The Short-Run Household, Industrial, and Labour Impacts of the Quebec Carbon Market

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Les résistances face à la mise en place de politiques en matière de tarification des émissions de gaz à effet de serre sont en partie liées à la crainte que ces mesures touchent plus certains secteurs économiques et certaines régions que d'autres, et touchent également moins les ménages aisés. Cela est compréhensible : de telles politiques, pour être équitables, doivent comporter des mesures permettant d'en atténuer les impacts. Toutefois, le système adopté récemment en cette matière par le Québec, en partenariat avec la Californie dans le cadre de la Western Climate Initiative, fixe des objectifs de prix relativement modestes, sera mis en place de façon progressive et prévoit l'affectation de fonds à des programmes de transition et d'atténuation des impacts qui toucheront le marché du travail et les ménages. Dans cet article, nous examinons les effets de ce système en en évaluant l'équité en matière de distribution des revenus entre les ménages et en ce qui a trait à la main-d'œuvre dans différents secteurs d'activité ; notre analyse se limite aux effets à court terme, c'est-à-dire avant une réaffectation importante du capital, et avant que la substitution de biens existants à d'autres, ayant un plus faible bilan carbone ou importés, ne se produise. Quand nous modélisons les émissions directes et indirectes, en tenant compte de prix raisonnables et selon deux scénarios de répercussions, les effets que nous observons sont faibles dans tous les cas ; toutefois, la généreuses allocation de permis pourrait entraîner des bénéfices exceptionnels. Par ailleurs, le Québec gagnerait à être plus transparent en ce qui a trait à l'affectation des revenus versés au Fonds vert. Bref, nous croyons que le système permet d'atteindre les objectifs visés – prévisibilité des prix, décarbonisation continue et coûts de transition gérables –, mais qu'il pourrait sûrement être plus audacieux.

Mots clés : prix du carbone, Québec, Western Climate Initiative, politiques sur les changements climatiques, répartition des revenus, politiques régionales, politiques industrielles

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, to be fair, policy can accommodate some transitional measures to soften the impact of sudden policy changes. However, 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 two domains: the household income distribution and labour in different industrial sectors. Our analysis focuses on the short-term effects, before capital is significantly reallocated, and before most substitution toward lower-carbon or imported goods has happened. 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.

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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 more aggressive.

Keywords: carbon price, Quebec, Western Climate Initiative, climate policy, income inequality, regional policy, industrial policy

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 percent 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 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 price 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 toward fewer GHG emissions, but in the short run it is important to identify the specific industries or areas that will have the most difficulty adjusting. This makes it possible to minimize labour losses via temporary subsidies, retraining programs, or 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 introduce and initiate policy. 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 (Jegou and Rubini 2011; Rootes 2014). 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 intended 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.

Predicting Carbon Price Impacts

While many analyses have focused on the economic efficiency and cost of carbon market mechanisms in reducing emissions, some address, like ours, the equity of such policies (European Commission, McKinsey, and Ecofys

2006; Gonne 2010; Ho, Morgenstern, and Shih 2008; Reinaud 2005). They assess the distribution of costs of these regulations across time scales, industrial sectors, regions, or household income levels 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. On the industrial side, carbon intensive industries such as petroleum refineries, primary metal manufacturing, or cement production usually face the largest costs and labour reductions.

A focus on equity effects and short-run effects is motivated in part by the challenge of gaining political support for carbon pricing, and for making its implementation politically feasible, as well as sustainable. If the political cost due to backlash from industry or hard-hit households is high, carbon pricing policies will not be feasible. If early experiences within the Western Climate Initiative are not positive, then an expansion of its membership or of compatible policies in neighbouring jurisdictions is unlikely.

Focusing on the short run affords several simplifications in our calculations, as well as a great deal of transparency that comes with simplicity. In the working paper version (Barrington-Leigh, Tucker, and Kritz Lara 2014) of this study, we provide a detailed review of the kinds of models that have been used to predict distributional impacts from carbon pricing systems. In our study, *short run* has the meaning explained in Ho et al. (2008), in that we treat primarily the effects of price changes on household budgets and industrial production costs without considering the various ways in which consumers and producers will ultimately change their mix of purchases by substituting some low-carbon goods and production inputs in place of extant higher carbon options. For household expenses, we consider the increasing costs borne due to direct burning of fossil fuels and to embodied carbon emissions in goods produced somewhere in Quebec. We also consider the shift away from private gasoline-powered transportation that households may undergo. However, we ignore other changes to household demand, including substitution toward imported goods not subject to the Quebec SPEDE, and capital investment such as more efficient homes or appliances.

For the effects on industry and workers, we consider the increase in production costs due to energy and materials subject to the carbon price, but we exclude the possibility of firms making capital adjustments or technological shifts to change their input mix. We do consider the possibility that firms change their prices in response to the extra costs, and in fact by addressing both a very limited price pass-through case and a complete pass-through case we are able to bracket the extent of effects on consumers, firms, and households.

