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# Carbon Pricing and the Canadian Beef Sector


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# Executive Summary

This report quantifies the implications of carbon pricing for the Canadian beef cattle sector. The Government of Canada will implement its Backstop Carbon Pricing Policy on January 1, 2018. Mandated carbon prices start at $10 per tonne carbon dioxide-equivalent (tCO2e), increasing by an additional $10/tCO2e each year for five years, reaching $50tCO2e in 2022. Given this progresson in carbon prices, estimates of the foregone producer surplus for the feedlot and cow-calf sectors are calculated at $20/tCo2e and $40/tCo2e for scenarios with and without a farm fuel exemption. Producer surplus measures the difference between revenues and variable costs. It is a short-run economic measure of the benefits that accrue to producers from their participation in the market (Church et al., 2012). In additional to modelling the prospective effects for feedlots and cow-calf operations, econometric evidence on the sector's experience with the British Columbia carbon tax and Quebec's cap-and-trade system is presented.

A brief summary of the main empirical findings is as follows.

**Econometric evidence.** Two sets of econometric models are provided. First, analysis of existing carbon pricing policies in British Columbia and Quebec is completed. The econometric evidence suggests that a $25/tCO2e carbon price yielded a 100,000 head reduction in the provincal herds. The farm fuel exemption granted by British Columbia in 2012 reverses the majority of this negative effect, however. By exempting dyed fuels used on-farm, 80,000 head are restored to the provincial herd, implying that the farm fuel exemptions do provide meaningful, but not complete, relief to the sector. Results on head slaughtered are not statistically robust.

Separate econometric analysis investigates the prospect for passing-along a share of the carbon pricing-related costs to consumers or to other levels of the market. Historical changes in fuel excise taxes are used to demonstrate that it is extremely unlikely that producers will be able to pass-through any unilaterally implemented carbon price at any stage of the supply chain.

**Cow-calf sector.** Carbon prices have two costs for cow-calf producers. First, there is a technical cost effect, which reflects the carbon price's direct and indirect increases in input costs. This is the "bottom-line" effect for producers. Second, there is an output effect, which measures the contraction in industry size that results from a carbon price. Both of these effects must be summed to obtain the total (private) cost of carbon pricing for cow-calf producers. A unique farm-level dataset and leading-edge econometric methods enabled especially detailed analysis of the output effect for cow-calf producers. It was possible to reconstruct a full supply function for the market and estimate different supply elasticities at different price levels. The elasticity of supply is larger at lower prices than higher prices, which implies that the output effect grows – and the costs of carbon pricing increase – as output prices decline.

The next table summarizes the estimated total costs of carbon prices for Albertan and Ontarian cow-calf producers. All estimates are in dollars per hundredweight (cwt) production. Eight scenarios are presented, four for each Alberta and Ontario. In Alberta, fuels used on-farm are exempted from the carbon tax, while in Ontario they are not. Along with the two carbon prices, two output price levels are considered: $100/cwt and $200/cwt.

**Increase in Total Costs from a Carbon Price, Cow-calf Producers ($/cwt)**

| Carbon price | | $20/tCO2e | | $40/tCO2e | |
|---|---|---|---|---|---|
| Output price | | $100/cwt | $200/cwt | $100/cwt | $200/cwt |
| Alberta | *With farm fuel exemption* | 2.70 | 1.71 | 3.61 | 2.04 |
| Ontario | *No farm fuel exemption* | 2.07 | 1.32 | 4.11 | 2.61 |

**Feedlot sector.** Like with the cow-calf sector, feedlots face two costs from carbon pricing. There is the technical cost effect. This is the increase in input costs from carbon pricing, which directly influences producers' margins. There is also an output effect, representing the change in the industry's size due to carbon pricing. Both effects must be included when calculating the change in total costs to the sector. Unlike the cow-calf situation, in the feedlot analysis, data limitations prevent calculating the output effect at different price levels, so four scenarios are considered. There are the two carbon price levels – $20/tCO2e and $40/CO2e – together with the two farm fuel exemption regimes. The next table presents the total estimated costs (i.e., the technical cost effect plus the output effect) for Canadian feedlots.

**Increase in Total Costs from a Carbon Price, Feedlots ($/cwt)**

| Carbon price | $20/tCO2e | $40/tCO2e |
|---|---|---|
| No farm fuel exemption | 1.50 | 2.53 |
| With farm fuel exemption | 1.10 | 1.83 |

Finally, given the unique characteristics of the agricultural sector, limited input-specific exemptions, such as those on dyed fuels used for on-farm activities, or price-contingent exemptions are recommended as practical safety valve mechanisms to offset potential leakage and competitiveness problems.

## Acknowledgements

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# Introduction

Canada has committed to pricing carbon dioxide emissions. These prices may be explicit taxes as in Alberta and British Columbia or they may be determined via cap-and-trade systems like the one linking Ontario and Quebec to California.[1] Many cattle producers are concerned about the implications of Canada's commitment to carbon pricing, especially because the policy is being unilaterally implemented.[2] Unilateral implementation means that Canada is proceeding with carbon pricing even as the other major cattle producers do not. Cattle markets are globally integrated, so the fear is that even a small increase in costs, due to a carbon levy, may jeopardize the sector's international competitiveness.

