in related regional and international partnerships" (Government of Quebec, 2013). One of the priorities of the Green Fund in Quebec's Climate Change Action Plan 2013-2020 is easing the effects for the industries disproportionately affected by the changing climate, but this does not include industries impacted by mitigation efforts like the SPEDE. Furthermore, while subsidies to assist households transition away from certain high-emission practices such as heating using fuel oil, no mention occurs in the Plan or relevant regulations of the Green Fund being used to alleviate any regressive effects of the carbon market for lower income households (Government of Quebec, 2013).

There are a number of existing analyses of the impacts of Quebec's Carbon Market, but these were generally conducted before the details of the policy were defined, take a long-run rather than short-run view of the effects, and do not break down households by income or look at specific industry of geographical effects as is done in this analysis. A number of analyses consider the effects of linking the Quebec and California markets, but these generally have more long-term considerations (see Western Climate Initiative, 2012; Purdon, Houle, and Lachapelle, 2014). The WCI has conducted a series of their own analyses as the details of the policy have developed, with the most recent 2012 report estimating a carbon price of $19-$34 per ton for 2013, much higher than the price observed so far in 2014, due to a higher emissions allowance being set than originally planned (Western Climate Initiative, 2012). A basic initial analysis conducted by the government in 2009 looked at different household characteristics and estimated mitigation costs for transportation and heating and found that to achieve a 20% emissions reduction from 1990 levels by 2020, it would cost the average one-car household with electric heating $255 per year and a two-car household using heating oil $804 per year (Government of Quebec, 2013).

# 4 Methodology

As is inherent to all carbon pricing schemes, Quebec's cap-and-trade system will have short-run economic costs on households and industrial sectors. The significance and distribution of these costs, however, depends on the structure of household expenditures and industrial production processes. For households, short run impacts fundamentally depend on the carbon intensity of annual expenditures and the degree to which industrial costs are passed on in the form of higher consumer prices. For industries, short run costs depend on industrial combustion and process emissions as well as the distribution of allowance permits and the ability to pass through costs to consumers. This section will outline the assumptions underlying the analysis, as well as the data sources and methodologies used in estimating the distributions of household, industrial, and geographical impacts.

Extra costs felt by households under carbon market systems such as Quebec's are those passed through from more direct effects on carbon intensive industries. As depicted in Table 1, firms face higher costs in the very-short run and pass through costs to the extent possible in the short-run until they are able to adjust structural factors in the medium to long run. Although a cap-and-trade system will unambiguously escalate per unit production costs, the extent of this increase depends on (i) the extent of an establishment's combustion and process emissions, (ii) the extent of free allocation granted to each firm under the policy and (iii) the degree of competition faced from firms not covered by the regulation and the related ability to pass through costs to consumers in the short run.

When markets are captive and demand is fairly inelastic, such as for fuel distribution, firms can easily pass on the full extent of the extra costs to consumers without costly reductions in demand. However, knowing the exact portion of costs a firm will be able to pass through would require a detailed analysis within each sector, which is outside the scope of this analysis. Additionally, the input-output method employed by some of the reviewed studies to look at the full combination of short-run effects in Table 1 is not feasible. This means we present costs to firms rather than reductions in their output as in (Reinaud, 2005; European Commission, McKinsey, and Ecofys, 2006) and Reinaud, (2005). Similar to Reinaud, (2005), two scenarios are created in order to represent a reasonable range of impacts.

In the first scenario, it is assumed that no costs associated with indirect emissions are passed through to households, due to the competition from firms outside of Quebec[3]. As the fuel-distributing firms associated with direct emissions essentially have a captive market due to the infrastructure of distribution, their costs are still assumed to be passed through 100%. In the second scenario, we assume that costs from all sectors get passed on fully to consumers, and therefore that the financial impact on households is simply the allowance price multiplied by their annual domestic GHG emissions. In reality, the short run effects will be somewhere between these two scenarios as different sectors will experience different levels of competition and be able to pass through different proportions of the market's carbon price to consumers. All sections of the analysis reflect short-run effects using 2015 prices and market coverage, meaning both industrial emissions and emissions from distribution of fossil fuels are considered to the extent possible. Three sample carbon prices are used to represent the range of possible effects: the 2015 price floor of \$12.07 per $tCO_2e$, the average reserve price (which acts as a price ceiling) of \$48.20, and an intermediate value of \$25.00.

## 4.1 Household impact

Calculating the impact of carbon permit prices on household income requires precise estimates of household GHG emissions across income levels. As discussed in the introduction and literature review, a Quebec cap-and-trade system will raise the price of carbon intensive products in the short to medium run. The extent to which households are affected therefore depends on the carbon content of their purchases. Total household emissions can be viewed as the sum of direct and indirect household emissions, defined above.

[3]For households, direct emissions refer to those greenhouse gases released by the burning of fuel for transport, heating, and cooking. Indirect emissions, also known as "embodied carbon," are the greenhouse gases released in the production of goods and services households consume. It is important to note that direct emissions do not encompass every domestic energy source. While electricity is used to operate many household appliances, it counts towards indirect emissions since GHGs are only released during its generation process and not by households directly.

| | Firms | Households |
|---|---|---|
| Scenario 1: Limited pass-through | Only firms associated with direct emissions raise their prices to cover increased marginal costs | Increased cost for goods associated with direct emissions only |
| Scenario 2: Full pass-through | All firms raise raise their prices to cover increased marginal costs | Increased cost for all sources of emissions covered |

Table 3: Overview of Scenarios

The effects of substitution towards relatively cheaper imports or less-carbon intensive goods and decreased demand for goods in response to price increases are for the most part assumed to be small in this analysis. However, a brief supplementary analysis is provided to estimate the decreased short-run demand for transportation fuel, and the related decrease in household costs relative to when fuel demand is held constant. This estimate of demand shift is provided for fuels because they make up the largest single category portion of the average household's emissions and because it is in these sectors that the costs of the market are most likely to be fully passed on to households, making the reduced demand easier to estimate accurately.

Statistics Canada's 2012 Survey of Household Spending (SHS) is used to calculate household emissions. The SHS provides expenditure estimates at the provincial level across income quintiles, thereby permitting a distributional analysis of Quebec household consumption. Both direct and indirect emissions calculations make use of this survey. Carbon intensity estimates for direct and indirect emissions are based on different data sets. Emissions factors for direct emission categories were obtained from the schedule of emissions factors used by the province in the "Regulation respecting the annual duty payable to the Green Fund," whereas the embodied carbon intensities of household purchases were calculated based on 2010 data made available by Statistics Canada's Environmental Accounts division. As direct and indirect emissions are based on different emission intensities, subsections 4.1.1 and 4.1.2 explain their methodologies separately.

### 4.1.1 Household direct emissions

For households, direct emissions are those released by the combustion of gasoline, heating oil, and natural gas. While small amounts of diesel, propane, or other fuels may be used, their consumption is not high enough to be included in the SHS 2012 and thus can be assumed to be negligible. Direct emissions were calculated by multiplying the annual volume of fossil fuels purchased by households times their corresponding emission factors. Because the SHS gives fuel consumption estimates in dollar terms, it is first necessary to divide these by their provincial unit price. Algebraically, direct household emissions for each fuel type were calculated by the following formula:

$$\text{Emissions}_{(\text{FUEL})} = \frac{\text{Expenditure}}{\text{Price}} \times \left(\frac{\text{Emissions}}{Q}\right)_{(\text{FUEL})}$$

where $\left(\frac{\text{Emissions}}{Q}\right)_{(\text{FUEL})}$ refers to a fuel's corresponding emissions factor.[4] Fossil fuels are normal goods, thus direct emissions can be expected to increase with income. Note that natural gas spending data were not available in the SHS for Q1, Q2, Q3, and Q4, and as an estimate, the reported average for all quintiles adjusted for the amount of Q5 spending data was used.

### 4.1.2 Household indirect Emissions

Indirect emissions depend on two factors: the composition of household spending and the embodied carbon intensity of purchased products. Importantly, indirect emissions also account for those greenhouse gases released in the production of gasoline, heating fuel and natural gas, which are not the same as those discharged by their combustion after purchase by a household. Our calculation of indirect emissions is less precise than for direct emissions because the SHS does not differentiate between expenditures in local and imported goods and services. This is an important distinction, as including imported goods would overestimate net household losses resulting from the cap, as their production is not covered by the SPEDE and thus firms have no increased production costs that would result in higher prices. For direct emissions such an adjustment was unnecessary as it is reasonable to believe that households purchase the majority of their gasoline from Quebec gas stations regardless of whether this is domestically refined or not.