For household income, we consider the scale of effects on workers in affected industries and we also discuss the distributional impacts of changing industry profits, which may be positive or negative and are likely to have differential impacts across household income distribution due to the variation in shareholder equity as a fraction of household assets.

Over the longer term, capital is reallocated between as well as within industries, and is reallocated by households; along with technological substitutions in industry and by consumers, these factors are all likely to reduce in the long run the scale of effects we estimate for the short run. However, considering full general equilibrium effects from changing aggregate production and, in particular, complex shifts due to import and export substitution, the ultimate magnitude or even sign of impacts cannot easily be constrained. On those time scales, we would argue, the uncertainties due to technological development and to subsequent policy shifts—including the participation of trade partners in carbon pricing systems—dominate anyway.

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 seven US states and four 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 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 on 13 November 2013 (MDDEP 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 et al. 2014).

This section describes the system's objectives, scope, and implementation as well as a brief discussion of the

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Table 1: Summary of SPEDE Scope and Implementation.

Industrial Sector	First Compliance Period	Free Allocation
Manufacturing	1	80% combustion, 100% process and "other"
Mining and quarrying	1	80% combustion, 100% process and "other"
Electric power generation, transmission, and distribution	1	80% combustion, 100% process and "other"
Steam and air conditioning production for industrial purposes	1	80% combustion, 100% process and "other"
Fuel distribution	2	0%
Pipeline transportation of fuel	2	0%

Note: Fuel includes gasoline, diesel fuel, propane, natural gas, and heating oil.
Source: Government of Quebec (2014).

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 1 January 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 (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The market's scope and implementation are summarized in Table 1.

The first period of the carbon market began in 2013 and covers the 79 emitters in the industrial and electricity generation sectors with annual greenhouse gas emissions that exceed 25 kilotonnes of carbon dioxide equivalent ($ktCO_2e$). The electricity generation sector includes all operators or facilities acquiring electricity produced outside Quebec that generate in excess of the annual threshold of 25 $ktCO_2e$. During this initial phase, the market covers approximately 28 percent of the province's emissions.

The second period began in January 2015, and it expands the market to include roughly 45 distributors of fossil fuels that distribute fuel and have emissions that *when consumed* exceed the 25 $ktCO_2e$ level, not including any fuel sold to firms already included in the carbon market in the first period. That is, industries already included in the first period 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 that 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 was an existing carbon levy on fuels that ended once the second compliance period began in 2015. The fuel levy amounted to $4.26 per tonne of carbon dioxide equivalent (tCO_2e), roughly one-third of the minimum that was initially enforced under SPEDE. 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 20.20 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 to 2020.

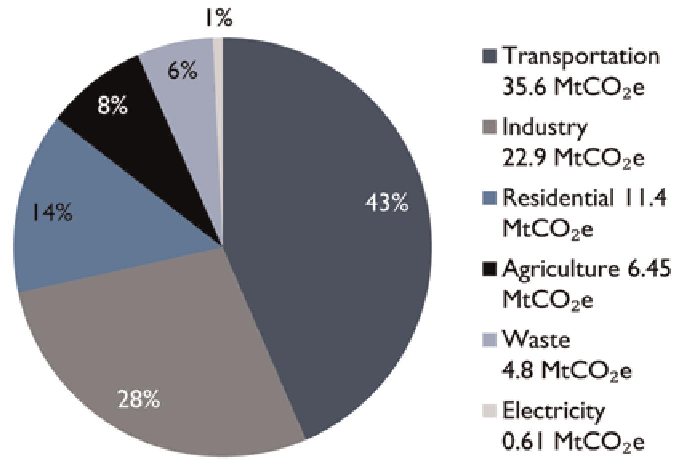

Figure 1: Quebec Emissions by Sector, 2009.
Source: Government of Quebec 2013.

During the second and third periods, the carbon market will cover about 85 percent of the province's total emissions, which are shown broken down by sector in Figure 1. The remainder is mostly the 14 percent of emissions from agriculture, waste, and deforestation, leaving only 1 percent made up of emitting companies below the 25 $ktCO_2e$ 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 third consecutive annual report in which their GHG emissions fall below the annual 25 $ktCO_2e$ threshold.

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The cap, and thus the number of GHG permits available for purchase, will decrease at an average annual rate of 4 percent from 2015 to 2020. Emission units will be auctioned by the MDDEP at most four times per year, and the price will be determined by demand at these auctions. However, there is a price floor (i.e., a minimum auction price per tonne of CO_2e set at \$10.75/tCO_2e 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* that 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 that are scheduled to increase annually in price by 5 percent 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. 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.

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 of annual permits for the industrial and electricity generation sectors that face competition from markets outside of Quebec. Free allocations are given 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 percent of their process emissions for free, 80 percent of their combustion emissions for free, and 100 percent 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 these 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 percent each year.