Since neither the Quebec Institute of Statistics nor Statistics Canada provides any measure of provincial indirect emissions, it is necessary to assume that the province's indirect carbon intensities are similar to those of Canada as a whole. The Statistics Canada's Environmental Accounts Division provided their 2010 import adjusted calculations of Canadian indirect

[4] Note that air travel is excluded from these calculations as the SPEDE regulations exclude aviation fuel. While for some individuals, and at the upper quintiles, this is a large omission, air travel does not account for a large fraction of average household emissions.

emissions for 48 SHS expenditure categories. By dividing these emissions by their corresponding aggregate expenditure levels, available through the SHS, carbon intensities per $1000 of produced good for each of these 48 categories were obtained. Note however that although the numerator is import adjusted, aggregate expenditure levels are not. Thus, aside from the above assumption it is also necessary to assume that the marginal propensity to import is (i) the same for Quebec and Canadian households and (ii) the same across income quintiles. This is perhaps easier to understand algebraically. The indirect emissions released in the production of domestic good $X$ ($\text{Emissions}_{(X)}$, measured for instance in $\text{ktCO}_2\text{e}$) are represented by:

$$\text{Emissions}_{(X)} = \frac{(1 - MPZ_{\text{CAN}}) \times \text{Emissions}_{\text{CAN}(X)}}{(1 - MPZ_{\text{CAN}}) \times AE_{\text{CAN}(X)}} \times \Big[(1 - \text{MPZ}_{\text{QC}}) \times E_{\text{QC}(X)}\Big]$$

where $(1 - MPZ_{\text{CAN}})$ and $(1 - MPZ_{\text{QC}})$ represent Canada's and Quebec's respective import adjustment ratios; $\text{Emissions}_{\text{CAN}(X)}$ the indirect emissions released by the national production of good $X$; $AE_{\text{CAN}(X)}$ the aggregate national expenditure on good $X$; and $E_{\text{QC}(X)}$ the average household expenditure of good $X$ in Quebec. Under the assumption that $MPZ_{\text{CAN}} = MPZ_{\text{QC}}$, then the above formula becomes:

$$\text{Emissions}_{(X)} = \frac{(1 - MPZ_{\text{CAN}}) \times \text{Emissions}_{\text{CAN}(X)}}{AE_{\text{CAN}(X)}} \times E_{\text{QC}(X)}$$

which means that, to the extent that Quebec's marginal propensity to import is similar to Canada's, then indirect household emissions from the purchase of Quebec products may be calculated even though there are no data for the actual share of domestically produced goods.

#### 4.1.3 Household Impact

For scenario one, "limited pass through", the direct household emissions for each quintile were multiplied by the three sample carbon price levels to forecast the impact for the average household in each quintile under each price. This reflects the minimum household cost under the SPEDE, where only fuel distributing firms with their relatively captive markets and little flexibility to bear short-term costs, pass on carbon prices to consumers. For scenario two, "full pass through", direct and indirect emissions were included, reflecting the maximum costs to households in the case that all firms pass on the full carbon price to consumers, regardless of threats to their market share.

This methodology relies on the assumption that all shareholders of the affected Quebecois firms are inhabitants of Quebec, when in reality some investors are likely more geographically dispersed. Also note that none of the firms whose coverage starts in period two — i.e, the fuel distributors — receive free allocation. Thus, these firms do not contribute to our calculation of shareholder profits from the SPEDE.

#### 4.1.4 Fuel Elasticities Analysis

As can be seen in Figure 2, gasoline for transport was by far the largest single category contributing to household emissions, accounting for 83% of the direct emissions released by the average Quebec household, and 27 percent of the total 15.7t$CO_2$e. Due to this dominance, an additional analysis of how households are likely to change gasoline consumption as a reaction to SPEDE in the short-run was conducted. To the extent families are able to reduce demand for or substitute away from gasoline, household income effects of the policy may be lessened, and impacts to retailers and producers will increase.

Price elasticity of transport demand is the amount by which demand for a certain mode of transport can be expected to change with a unit change in price. As could be expected, demand elasticities vary depending on a number of factors, including the type of price change, type of trip and traveler, quality and price of alternatives, scale and scope of pricing, and the time frame of adjustment (Litman, 2013). A number of empirical studies have been done to determine values for price elasticities of transport demand in different transport settings. In general, the elasticity of vehicle travel with respect to fuel price has varied between $-0.1$ and $-0.8$ depending on these different factors. However, a variety of reviews have found average short-run elasticities for transport demand for private car travel with respect to fuel price increase to be near $-0.25$ (Litman, 2007; Goodwin, Dargay, and Hanly, 2004; Litman, 2013). When separated into urban compared to rural consumers, elasticities of approximately $-0.3$ for urban and $-0.17$ for rural have been found, with the higher urban elasticity attributable to public transit access (Santos and Catchesides, 2005; Blow and Crawford, 1997; Wadud, Graham, and Noland, 2009). These values were used in order to provide an estimate of how Quebecois households would change their transport behaviour in the short run in response to carbon price changes.

First, the 2006 Census Public Use Microdata Files were used to determine the portion of households in each quintile living in urban (greater metropolitan areas of Quebec City, Montreal, Sherbrooke-Trois-Rivieres, and Ottawa-

Gatineau) compared to rural (all other) areas. Next, the estimated fraction change in demand for gasoline, $\triangle L(q_n)$ for a specific quintile $q_n$ was predicted as

$$\triangle L(q_n) = \frac{p_{\text{new}}}{p_{\text{old}}} \left( q_{n_u}\eta_u + q_{n_r}\eta_r \right)$$

where $p_{\text{old}}$ and $p_{\text{new}}$ are the average gasoline prices before and after the 2015 inclusion of fuel distributors in the SPEDE, $q_{n_u}$ is the portion of the quintile's population that is urban, $q_{n_r}$ is the rural portion, and $\eta_u = -0.3$ and $\eta_r = -0.17$ are the urban and rural short-run elasticities for transport demand described above. The average price, $p_{\text{new}}$, is calculated at the carbon prices of \$12.07, \$25.00, and \$48.20 as with the rest of the analysis. The change in demand in litres was also calculated by multiplying the initial demand by $\triangle L(q_n)$ for a specific quintile.

## 4.2 Industrial Impact

As explained in Section 3, there is generous free allocation for firms in industrial sectors except for those related to fossil fuels, as well as for firms with fixed electricity power generation contracts. This free allocation reduces costs for firms as they do not have to buy their permits in auctions at the market price. In 2015, free allocation of permits is scheduled to be approximately 97% for fixed process and 'other' emissions, and 77% for combustion emissions (Government of Quebec, 2014a). As no industry-wide estimates of the proportion of combustion emissions compared to the other sources were available for Canada, a 2002 report from the US Environmental Protection Agency on emission sources across different industries was used to estimate the percentage of free allocation that will be allotted to each sector. We use the North American Industry Classification System (NAICS) for aggregating firms into sectors. The emissions distributions from the US EPA are reported in Table 10 in Appendix A on page 50, using the 4-digit level of precision in NAICS. The fossil fuel distributing firms covered starting in 2015, after the first period, do not receive any free allocation as their markets are considered to face minimal competition from firms outside the province due to the infrastructure inherent in distributing fuel. Besides the negligible fraction of trips across borders for Quebecois households to buy their gasoline in other jurisdictions there are no opportunities for non-Quebecois firms to gain market share in this sector due to the nature of its distribution.

The only difference between the study's industrial and geographical impact is how costs are grouped. Splitting costs across industrial sectors and administrative regions requires precise information on GHG emissions, industrial classification codes and geographical locations of the emitters. The MDDEP published a list of facilities covered by the SPEDE for 2013, their locations and their 2012 emissions. This list only includes industrial and electricity generating facilities included in the first period of the SPEDE, and not fuel-distributing ones. Put together, these 79 facilities emitted 19.1 $MtCO_2e$ in 2012, representing just under a quarter of the province's total 80.0 $MtCO_2e$ emissions, and below the 2013 and 2014 cap of 23.2 for these sectors. We first calculated what the short-run costs would be in the absence of any free allocation by multiplying the number of annually auctioned allowances by the system's price floor for 2015 (\$12.07/$tCO_2e$), the average reserve (maximum) price (\$48.20/$tCO_2e$) and an intermediate value (\$25/$tCO_2e$). Unlike most previous studies, it is possible to analyze the number of allowances as a function of individual facility emissions rather than from broad industrial categories, allowing for an analysis of impacts across administrative regions as well as industrial sectors. This analysis also addresses labour impacts by showing costs as a function of the number of jobs in each sector. Because the procedures used for the industrial and geographical analyses largely differ from the labour force assessment, their methodologies are described separately.

Less detail is available for the second period, i.e. fuel-distributing firms. A list of firms who are responsible for reporting emissions in order to pay the carbon levy on fossil fuels that will be phased out at the end of 2014 is available, but it does not include their approximate emissions. "A more detailed analysis will be possible when the emissions data associated with the fuel distributed by these firms becomes available."

### 4.2.1 Impacts by sector and region

To carry out the analysis for these first period firms, we grouped the 79 facilities in 2- and 4- digit NAICS categories. Adding up the number of emissions for each facility in a given NAICS sector and multiplying this figure by each of the three allowance price points and each of the pass-through scenarios yields a series of short-run dollar loss estimates for each of these sectors. For analytical purposes, we then compared these figures with the sector's contribution to provincial GDP. Sectoral GDP data were retrieved from Statistics Canada CANSIM table 384-0038. At the 2-digit level, 4 of the establishments are listed under mining and quarrying (21),3 under utilities (22) and 70 under manufacturing (31-33). At the 4-digit level in turn, the three categories with the most emitters are pulp, paper and paperboard mills (3221) with 19 establishments, alumina and aluminum production and processing (3313) with 9 establishments, and basic chemical manufacturing (3251) with 9 as well. The geographical analysis uses the same methodology only instead of separating installations by NAICS codes it was done according to administrative regions (ARs). The 79 assessed facilities are located in 13 out of Quebec's 17 ARs, with only Bas-Saint-Laurent, Laval, Laurentides, and Nord du Quebec without any covered facilities.

For period two firms, the 45 companies are more difficult to separate by sector and region. With respect to sector, many are vertically integrated in the fossil fuel production process, meaning they fit within multiple NAICS categories. Additionally, some also distribute multiple fuel types. With respect to region, although their head office or main facility is listed, by nature these firms have multiple locations or geographically dispersed infrastructure such as a pipeline. Therefore, for these firms an analysis by administrative region is not relevant in terms of determining employment or GDP impact in a specific area.

### 4.2.2 Labour force impacts

When industries or regions suffer a decline in competitiveness and output falls, many of these costs are born by employees. We calculate the industrial costs per job in both scenarios in order to assess the degree of possible labour impacts and identify in which industries labour may be most threatened. Environment Canada's National Pollutant Release Inventory (NPRI) lists the total number of workers employed in each of the 79 facilities covered by period one of the SPEDE. Equipped with NPRI job data we separated the 48,955 workers hired by these establishments into the three 2-digit NAICS categories, manufacturing, mining, and utilities. We then divided the total dollar loss faced by each industry at each of the three price estimates with free allocation for both scenarios 1 and 2. This was repeated for the 22 categories at the 4-digit NAICS level. At the 2-digit NAICS level, total labour expenditures across industries (number of employees $\times$ average wages) using average wages data from the 2006 Census Public Use Microdata Files were also calculated to provide a point of comparison. This was not done at the 4-digit NAICS level as average wages are not available at this level of aggregation.

There is a limitation for information on period two firms with respect to labour as well. Employee numbers from NPRI are only available for some of the firms, and in many cases appear to be underreported, or only include employees from certain sections of the firm. As a result, it was not possible

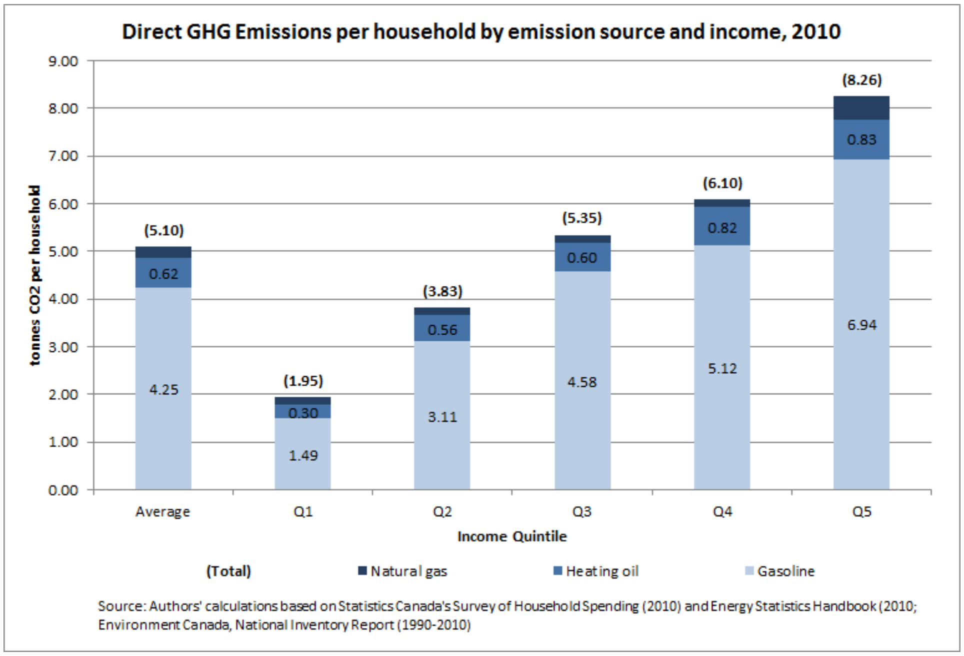


Figure 2: Direct GHG emissions per household by emission source and income, 2012. Source: Authors' calculations based on Statistics Canada's Survey of Household Spending 2012 and emissions factors from the Regulation respecting the annual duty payable to the Green Fund (Government of Quebec, 2014b)

to conduct a labour analysis for the fossil fuel distributors that will come under SPEDE in 2015.

# 5 Results

Below we report estimates of distributional impact ranges for households, for industries, and for geographic regions.

## 5.1 Household Emissions

As can be seen in Figure 1, households in Quebec's highest income quintile in 2012 were responsible for about 4.6 times more direct emissions than families in the poorest quintile. However, it is important to note that the average household in the highest income quintile has more individuals than in the

| | All | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|---|
| **Mean household size** | 2.31 | 1.35 | 1.86 | 2.33 | 2.77 | 3.25 |
| **Mean pre-tax income** | $57k | $16k | $33k | $48k | $68k | $120k |
| **Food** | 3.8 | 1.81 | 2.7 | 3.5 | 4.4 | 6.4 |
| **Shelter** | 1.30 | 1.66 | 1.48 | 1.32 | 1.09 | 0.64 |
| **Transportation** | 2.3 | 0.93 | 1.54 | 2.4 | 2.9 | 4.1 |
| **Household operation / equipment** | 0.76 | 0.36 | 0.52 | 0.71 | 0.91 | 1.28 |
| **Health care** | 0.56 | 0.33 | 0.50 | 0.56 | 0.62 | 0.81 |
| **Clothing and accessories** | 0.28 | 0.11 | 0.17 | 0.25 | 0.33 | 0.55 |
| **Recreation** | 0.60 | 0.25 | 0.37 | 0.50 | 0.73 | 1.16 |
| **All other expenditures** | 0.97 | 0.47 | 0.68 | 0.84 | 1.14 | 1.70 |
| **Total** | **10.6** | **5.9** | **8.0** | **10.0** | **12.1** | **16.7** |

Table 4: Indirect Household GHG Emissions by Expenditure Category ($tCO_2e$), 2012. "Shelter" includes indirect emissions from the production of electricity, natural gas and heating fuel; "Transportation" includes indirect emissions from the refining of gasoline. Source: Authors' calculations based on 2012 Statistics Canada's Survey of Household Spending and 2010 indirect emissions from Statistics Canada Environmental Accounts Division.

lowest quintile, and adjusting for this fact shows there is only 2 times more consumption per person. Direct emissions were primarily driven by gasoline emissions regardless of the income group. On average, gasoline explained about 27% percent of all household emissions, and 83% of direct emissions. Gasoline is in the mid-range of the different fuels' emissions factors, and thus the high portion of emissions from gasoline is a consequence of much higher gasoline consumption compared to either natural gas or heating oil. The average household, for instance, consumed more than 1800 liters of gasoline in 2012, compared to 119 L of heating oil and 228$m^3$ of natural gas. Natural gas and heating oil usage is typically much higher in similar climatic regions, but Quebecers rely primarily on electricity for heating and cooking. This power is 98% hydroelectricity with an extremely low emission factor, significantly lowering their direct emissions relative to other Canadian provinces, as discussed in Bernard, Bolduc, and Yameogo, (2011).