The market is expected to raise an estimated revenue of \$2.7 billion between 2013 and 2020. As stipulated in Section 46.16 of the Environmental Quality Act (R.S.Q., c. Q-2), this revenue 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 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 several 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 or geographical effects as is done in this analysis. Several analyses consider the effects of linking the Quebec and California markets, but these generally have more long-term considerations (see Purdon et al. 2014; Western Climate Initiative 2012). The WCI has conducted a series of its own analyses as the details of the policy have developed, with the most recent 2012 report estimating a carbon price of \$19–\$34 per tonne 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 percent 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).

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

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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.[2]

The effects of substitution toward 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.

Data

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. We also make use of the 2006 Census Public Use Microdata Files and other ancillary data sets as described later.

Methodology

As direct and indirect emissions are based on different emission intensities, the two sections below explain their methodologies separately.

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 and thus can be assumed to be negligible. Direct emissions were calculated as the product of the annual volume of fossil fuels purchased by households and 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:

$$\text{Emissions}(\text{FUEL}) = \frac{\text{Expenditure}}{\text{Price}} \times \left(\frac{\text{Emissions}}{Q}\right)(\text{FUEL}), \quad (1)$$

where $\left(\frac{\text{Emissions}}{Q}\right)(\text{FUEL})$ refers to a fuel's corresponding emissions factor.[3] 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 income quintiles Q1, Q2, Q3, and Q4; as an estimate, the reported average for all quintiles adjusted for the amount of Q5 spending data was used.

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.

For this calculation, differentiating between expenditures in local and imported goods and services is an important distinction. 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 not necessary 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.

We use Statistics Canada's Environmental Accounts Division's tabulations of indirect emissions by expenditure in 48 categories of goods as a basis for imputing the domestic component of Quebec's indirect emissions in each category and income quintile. Our calculation relies on an assumption that the propensity in Quebec to purchase imported goods is similar to the Canadian average. The indirect emissions released in the production of domestic good X are then calculated by:

$$\text{Emissions}_{(X)} = \frac{(1 - MPZ_{\text{CAN}}) \times \text{Emissions}_{\text{CAN}(X)}}{AE_{\text{CAN}(X)}} \times E_{\text{QC}(X)}, \quad (2)$$

where $(1 - MPZ_{\text{CAN}})$ represents Canada's import adjustment ratio, $\text{Emissions}_{\text{CAN}(X)}$ 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. Further details on the derivation of this expression are provided in the working paper version (Barrington-Leigh et al. 2014) of this study.

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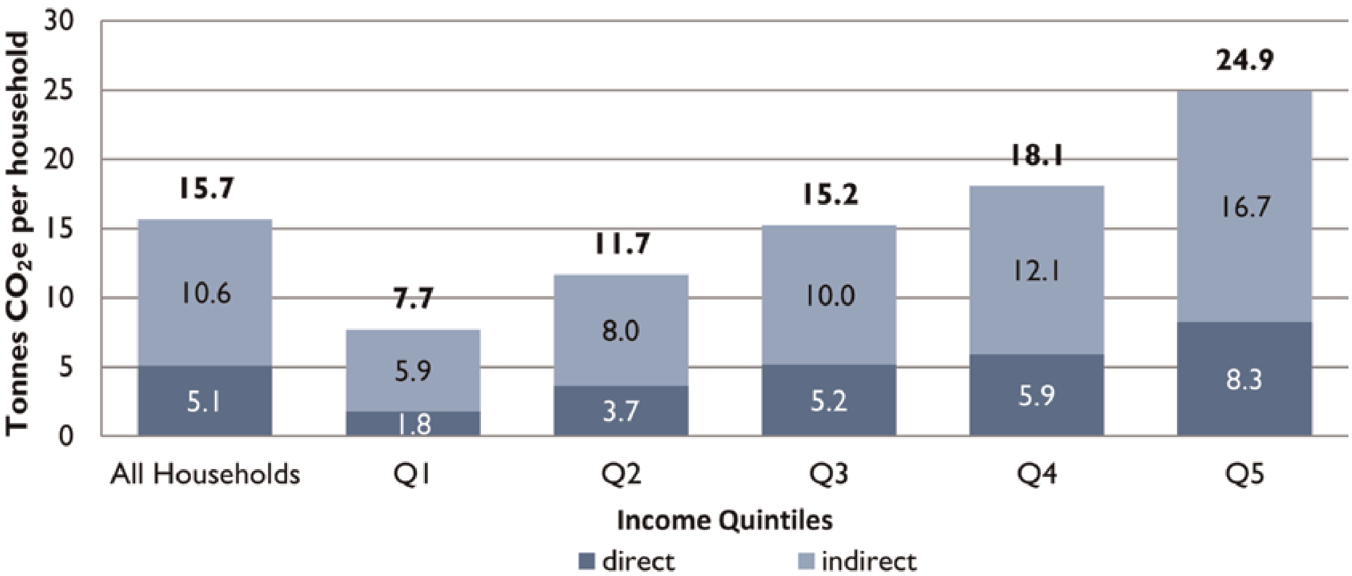

Figure 2: Quebec Direct and Indirect Household Emissions by Income Quintile, 2012
Source: Authors' calculations based on multiple sources (see Barrington-Leigh et al. 2014).

Fuel Elasticities Analysis

Gasoline for transport is by far the largest single category contributing to household emissions, accounting for 83 percent of the direct emissions released by the average Quebec household, and 27 percent of the total (15.7 tCO_2e). Due to this dominance, we analyze how households are likely to change their transport behaviour in the short run in response to carbon price changes. To the extent families are able to reduce their use of gasoline through shifts to alternative trasport, household income effects of the policy may be lessened, and impacts to retailers and producers will increase.

We use 2006 Census Public Use Microdata Files to find the rural and urban proportions of households in each income quintile, and to apply fuel price elasticities appropriate to each type of community (Goodwin, Dargay, and Hanly 2004; Litman 2007, 2013). Urban areas tend to have higher price sensitivities for gasoline due to the availability of public transit (Blow and Crawford 1997; Santos and Catchesides 2005; Wadud, Graham, and Noland 2009). The details of our calculations are available in the working paper version (Barrington-Leigh et al. 2014).

Pass-Through Scenarios

In one scenario, "limited pass-through," the direct household emissions for each quintile are multiplied by 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 the second scenario, "full pass-through," direct and indirect emissions are 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.

Results

In the working paper version (Barrington-Leigh et al. 2014) of this study we report and discuss in detail our calculations of household direct emissions by fuel type and income quintile, and of household indirect emissions by consumption category and income quintile. Figure 2 shows total emissions by income quintile. Across all households, indirect emissions account for two-thirds of the total. On average, households in the highest income quintile emitted 24.9 tCO_2e in 2012, 3.2 times more than those in the lowest income category. However, because the average number of people in a household increases with income quintile, emissions *per person* are only about one-third higher in the top group than in the bottom one.

Later, when considering industry impacts and profits, we discuss household income effects that come through shareholder profits. For the moment, we focus only on the expense side of household finances. The two pass-through scenarios are designed to show the total possible range of impacts for households across income quintiles. Figure 3 shows the impacts of three different prices for Quebec's carbon market for the limited pass-through scenario: at the 2015 price floor of $12.07 per tCO_2e, at

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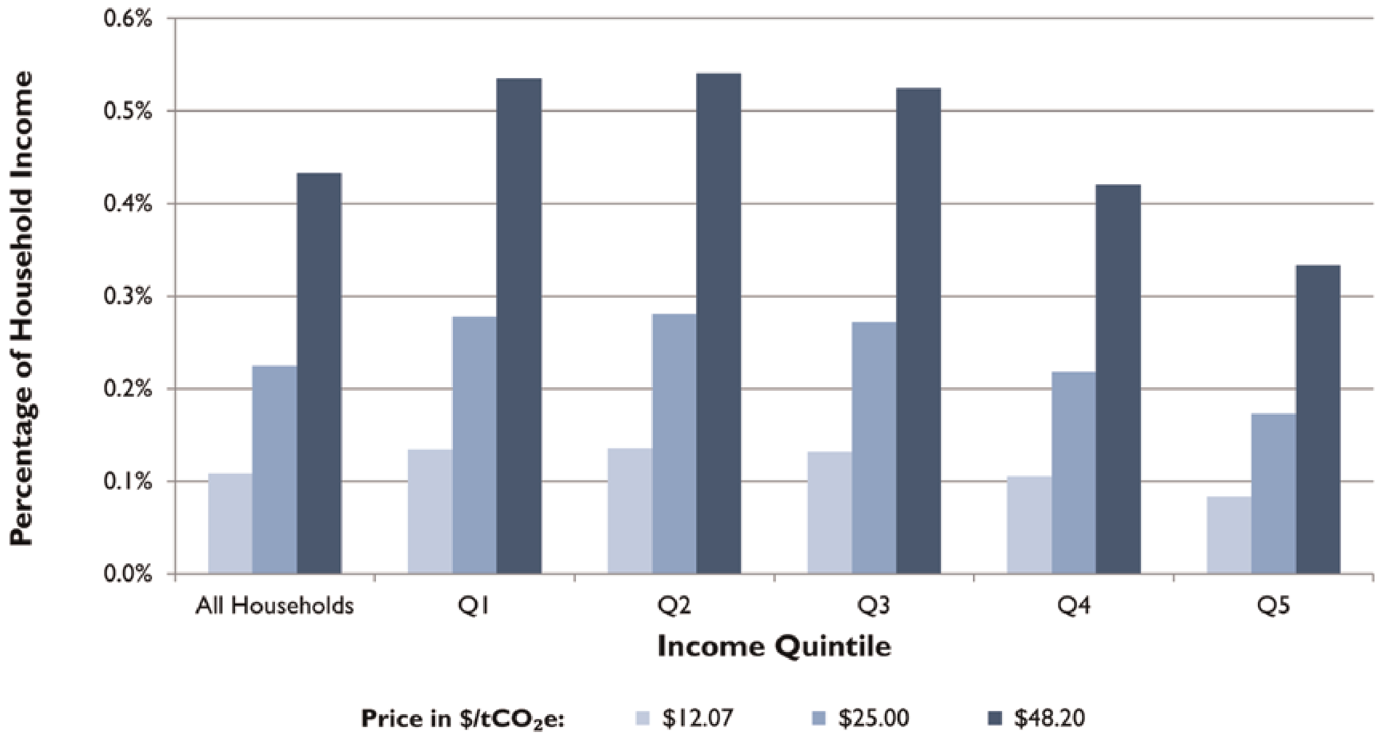

Figure 3: Limited Pass-Through: Impact as a Fraction of Household Income by Income Group
Source: Authors' calculations based on Statistics Canada 2012 and Institut de la Statistique du Québec 2011.

an intermediate value of $25.00, and at the 2015 reserve price ceiling[4] of $48.20.