Table 4 shows Quebec's indirect household emissions for domestic goods and services across the province's seven largest expenditure categories, as well as the average household size in each quintile.

On average, indirect emissions for domestically produced goods were 10.6 $tCO_2e$ per household in 2012. Like direct emissions, indirect emissions increase with income. The richest income quintile has indirect emissions of 16.7 $tCO_2e$, about three times more than the lowest quintile of households at 5.9 $tCO_2e$. However, it is important to note that, as could be expected, the average number of people per household increases with average income, and when average household size is considered, the richest individuals emit only 40% more than those in the lowest quintile.

Table 4 shows that food, shelter and transportation are the largest contributors to indirect household emissions. Food expenditures account for a particularly impressive share of indirect emissions, accounting for at least 35% across all income categories. This is not so much explained by particularly high emission intensity of food products but because store-purchased food accounts for a large share of total household expenditures. Interestingly, shelter emissions is the only category that appears to be negatively correlated with income. While shelter explains 28.0% of Q1's indirect emissions it accounts for only 3.9% of Q5's total indirect emissions. Although shelter expenditures are much lower for poorer households, 'rented living quarters' have a much higher reported indirect emissions factor than 'owned living quarters'. This is due to the fact that renters often paying their landlords for heating and electricity costs, causing their associated emissions to be reported as a part of shelter costs rather than separately as would be done for owned living quarters. Finally, indirect emissions from transportation increase with income both in absolute and relative terms. In relative terms, while transportation accounts for roughly 13% of Q1's indirect emissions it represents almost 25% of Q5's 16.7 $tCO_2e$. Moreover, it is also the first or second largest source of indirect emissions for every quintile aside from Q1, where it falls below shelter. These indirect transport emissions represent emissions from the petroleum refining used for personal vehicle use as well as usage of recreational vehicles and public transportation.

Adding up direct and indirect emissions gives total GHG emissions per household. Figure 3 shows both emission types combined. Indirect emissions account for two-thirds of total household emissions. There was a smaller difference between Q1 and Q5 for indirect emissions than direct ones, but indirect emissions increase in a more stepwise fashion compared to direct emissions which stay fairly constant amongst the middle quintiles. Overall, households in the richest quintile emitted 24.9 $tCO_2e$ in 2012, 3.2 times more than those in the poorest income category.

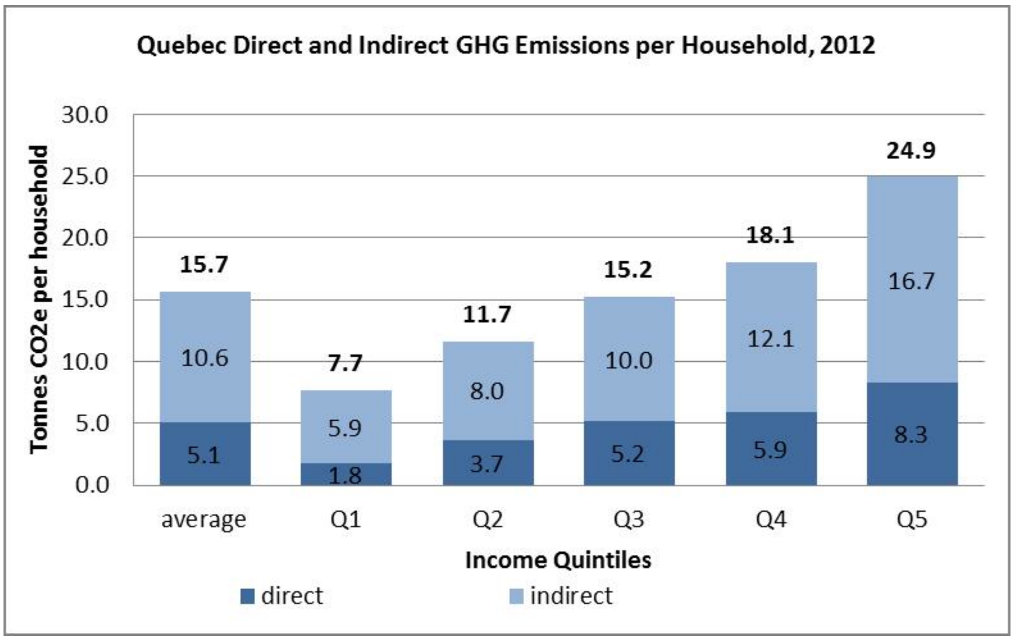


Figure 3: Direct and Indirect Household Emissions by Quintile, 2012. Source: Authors' calculations based on 2012 Statistics Canada's Survey of Household Spending, 2010 indirect emissions from Statistics Canada Environmental Accounts Division, and emissions factors from the Regulation respecting the annual duty payable to the Green Fund (Government of Quebec, 2014b)

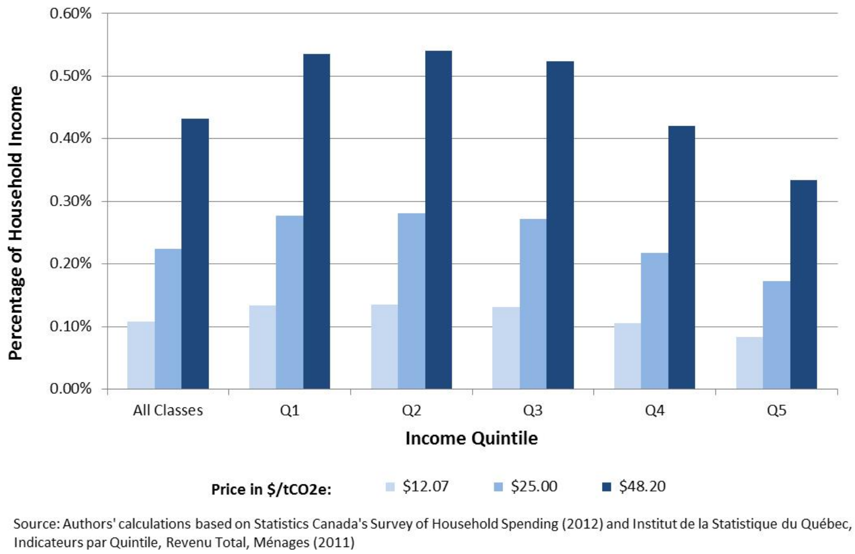


Figure 4: Limited Pass-Through: Impact as a fraction of household income by income group, 2012. Source: Authors' calculations based on Statistics Canada's Survey of Household Spending (2012) and Quebec Institute of Statistics, Household Income by Quintile (2011).

## 5.2 Household impact

The two scenarios outlined in Section 4.1 have been designed to show the total possible range of impacts for households across income quintiles. Figure 4 shows the impacts of three different prices for Quebec's carbon market for the first scenario: at the 2015 price floor of $12.07, at an intermediate value of $25.00, and at the 2015 average reserve price ceiling[5] of $48.20. This is the minimal household impact scenario where, due to the competition they face, firms other than fuel distributors bear the costs of the carbon market rather than passing on costs to consumers. In this scenario the costs as a portion of household income are fairly uniform across the three lowest income quintiles, and decrease only in Q4 and Q5. This indicates that direct fuel consumption for heating and transport by households is closely related to income for lower and middle class households, but extra income in richer quintiles is spent on other goods instead. In this scenario, costs are actually highest relative to income for Q2, but even at the price ceiling these are relatively low at just

[5] This is the average of three soft ceiling levels; see 3.

0.54% of household income.

Figure 5 shows the three different impact scenarios for Quebec's carbon market for pass-through scenario 2. These results would become even more regressive than these calculations suggest if windfall profits from free allocation are considered. With any pass-through of costs from freely-allocated permits, there is the potential for households that are shareholders to receive significant benefits from the SPEDE due to free allocation (Jegou and Rubini, 2011). Shareholder benefits occur because firms are passing through the opportunity cost of not selling the permit they receive under free allocation. As higher income quintiles would hold more shares than lower income ones, this creates the potential for another regressive aspect for the policy outside of the higher carbon intensity of spending of low income households. For example, Lee, (2011) found the equity impacts of the corporate tax cuts from BC's carbon tax had regressive effects. While a full analysis of windfall profits is not possible due to data limitations, investment income by quintiles defined by individuals from the 2006 Census Public Use Microfiles [6] shows that the richest quintile receives 55% of the investment income in the province compared 8% for the lowest quintile. The strong trend of the increasing investment income across individual quintiles suggests that a similar regressive effect from extra shareholder profits from free allocation may occur under the SPEDE.

In Figure 6 the impact at the 2015 price floor is shown for both pass-through scenarios. As discussed earlier, the difference in impact is much stronger if there is full pass through; for limited pass-through the first three quintiles are similarly impacted. In particular, the effect on the lowest income quintile will be stronger if a scenario closer to full pass through plays out and almost all of the costs of period one firms are passed on to households. However, both scenarios do show that poorer households will be disproportionately affected by the cap in percentage terms. Although higher quintiles experience higher dollar losses, the cap reduces the average income of poorer households by a greater extent.

### 5.2.1 Fuel Elasticity Analysis

Quebec's carbon market is not expected to have large effects on the price of gasoline. We calculated price increases of \$0.02, \$0.05 and \$0.10 per litre for the carbon prices of \$12.07, \$25.00 and \$48.20/ $tCO_2e$ respectively, taking into account an existing carbon levy of \$4.26/ $tCO_2e$. These are increases

[6] As opposed to quintiles by household as used in the Survey of Household Spending, the primary dataset used in the household analysis

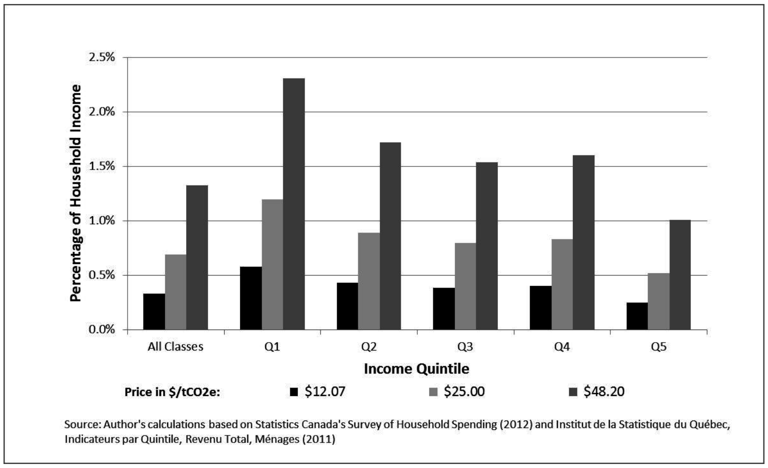


Figure 5: Full Pass-Through: Impact as % of Household Income by income group

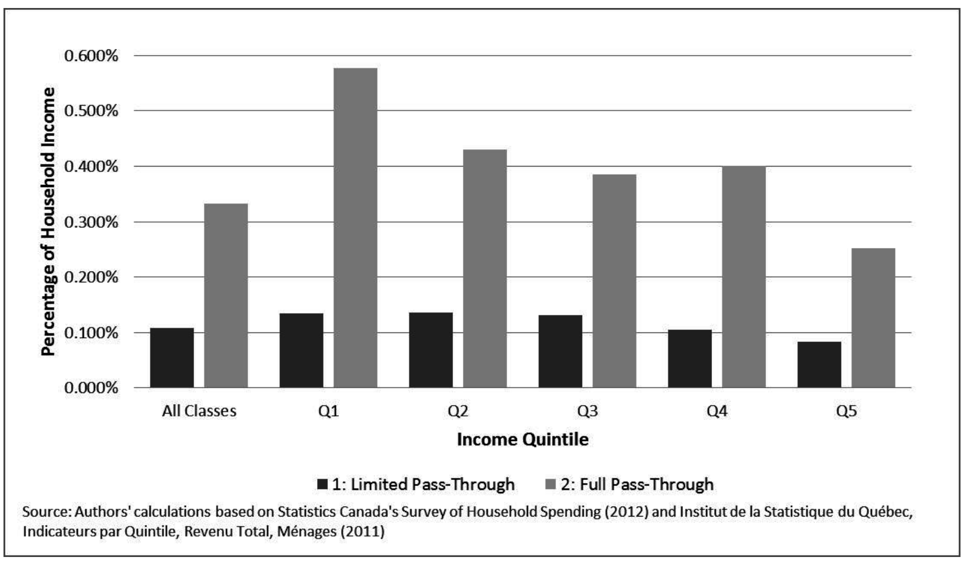


Figure 6: Comparing Scenarios: Impact as a fraction of household income by income group at 2015 price floor. Source: Authors' calculations based on Statistics Canada's Survey of Household Spending (2012) and Quebec Institute of Statistics, Household Income by Quintile (2011)

of 1.4%, 3.6% and 7.6% on existing fuel prices, and are in line with those calculated by the authors of the report on the recent commission on energy in Quebec (Lanoue and Mousseau, 2014). In order to determine how households are likely to react to changes in gasoline prices under the SPEDE, the short-run price elasticity of transport demand for cars was found according to the percentage of urban and rural inhabitants in each quintile. Although there was a trend of increasing proportion of urban residence with income, the overall differences were not substantial enough to cause large differences in price elasticity of transport demand across quintiles, with Q1 elasticity at -0.253, and Q5 at -0.270.

As these elasticities areless than 1,, the change in demand for transport in cars is expected to be less than the change in price of fuel. In terms of percentage change in demand — and the associated emissions — at $12.07 per $tCO_2e$, all quintiles are below a decrease of 0.4%, and on average this result in an $7.50 decrease in annual spending on gasoline per quintile relative to a scenario where SPEDE is in place but no behavioural changes occur. Even at the price ceilling, these changes remain moderate, with all quintiles decreasing their spending on gasoline by less than 2.5%, with an average decrease in annual spending of $42.40. This means the cost of the SPEDE per household falls by 3.7% on average at the price floor. With these fuel elasticity considerations, there is still a net increase in spending on gasoline,

The changes in reaction to the price increase from the SPEDE are not dramatic. While this does not have any implications on the equity of the policy, it does indicate that the market will not likely discourage emissions from gasoline in the short-run enough to make significant progress towards the emissions reduction goal of 20% below 1990 levels. This suggests that incentives to reduce gasoline use will need to come from elsewhere, such as spending on public transport, an important part of the province's current plan for the SPEDE revenues (Government of Quebec, 2013).

## 5.3 Industrial Impact

We next assess impacts on two more dimensions: variation across industry groups and variation across geographic areas.

### 5.3.1 Industry Costs

In 2015, average levels of free allocation are 85% for manufacturing, 97% for utilities, and 91.4% for mining due to the combination of industries in each of these sectors and the different levels of free allocation assigned for

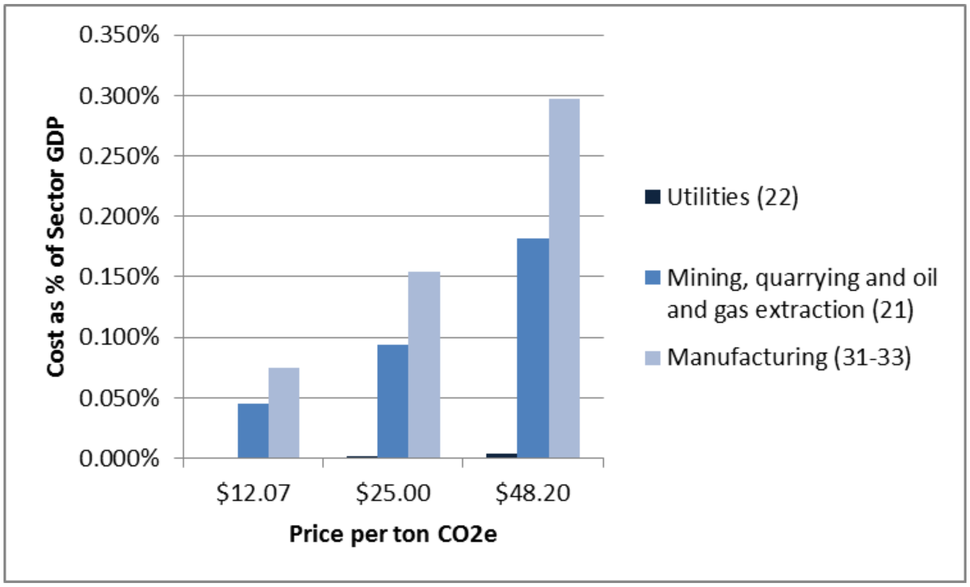


Figure 7: 2-digit NAICS industry impacts relative to contribution to GDP, limited pass-through

different kinds of emissions. Without this free allocation, short-run costs to each of these sectors would be high in the case where no pass-through is possible, at $209.2 million for manufacturing, $16.3 million for mining, and $4.4 million for utilities at the price floor of $12.07. However, free allocation limits these costs substantially, to $31.7 million for manufacturing, $1.4 million for mining, and $0.13 million for utilities at the price floor. As 70 of the 79 facilities covered in period one are in the manufacturing sector, with only 3 in utilities and 4 in mining and quarrying, it is reasonable that the manufacturing sector as a whole would experience the highest short-run costs.