Limited pass-through is the minimal household impact scenario where, due to the competition that firms other than fuel distributors face, they bear the costs of the carbon market rather than passing on costs to consumers. For instance, in this scenario the extra cost of fuel in rented accommodation is borne by landlords when it is included in a lease, but borne by occupants if they pay those bills directly. In this scenario, costs are actually highest relative to income for Q2, but even at the price ceiling these are just 0.54 percent of household income.

Figure 4 shows impacts for the full pass-through scenario. 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 British Columbia'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 Microdata Files[5] shows that the richest quintile receives 55 percent of the investment income in the province compared with 8 percent for the lowest quintile.

In Figure 5 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 first-period 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. These effects are small. For annual average household emissions of about 16 tCO_2e (Figure 2) and the ceiling price of $48, the extra cost is $750 per annum, or 1.3 percent of mean annual income. To assess the sensitivity of our estimates

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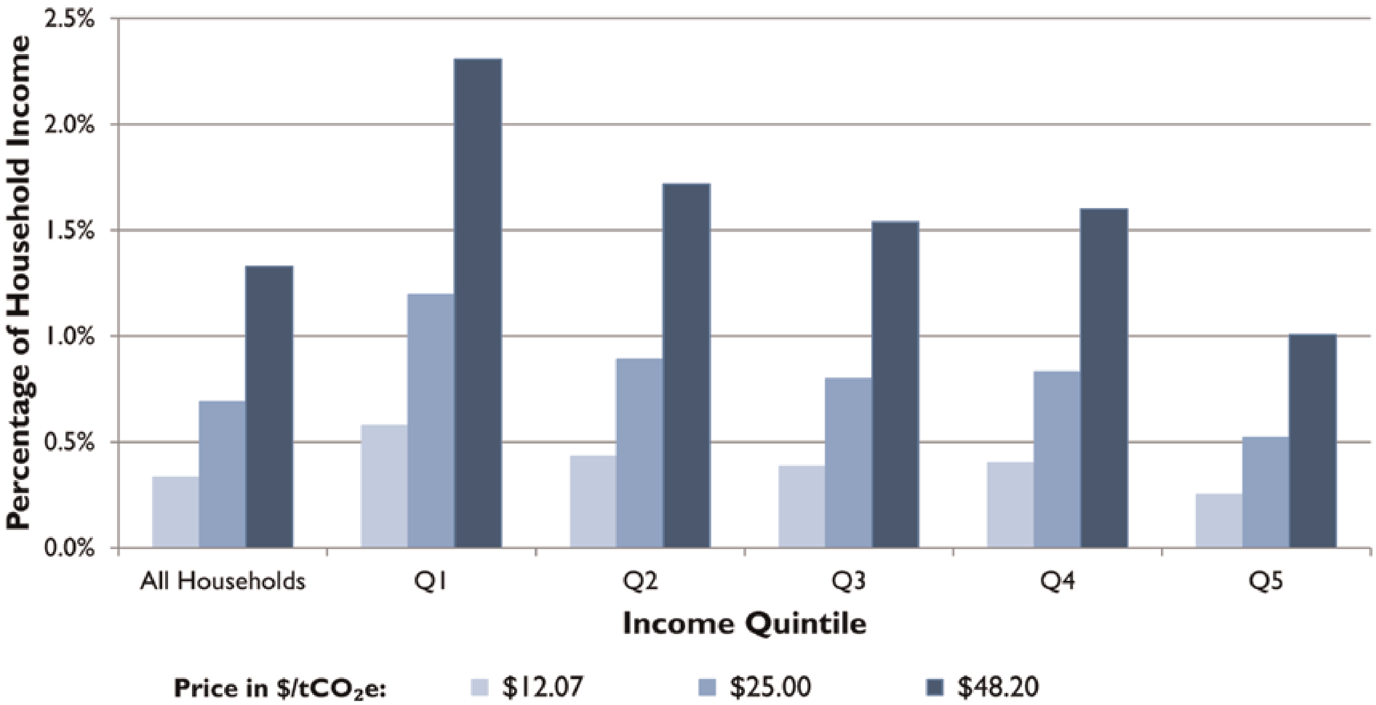

Figure 4: Full Pass-Through: Impact as Percent of Household Income by Income Group
Source: Authors' calculations based on Statistics Canada 2012 and Institut de la Statistique du Québec 2011.

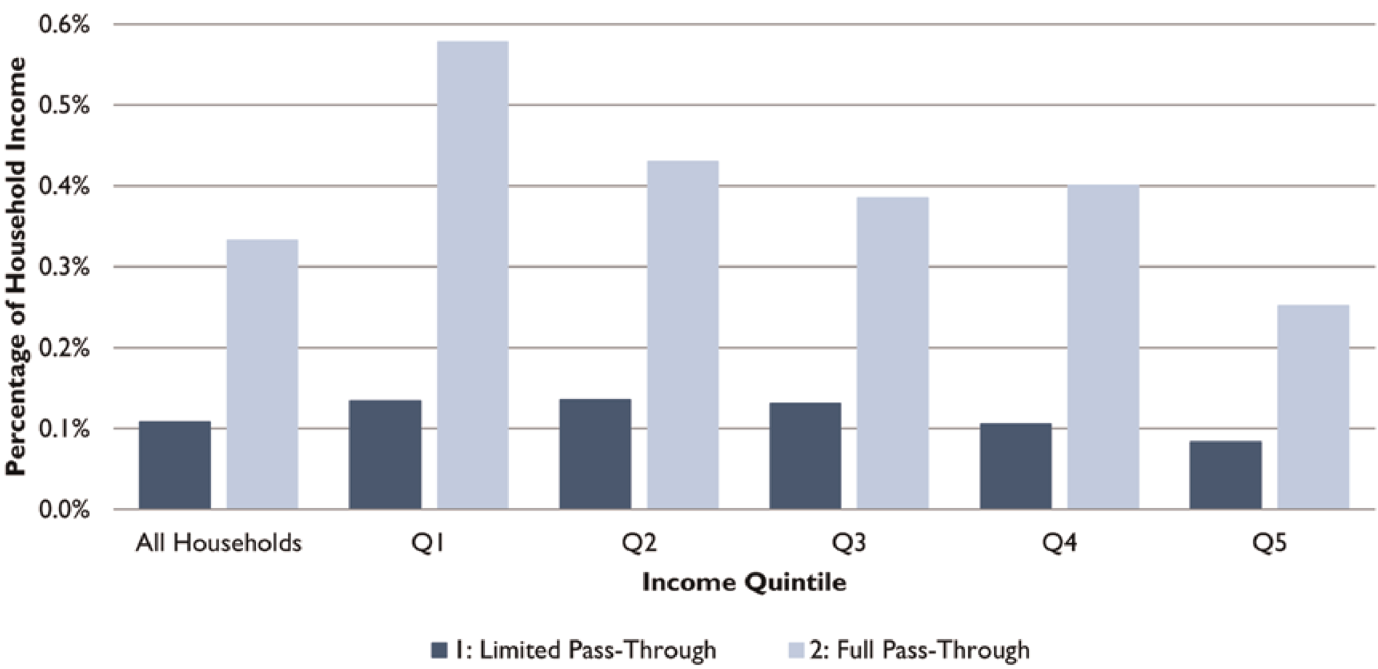

Figure 5: Comparing Scenarios: Impact as a Fraction of Household Income by Income Group at 2015 Price Floor
Source: Authors' calculations based on Statistics Canada 2012 and Institut de la Statistique du Québec 2011.

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to changes in spending patterns (i.e., demand response), we consider gasoline, which constitutes nearly a third of household emissions. In the near term, Quebec's carbon market is not expected to have a large effect on the price of gasoline. Price increases of \$0.02, \$0.05, and \$0.10 per litre correspond to the carbon prices of \$12.07, \$25.00, and \$48.20 per tCO_2e respectively, taking into account an existing carbon levy of \$4.26 per tCO_2e (Lanoue and Mousseau 2014 estimate similar values). We estimate the short-run price elasticity of transport demand for cars based on the fractions of rural and urban inhabitants in each income quintile, and find roughly uniform values of −0.253 for Q1 and −0.270 for Q5.

As these elasticities are less than one, the change in demand for transport in cars is expected to be less than the change in price of fuel. Even at the price ceiling, these changes in demand and associated emissions are moderate, with all quintiles decreasing their spending on gasoline by less than 2.5 percent, with an average decrease in annual spending of \$42.40 per year. The largest component of indirect emissions, food purchases, seems likely also to have a low short-run demand response, lending support to our predictions summarized in Figures 3 to 5.

A relatively small demand response implies that the market will not greatly discourage emissions from gasoline in the short run. We discuss the scale and distribution of household impacts after considering effects felt by industry.

Industrial Impact

As explained earlier, 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 percent for fixed process and "other" emissions, and 77 percent for combustion emissions (Government of Quebec 2014). 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. Later we focus on shareholder and labour impacts according to industrial sector categories. In the working paper version (Barrington-Leigh et al. 2014), we also examine the geographical distribution of these effects throughout the Quebec administrative regions.

Methodology

We use the North American Industry Classification System (NAICS) for aggregating firms into sectors; see the working paper version (Barrington-Leigh et al. 2014) for details. The MDDEP published a list of facilities covered by the SPEDE in the first period. We first calculate the short-run costs 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, in ours 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 labour impacts as well as the geographical distribution.