Figure 7 shows the impact to each of these three broad sectors for the no pass-through scenarios relative to each sector's contribution to GDP at each of the three price levels. As can be seen, manufacturing also faces the highest costs when put in terms relative to its sectoral GDP, with mining slightly lower, and utilities with very low costs relative to sectoral GDP.

Table 5 shows all of the sectors ranked from highest to lowest cost relative to their contribution to GDP as well as the total cost to the sector at the 2015 price floor for the no-pass through scenario. Costs would be proportionately higher for the middle and ceiling price points, but relative costs between industries remain the same at all prices. Both the mining and utility sectors are near the bottom in terms of impact. Iron and steel manufacturing has the largest costs relative to its industry size, followed by an aggregation of the non-metallics mineral production category, which in the Quebec case includes mostly lime, gypsum, and glass manufacturing. Aluminum manufacturing is fifth in terms of relative impact, but first in terms of overall cost to the industry due to its high contribution to GDP. Notably, the traditionally economically important sectors of power generation and forestry product manufacturing (3221, 3211, and 3212) all have relatively low costs compared to their value-added contributions.

In scenario two, where companies are able to pass-through their costs to consumers, there are substantial revenues for each of the sectors, as they are able to pass on their increased costs to consumers, but are receiving most of their permits for free from the government. This phenomenon of 'windfall profits' from free allocation, discussed in Section 5.2, has been observed in the EU ETS in sectors receiving high levels of permits for free, and an analogous effect has been seen with corporate tax cuts included in BC's carbon tax (Jegou and Rubini, 2011; Lee, 2011). Thus, it is reasonable that firms will pass on some portion of the 'opportunity cost' of not making emissions reductions in the form of higher consumer prices, and increase their revenue as a result of the policy. At the 2015 price floor, \$12.07/t$CO_2$e, manufacturing has a potential increase in revenue of \$177.5 million, mining one of \$14.9 million, and utilities \$4.3 milllion, representing 0.42%, 0.48% and 0.03% of their current sectoral GDPs respectively. At the price ceiling, these revenues rise to 1.66%, 1.92% and 0.13%.

At the 4-digit NAICS level, those industries that would face the highest costs relative to their industry size in the no-pass through scenario also generally face the highest potential for windfall revenues if their sector characteristics allow them to pass-through costs. Iron and steel manufacturing therefore has the highest maximum potential windfall at 10.6% of industry GDP at the 2015 price floor, followed by cement at 3.8%. and petroleum refining at 2.2%. The aluminum industry has the highest total possible windfall profits at \$58.7 million in freely allocated permits. It is important to note that in reality due to market structure, most firms will not pass on all of their new marginal costs in order to avoid losing market share, and these are estimates of the maximum possible profit to industries from free allocation.

| Sector | NAICS Code | Cost to Sector at $12.07 per $tCO_2e$ | Cost as a fraction of contribution to GDP |
|---|---|---|---|
| iron and steel manufacturing | 3311 | $2.4M | 1.0% |
| non-metallics mineral production (excl. cement) | 327A | $4.4M | 0.72% |
| petroleum refinery | 3241 | $6.8M | 0.50% |
| cement manufacturing | 3273 | $3.4 | 0.49% |
| aluminum manufacturing | 3313 | $14M | 0.41% |
| foundries | 3315 | $5.6M | 0.22% |
| pulp and paper | 3221 | $2.5 | 0.15% |
| sugar manufacturing | 3113 | $0.20M | 0.095% |
| plastic manufacturing | 3261 | $1.4M | 0.078% |
| sawmills | 3211 | $0.24M | 0.037% |
| other chemical manufacturing | 3259 | $0.062M | 0.019% |
| particle board mill | 3212 | $0.066M | 0.013% |
| metal ore mining | 2122 | $1.4M | 0.012% |
| metal smelting and refining manufacturing | 3314 | $0.12M | 0.011% |
| electronic manufacturing | 3344 | $0.047M | 0.009% |
| power generation | 2211 | $0.85M | 0.007% |
| basic organic chemical manufacturing | 3251 | $1.7M | x |
| distilleries | 3121 | $0.049M | x |

Table 5: 4-digit NAICS industry impacts relative to contribution to provincial GDP, limited pass-through. Note: 'x' denotes industry GDP was not available at the 4-digit level. Source: Authors' own calculations; emissions data from Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013); sectoral GDP information from Statistics Canada CANSIM Table 384-0038

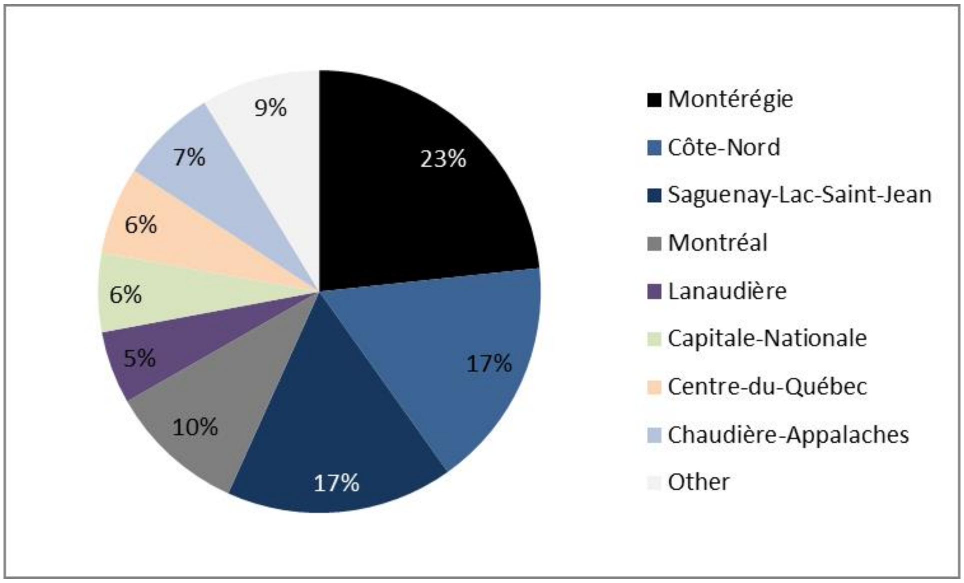


Figure 8: Period 1 Emissions by Administrative Region, 2012. Source: Author's calculations from Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013)

#### 5.3.2 Administrative regions

For the province as a whole, total cost to industry for period one firms assuming the "limited pass-through" scenario is 0.01% of the GDP. Disaggregating first-period facility-based emissions into Quebec administrative regions (ARs), we find that the four regions with the highest level of industrial GHG emissions are Montérégie, Côte Nord, and Saguenay-Lac Saint-Jean, and Montréal. All other regions had less than 10% of the total emissions coverage, as can be seen in Figure 8.

Other than Montreal, whose regional GDP is the highest in the province, these administrative regions with high emissions unsurprisingly face the highest costs relative to their regional GDP. As seen in Table 6, when costs are scaled to regional GDP, Côte-Nord followed by Saguenay-Lac-Saint-Jean, Centre-du-Québec and Chaudière-Appalaches face the highest costs in the no-pass through scenario. However, even these costs are small relative to GDP, with impacts being 0.090% of Côte-Nord's GDP, and the average cost for affected administrative regions being 0.022% of GDP. If proportionately higher costs at the price ceiling are calculated, the impacts relative to GDP remain fairly low, at 0.36% for Côte-Nord, 0.27% for Saguenay-Lac-Saint-

| Administrative Region | Facilities | Maximum Cost to Region at $12.07 per $tCO_2e$ | Maximum Cost to region as a fraction of of GDP at $12.07 per $tCO_2e$ |
|---|---|---|---|
| Côte-Nord | 6 | $6.1M | 0.0902% |
| Saguenay-Lac-Saint-Jean | 10 | $7.5M | 0.0679% |
| Centre-du-Québec | 6 | $2.4M | 0.0276% |
| Chaudière-Appalaches | 1 | $3.7M | 0.0259% |
| Mauricie | 5 | $1.3M | 0.0149% |
| Montérégie | 18 | $6.7M | 0.0135% |
| Lanaudière | 3 | $1.5M | 0.0129% |
| Abitibi-Témiscamingue | 3 | $0.68M | 0.0096% |
| Estrie | 3 | $0.69M | 0.0065% |
| Capitale-Nationale | 4 | $2.1M | 0.0064% |
| Montréal | 11 | $4.6M | 0.0040% |
| Outaouais | 4 | $0.43M | 0.0035% |
| Gaspésie–Îles-de-la-Madeleine | 1 | $0.045M | 0.0016% |

Table 6: Estimated short-run impacts by Administrative Region, limited pass-through, 2015. Source: Regional GDP from Quebec Institute of Statistics, 2010-2013 average, emissions data from Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013).

Jean, and 0.11% for Centre-du-Québec. At this maximum price level, all other regions have impacts below 0.10%. In some cases, certain facilities that are large and carbon intensive can make a large difference for a whole region. For example, Chaudière-Appalaches has the fourth highest relative costs but only one facility, a petroleum refinery.

For the full pass-through scenario, there is a net benefit to administrative regions' GDP, as firms are not paying for the bulk of their emissions and are still raising prices to cover the full market price of $CO_2$-equivalent. This net benefit is a maximum estimate, and relies on the assumption that firms will pass on the full opportunity cost of the permits they receive through free allocation, as well as the full cost of any permits they need to purchase.

In reality, many firms will only be able to pass on some of the opportunity cost to consumers in the form of higher prices due to concerns about the resulting fall in demand for their products as consumers switch to imports or substitute goods. The regions that had the highest costs also have the highest potential for windfall profits if their firms are able to pass through prices to consumers, with potential revenues of 0.48% of GDP for Côte-Nord, 0.28% for Saguenay-Lac-Saint-Jean, and 0.139% for Centre-du-Quebec at the 2015 price floor. It is important to note however, that these extra revenues are merely a redistribution of money from household savings and investment to revenue for producers, and are a direct result of reduced effective expendable income for households.

#### 5.3.3 Labour Force

It is important to assess what potential there is for a concentration of short-run impacts with respect to labour in a certain sector or region from the SPEDE. Many past analyses, such as Ho, Morgenstern, and Shih, (2008), model losses to labour or wages in the short-run as proportionate to the decrease in output resulting from reduced consumer demand from higher prices. This assumes that all costs to the company are borne directly to labour, while it is possible companies will choose to bear extra costs rather than make cuts to labour if the decrease in output is expected to be only short-run. While we provide no estimates of how firms will react to higher costs and the resulting lower output in terms of number of jobs lost, we show the maximum cost per job for the limited pass through scenario, at each of the three sample carbon prices. This allows for relative comparisons of how labour might be affected among regions. In reality, firms will likely pass on some of the costs in the form of higher prices, thus experiencing lower costs in per-job terms. Table 7 shows costs relative to the number of jobs in each broad sector at the 2-digit level. As could be expected from its high cost as a fraction of income, described above, manufacturing also has the highest costs per job. It is important to note that utilities have extremely low costs, and are thus not likely to experience any short-run labour effects.

Table 8 shows the same per-job estimates at the 4-digit sectoral level, ranked from highest to lowest. Here, trends are somewhat different when looking at costs relative to the sectors' contributions to GDP. On a per-job basis, plastic manufacturing, petroleum refining, "other" non-metallics mineral product manufacturing [7] and cement manufacturing all face maximum

[7]"Other non-metallics mineral production" (3279) does not include cement, lime and gypsum which have their own 4-digit NAICS codes

| Sector | Jobs in Sector | Average cost per job ($12.07 / $tCO_2e$) | Average cost per job ($25.00 / $tCO_2e$) | Average cost per job ($48.20 / $tCO_2e$) |
|---|---|---|---|---|
| Manufacturing (31-33) | 23,311 | $1,400 | $2,800 | $5,400 |
| Mining, quarrying (21) | 3,811 | $370 | $770 | $1,500 |
| Utilities (22) | 21,698 | $6.0 | $12 | $24 |

Table 7: Estimated short-run cost per job by 2-digit NAICS, limited pass through, 2015. Source: Authors' calculations.

costs of over $5000 per job at the 2015 price floor. Sectors like plastic manufacturing and other non-metallics mineral product manufacturing rank much higher according to cost per job than they did for cost relative to the size of the industry, suggesting that these firms may typically have a high capital to labour ratio, which means they may be able to adjust capital more easily in the short-run than make cuts to labour as the chronology of impacts in Table 1 suggests. It is also notable that aluminum manufacturing has the second highest number of jobs and has significant costs at $1,857 per job, and thus further investigation into how the industry is likely to react to short-run costs could help prevent a concentration of labour impacts.

A similar analysis was done across regions, with results in Table 9 . As with the 4-digit NAICS cost per job assessment, the picture differs from that of the cost relative to regional GDP. Chaudière-Appalaches has the highest cost per job of any region, due to the fact that the only facility affected in the region is a petroleum refinery, with high emissions intensity. Capitale-Nationale, in second, has four facilities, with an aluminum manufacturing plant and a cement manufacturing firm contributing to most of the costs. Chaudière-Appalaches, Capitale-Nationale, and Centre-du-Québec also appear in the top five administrative regions for costs relative to regional GDP, suggesting these regions are likely to bear more costs from the SPEDE than others.[8] However, with the possibility of pass-through and firms bearing extra costs temporarily, the portions of the "cost per job" figures that will actually be born by labour are likely to be low, especially if the carbon price remains nearer to the price floor, as is projected for 2015 Point Carbon,

[8]Note that Hydro Quebec has the largest number of employees, but is listed as only one facility in Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013), located in Montreal. As all of these jobs are surely not in Montreal alone, hydroelectricity was not included in the labour assessment by region.

| Sector | NAICS | Jobs | Average cost per job | | |
|---|---|---|---|---|---|
| | | | $12/ $tCO_2e$ | $25/ $tCO_2e$ | $48/ $tCO_2e$ |
| plastic manufacturing | 3261 | 105 | $14,000 | $28,000 | $54,000 |
| petroleum refinery | 3241 | 830 | $8,200 | $17,000 | $33,000 |
| other non-metallics mineral product manufacturing | 3279 | 66 | $6,100 | $13,000 | $25,000 |
| cement manufacturing | 3273 | 578 | $5,900 | $12,000 | $24,000 |
| lime and gyspsum manufacturing | 3274 | 477 | $2,700 | $5,600 | $11,000 |
| basic organic chemical manufacturing | 3251 | 879 | $1,900 | $4,000 | $7,700 |
| aluminum manufacturing | 3313 | 7796 | $1,900 | $3,800 | $7,400 |
| sawmills | 3211 | 145 | $1,700 | $3,500 | $6,700 |
| glass manufacturing | 3272 | 200 | $880 | $1,800 | $3,500 |
| iron and steel manufacturing | 3311 | 2990 | $800 | $1,700 | $3,200 |
| particle board mill | 3212 | 102 | $640 | $1,300 | $2,600 |
| foundries | 3315 | 878 | $640 | $1,300 | $2,500 |
| other chemical manufacturing | 3259 | 108 | $580 | $1,200 | $2,300 |
| sugar manufacturing | 3113 | 350 | $560 | $1,200 | $2,200 |
| pulp and paper | 3221 | 6068 | $410 | $840 | $1,600 |
| metal ore mining | 2122 | 3811 | $370 | $770 | $1,500 |
| distilleries | 3121 | 215 | $230 | $480 | $920 |
| electronic manufacturing | 3344 | 420 | $110 | $230 | $450 |
| metal smelting and refining manufacturing | 3314 | 1104 | $110 | $230 | $450 |
| power generation | 2211 | 21698 | $39 | $81 | $160 |

Table 8: Estimated short-run annual cost per job by 4-digit NAICS, limited pass through, 2015. Source: Authors' calculations from Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013) and Environment Canada, (2014).

(2013).

## 6 Conclusion

We find that overall, Quebec's SPEDE is unlikely to place a high burden of costs for any household income groups or industries, with costs below 2.3% of household income and 4% of industry contribution of GDP for all groups even at the maximum carbon price for 2015. Market analyses, and the auctions to date, indicate that the price will remain far below the ceiling and closer to the $12.07 price floor, minimizing these costs further.

While these impacts appear likely to remain low, it is notable that one source of increased inequality through the policy comes from windfall profits to shareholders, predominantly among higher income households, as a result of permit handouts. Future policy platforms from the Quebec government should include higher subsidies or energy efficiency rebate programs for lower income families.

In addition, as the carbon price does rise significantly from its lower bound, the Province should have in place its own mitigation infrastructure programs such as the continued electrification of transport, which may also provide a progressive counterbalance to the modest regressive household effects we have estimated.