Less detail is available for the second period (i.e., fuel distributing firms). A list of firms that are responsible for reporting emissions to pay the carbon levy on fossil fuels that were phased out at the end of 2014 is available, but it does not yet include their approximate emissions. Because these firms face minimal competition from firms outside the province, they receive no free allocations and are also more likely to pass their permit prices through to consumers. We therefore expect impacts on these firms to be relatively small.

Impacts by Sector

We make short-run dollar loss estimates for each sector impacted by the first period rules and compare these figures with the sector's contribution to provincial GDP. Sectoral GDP data were retrieved from Statistics Canada CANSIM Table 384–0038. At the two-digit level, four of the establishments are listed under mining and quarrying (21), three under utilities (22), and 70 under manufacturing (31–33). At the four-digit level, 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 nine establishments; and basic chemical manufacturing (3251), also with nine establishments.

For second-period 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. In addition, some also distribute multiple fuel types.

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 to assess the degree of possible labour impacts and identify industries in which labour may be most threatened. Environment Canada's National Pollutant Release Inventory (NPRI; Environment Canada 2014) lists the total number of workers employed in each of the 79 facilities covered by the first period of the

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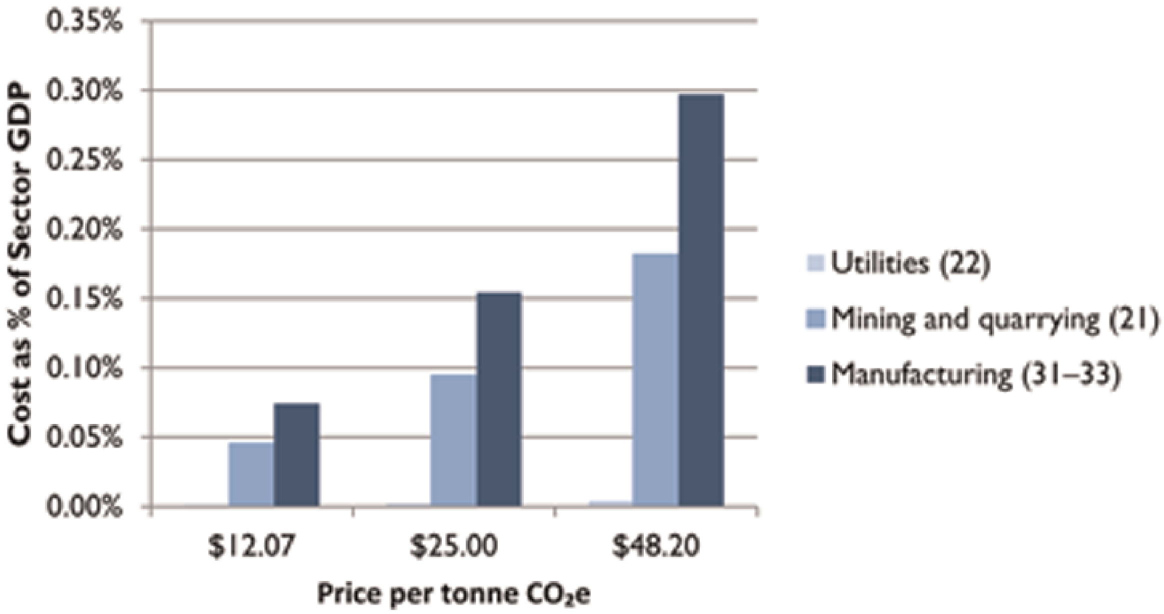

Figure 6: Two-Digit NAICS Industry Impacts relative to contribution to GDP, limited pass-through

SPEDE. Equipped with NPRI job data we separated the 48,955 workers hired by these establishments into the three two-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 the first and second pass-through scenarios. This was repeated for the 22 categories at the four-digit NAICS level. At the two-digit NAICS level, total labour expenditures across industries (number of employees × average wages) were also calculated to provide a point of comparison, using average wages data from the 2006 Census Public Use Microdata Files. This was not done at the four-digit NAICS level as average wages are not available at this level of aggregation.

There is a limitation for information on second-period firms with respect to labour. Employee numbers from NPRI are available for only 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 to conduct a labour analysis for the fossil fuel distributors that came under SPEDE in 2015.

Results

We report industrial impacts by sector, first scaled to the economic size of industries and then scaled to the number of workers in each industry.

Industry Costs

In 2015, average levels of free allocation are 85 percent for manufacturing, 97 percent for utilities, and 91 percent for mining due to the combination of industries in each of these sectors and the different levels of free allocation assigned for 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 million for manufacturing, $16 million for mining, and $4.4 million for utilities at the price floor of $12.07. However, free allocation limits these costs substantially, to $32 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 the first period are in the manufacturing sector, with only three in utilities and four in mining and quarrying, it is reasonable that the manufacturing sector as a whole would experience the highest short-run costs.