We estimate industrial impacts on period one firms to be generally positive, or minor, due to profits flowing from the generous free allocation policy. These estimates exclude a full input-output analysis; however, this is expected to introduce very little bias due to the low indirect emissions of intermediate goods firms operating with Quebec Hydro's low-carbon energy. As a result, the planned schedule of emissions cuts in Quebec should not be the cause of significant job losses. If there are exceptions, they are likely to be in the aluminum industry and in the regions of Chaudière-Appalaches, Montréal, and Centre-du-Québec. Retraining and labour transition plans in sensitive regions and industries should become part of the policy associated with the cap and trade system.

#### Strengths and challenges

Above all, important features of a carbon pricing system are predictability combined with steady increases towards true social costs. Especially in light of the low prices for carbon permits in Europe, New Zealand, Australia, futures in California, and elsewhere, the price floor in Quebec's system tells investors that they are ensured a minimum return on any carbon efficiency

| Administrative Region | Jobs | average cost per job ($12.07 per $tCO_2e$) | average cost per job ($25.00 per $tCO_2e$) | average cost per job ($48.20 per $tCO_2e$) |
|---|---|---|---|---|
| Chaudière-Appalaches | 465 | $8,030 | $16,632 | $32,066 |
| Montréal | 2015 | $2,300 | $4,763 | $9,184 |
| Capitale-Nationale | 953 | $2,184 | $4,523 | $8,720 |
| Centre-du-Québec | 1432 | $1,685 | $3,490 | $6,729 |
| Lanaudière | 966 | $1,578 | $3,268 | $6,300 |
| Saguenay-Lac-Saint-Jean | 4825 | $1,548 | $3,206 | $6,182 |
| Montérégie | 5428 | $1,240 | $2,568 | $4,950 |
| Côte-Nord | 5523 | $1,101 | $2,280 | $4,396 |
| Mauricie | 1738 | $742 | $1,537 | $2,964 |
| Outaouais | 678 | $640 | $1,326 | $2,556 |
| Estrie | 1133 | $607 | $1,257 | $2,423 |
| Gaspésie–Îles-de-la-Madeleine | 77 | $588 | $1,219 | $2,349 |
| Abitibi-Témiscamingue | 2056 | $331 | $686 | $1,323 |

Table 9: Estimated short-run annual cost per job by administrative region, limited pass through, 2015. Source: Authors' calculations from Ministry of Sustainable Development, Environment and Parks (MDDEP), (2013) and Environment Canada, (2014)

investments they make. Combined with a price ceiling, to ensure against high short-run costs, this hybrid pricing mechanism provides some of the respective benefits of both an escalating carbon tax and a cap and trade system. As a result, everyone in Quebec has an idea of future costs in the medium run, is ensured against too sudden a transition, and has an incentive to invest in transitioning towards more climate-friendly consumption and production patterns and technologies.

Secondly, the Quebec policy achieves a balance between raising revenue from the carbon permits (through auctions) and minimising the short-run impact on workers and firms, by handing out permits for free rather than selling them. Giving some permits away for free does not, in the short term, reduce the incentive for firms to invest in emissions-reducing technology, but it does diminish the revenue available for the government to spend on a bundle of related policies. This package should include measures to counteract the regressive impacts on household budgets, subsidising retraining of workers in the most affected industries, and investing in other, complementary climate mitigation policies, in particular through public infrastructure.

Our calculations of economic impacts reflect this balance, in that we have assumed some fraction of the permits are handed out for free. However, while we have identified regressive effects on households and labour markets, we have included no programmes for redistribution or retraining since none are guaranteed or even detailed as part of the policies announced so far. As already mentioned, auction revenues will be spent entirely on mitigating both greenhouse gas emissions and the social and economic impact of the cap and trade costs; however the details of this spending are unspecified.

As compared with the revenue-neutral commitment of British Columbia's carbon tax, in which all new revenues have been offset by concurrent income and corporate tax cuts, the flexibility of Quebec's Green Fund has a drawback in terms of political commitment. In Quebec, the credibility of the stated timetable to 2020 comes largely through the lost investments which would be incurred by industry were the planned caps to be relaxed in the future. However, the size of these losses is not clear, and relaxing any of the constraints may not be too unpopular for a future government, opposed to the policy, to consider. By contrast in B.C., revoking the carbon tax would require an unpopular increase in other taxes to avoid a drastic shortfall in general revenue; thus the tax shift is politically locked in.

In fact, given our analysis of the apparently gentle transition costs on the short term, the Quebec policy could to be revised to be considerably more stringent, with an aggressively shrinking cap, in the case that more trade partners begin to join the WCI. It would be natural that each new negotiation and entrance of new partners be an opportunity to strengthen the long-term price signal, since trade risks diminish as the partnership grows. This could come in the form of setting a more stringent reduction schedule for post-2020, in order to bolster industry confidence about the price trajectory.

Quebec's policy provides a model of a cap implementation without undue hardship for the population. While described as a cap and trade program, it has features which provide price predictability in the short term, when that is most important. However, it has a great deal of detail built into it in order to assure its impact on the quantitative emissions problem over time, and may have advantages over a simple, predictable tax in a jurisdiction like Quebec where new fossil fuel development is unlikely to play a major role. In this regard, its only drawback is that it is still too weak to meaningfully address the environmental imperatives as outlined in the IPCC's 2014 Fifth Assessment Synthesis Report, in which fully eliminating carbon emissions is the benchmark for long-term policy goals.

So far, market prices have remained near the floor while achieving the earliest part of the emissions reductions timeline. However, should they instead find themselves near the ceiling price, then achievement of the stated mitigation reduction targets would be at risk. The steady increase of these ceilings is another vital feature of the WCI policy.

Our focus on short term impacts reflects the idea that once a system is politically accepted, the new institutions implemented, and a transparent emissions reduction trajectory is in place, countless sources of adjustment and innovation in the economy, both foreseeable and unforeseen, are likely to be able to adapt to maintain a manageable level of economic costs. The gentle introduction that has been achieved suggests that the system in Quebec may have been sufficiently well-tailored to achieve this balance, which characterizes economic efficiency given the mitigation imperative. More specifically, if decarbonisation by mid-Century, for instance, is taken as a policy benchmark, then the most efficient or cost-effective policy is the one which spreads out the economic costs of transition as evenly as possible over time.

Lastly, our calculations, which find low costs and moderate equity impacts of the programme for Québec, are relevant to the short term. The short run is important for introducing and entrenching the policy, thereafter letting transparent incentives do their work, and for making the policy seem politically feasible (a short run condition) to neighbouring jurisdictions. For the SPEDE policy to remain sustainable, it becomes increasingly urgent that Québec and California recruit other jurisdictions to join their carefully-designed market in order to keep the playing field fair between trading partners.

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# A Appendix

Table 10 shows the fraction of combustion emissions relative to other emissions as reported in a US Environmental Protection Agency (EPA), (2008) industry wide analysis. Based on the 2015 levels of free allocation for combustion and other emissions (77% and 97% respectively), the level of free allocation received by each industry in 2015 was calculated, and these numbers were used to calculate impacts for industry and regions in both pass through scenarios.

| Sector | NAICS | Combustion Emissions | Free Allocation in 2015 |
|---|---|---|---|
| metal ore mining | 2122 | 28.2% | 91.4% |
| power generation | 2211 | 82% | 80.6% |
| sugar manufacturing | 3113 | 100% | 77.0% |
| distilleries | 3121 | 100% | 77.0% |
| sawmills | 3211 | 100% | 77.0% |
| particle board mill | 3212 | 100% | 77.0% |
| pulp and paper | 3221 | 92.1% | 78.6% |
| petroleum refinery | 3241 | 99.5% | 77.1% |
| basic organic chemical manufacturing | 3251 | 76.6% | 81.7% |
| other chemical manufacturing | 3259 | 76.6% | 81.7% |
| plastic manufacturing | 3261 | 100% | 77.0% |
| glass manufacturing | 3272 | 100% | 77.0% |
| cement manufacturing | 3273 | 83.8% | 88.5% |
| lime and gypsum manufacturing | 3274 | 42.9% | 88.4% |
| non-metallics mineral product manufacturing | 3279 | 100% | 77.0% |
| iron and steel manufacturing | 3311 | 42.9% | 91.4% |
| aluminum manufacturing | 3313 | 83.8% | 80.2% |
| metal smelting and refining manufacturing | 3314 | 50% | 87.0% |
| foundries | 33115 | 100% | 77.0% |
| electronic manufacturing | 3344 | 100% | 77.0% |

Table 10: Percentage of Combustion Emissions and Free Allocation by 4-digit NAICS Classification. Source: Authors' calculations, with data from US Environmental Protection Agency (EPA), (2008) except for power generation, which is from HydroQuebec, (2013)