Figure 6 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 2 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 limited 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

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Table 2: Four-Digit NAICS Industry Impacts Relative to Contribution to Provincial GDP, Limited Pass-Through

Sector	NAICS Code	Cost to Sector at $12.07 per tCO$_2$e	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	$14.0M	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*

Note: *x* denotes industry GDP was not available at the four-digit level.
Source: Authors' calculations.

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 (2211) and forestry product manufacturing (3221, 3211, and 3212) all have relatively low costs compared to their value-added contributions.

In the second scenario, 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 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 British Columbia'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/tCO$_2$e, manufacturing has a potential increase in revenue of \$178 million, mining one of \$15 million, and utilities \$4.3 million, representing 0.42 percent, 0.48 percent, and 0.03 percent of their current sectoral GDPs respectively. At the price ceiling, these revenues rise to 1.66 percent, 1.92 percent, and 0.13 percent.

At the four-digit NAICS level, those industries that would face the highest costs relative to their industry size in the first 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 11 percent of industry GDP at the 2015 price floor, followed by cement at 3.8 percent and petroleum refining at 2.2 percent. The aluminum industry has the highest total possible windfall profits, at \$59 million in freely allocated permits. It is important to note that due to market structure, some firms may not pass on all of their new marginal costs to avoid losing market share, and hence these are estimates of the maximum possible profit to industries from free allocation.

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 et al. (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 a 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,

Table 3: Estimated Short-Run Cost Per Job by Two-Digit NAICS, Limited Pass-Through, 2015

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 and quarrying (21)	3,811	$370	$770	$1,500
Utilities (22)	21,698	$6.0	$12	$24

Source: Authors' calculations.

Table 4: Estimated Short-Run Annual Cost per Job by Four-Digit NAICS, Limited Pass-Through, 2015

			Average Cost per Job		
Sector	NAICS	Jobs	$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

Source: Authors' calculations.

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 (see Barrington-Leigh et al. 2014 for a regional analysis). 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 3 shows costs relative to the number of jobs in each broad sector at the two-digit level. As could be expected from its high cost as a fraction of income, described earlier, 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 4 shows the same per-job estimates at the four-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,[6] and cement manufacturing all face maximum costs of more than $5,000 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 near term than to make cuts to labour. It is also notable that aluminum manufacturing has the second highest number of jobs and has significant costs at $1,900 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.

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Conclusion

We find that, overall, Quebec's SPEDE is unlikely to place a high burden of costs on any household income groups or industries, with costs below 2.3 percent of household income and 4 percent of industry contribution of GDP for all groups even at the maximum carbon price for 2015 of \$48/tCO_2e. 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 in early years, from windfall profits to shareholders (predominantly among higher income households) as a result of permit handouts. Future policy platforms from the Quebec government could offset this by including 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.

While we do not yet have sufficient information for the large fossil fuel distributors that were enrolled in 2015 (the second period), they are not subject to free permits or windfall profits, nor to competition from distant suppliers that can encourage other industries to absorb some of the new costs. For first-period firms (that is the large emitters who were enrolled from the beginning of the policy in 2013), we can estimate industrial impacts. These are found 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 certain specifically affected regions (see Barrington-Leigh et al. 2014). 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 toward true social costs. Especially in light of the low prices for carbon permits in Europe, New Zealand, Australia, and elsewhere, the rising price floor in Quebec's system tells investors that they are assured a minimum return on any carbon efficiency 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 toward more climate-friendly consumption and production patterns and technologies.

In addition, the Quebec policy achieves a balance between raising revenue from carbon permits (through auctions) and minimising the short-run impact on workers and firms, by handing out annual 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 could 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 GHGs 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 that 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 British Columbia, 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 in the short term, the Quebec policy could to be revised to be considerably more stringent, with an aggressively shrinking cap, in the case that

 doi:10.3138/cpp.2015-015

more trade partners begin to join the WCI. It would be natural for each new negotiation and entrance of new partners to 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, 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 that provide price predictability in the short term, when that is most important. However, it has a great deal of detail built into it to ensure 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 Intergovernmental Panel on Climate Change'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. More specifically, if decarbonisation by mid-century 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.

Finally, our calculations, which find low costs and moderate equity impacts of the program for Québec, are relevant to the short term. The short run is important for political feasibility and for introducing and entrenching the policy, thereafter letting transparent incentives do their work. Positive early experiences in Quebec may make similar policies more attractive for neighbouring jurisdictions.

The steadily rising prices of the SPEDE will make it increasingly important that Quebec and California recruit other jurisdictions to reduce political and economic difficulties associated with trade competition.

Notes

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

2 Direct emissions are those 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. This includes electricity used to operate many household appliances, since GHGs are only released during its generation process and not by households directly.

3 Note that air travel is excluded from this calculation 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.

4 This is the average of the three soft ceiling levels described in our overview of Quebec's carbon market.

5 These categories differ in principle from the *household* quintiles as used in the Survey of Household Spending, the primary data set used in the household analysis.

6 "Other non-metallics mineral production" (3279) does not include cement, lime, and gypsum, which have their own four-digit NAICS codes.

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