Typically, carbon prices are comprehensively applied to all greenhouse gas emissions with the effective rates based on carbon dioxide equivalent ($CO_2e$) content.[3] The federal government has mandated prices that start at $10/t$CO_2e$ in 2018, increasing to $50/t$CO_2e$ by 2022. But this tax only applies to 70% of total emissions. Fugitive emissions from manure and soils and methane from enteric fermentation are not included in the tax base. Dyed fuels intended for on-farm use are also exempted in British Columbia, Alberta and the federal backstop policy. Casual consideration of this tax base and the exemptions given to agriculture might suggest small effects for the sector. Carbon prices interact with other features of the cattle market however. Increasing the price of fuels, for instance, leads to increased energy costs that could yield decreased profits, reduction in herd sizes or more firms exiting the industry.

Pricing carbon emissions increases the costs of consuming fossil fuels and, with 45% of Canadian production exported, the beef sector is susceptible to both domestic and international pressures that are challenging to avoid. Leakage, due to this international integration, is a key concern for both the sector and for policy-makers. The term leakage refers to an unintended consequence of carbon pricing. Producers in highly traded sectors

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[1] The terms carbon tax, carbon levy, carbon charge and carbon pricing will, on occasion, be used interchangeably in this report. Even though Ontario and Quebec use cap-and-trade systems, while Alberta and British Columbia apply explicit taxes, the textbook formulation of carbon pricing demonstrates that carbon taxes and cap-and-trade systems are equivalent in terms on their impacts on producers (provided their stringencies are identical). The two systems only differ in their administration, not their effect on producers. Of course, the textbook model is rarely applied implemented and meaningful differences between taxes and cap-and-trade schemes have the potential to be introduced in practice.

[2] For example, several producers have claimed that if they ``don't get [an] exemption [from the carbon tax] there's going to be a piling on, we'll be paying for the carbon on all of our inputs, we'll be paying the carbon tax on all of our production and we'll be stuck in the middle with no ability to actually pass any of those costs on" (Glowacki, 2017), that the government should ``[l]eave cows out of carbon taxes" (Glowacki, 2017) and that a ``tax could mean the difference between a breakeven year and suffering a loss" (Dyck, 2017).

[3] Carbon in Canada is priced on a carbon dioxide equivalent ($CO_2e$) basis. $CO_2e$ is an internationally recognized standard that is composed of seven greenhouse gases. The seven gases are carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons, sulphur hexafluoride and nitrogen trifluoride. Equivalencies and conversions are based on the reporting requirements established in United Nations Framework Convention on Climate Change. Throughout this report, all prices apply to $CO_2e$. Additional detail can be found in Annex 1 of https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html.

face perfectly elastic demand at world prices. The fear is the carbon charge will lead Canadian producers to decrease their output – indeed, the purpose of carbon pricing in sectors such as cattle is to decrease output. Decreased output means fewer calves are sold and less profit for the sector. But because Canada is acting alone on carbon pricing, other cattle producing regions will respond to Canada's reduced production by *increasing their output*. Ultimately, in a pessimistic scenario, all the carbon levy accomplishes is an off-shoring of emissions (with little net improvement in global emissions), in conjunction with a smaller Canadian beef cattle industry. Leakage yields a reduction in domestic competitiveness with minimal environmental benefit.

Of course, whether leakage is meaningful in a real-world context is an empirical question. Modelling is required to assess the private costs of unilateral carbon pricing for cattle producers. Energy consumption is a small share of the overall costs of most cattle operations, typically accounting for less than 5% of a feedlot's or cow-calf enterprise's net-of-cattle costs. Thus one might expect that the implications of a carbon charge will be equally small. Still, assessing the implications of carbon pricing must account for how the levy influences decision-making. A unilaterally implemented carbon price has two effects for producers: a cost effect and an output response. And, depending on the state of the industry, it turns out that even small increases in costs can have large implications.

The two channels, the cost effect and output response, work in different ways and only in jointly considering them can the total costs of a carbon price on the sector be measured. The cost effect is the increase in an operation's marginal costs from the carbon levy. There will be direct and indirect implications. Energy costs will increase as will the cost of other inputs via the price's indirect effects. For example, the cost of feed for Alberta cow-calf operations is estimated to increase by $8.56 per calf with a $40/tCO2e tax. Producers notice the cost effect on their bottom line, so it is salient to the industry. As is shown below however, the consequences of the output effect, a cost of carbon pricing that is overlooked in the cost of production models used by Agriculture and Agri-food Canada (AAFC), can be nearly as important as the cost effect. The output effect measures the change in the size of the industry – the reduction in head sold per year – that results from a carbon charge. The output effect can be large, even for small changes in costs.

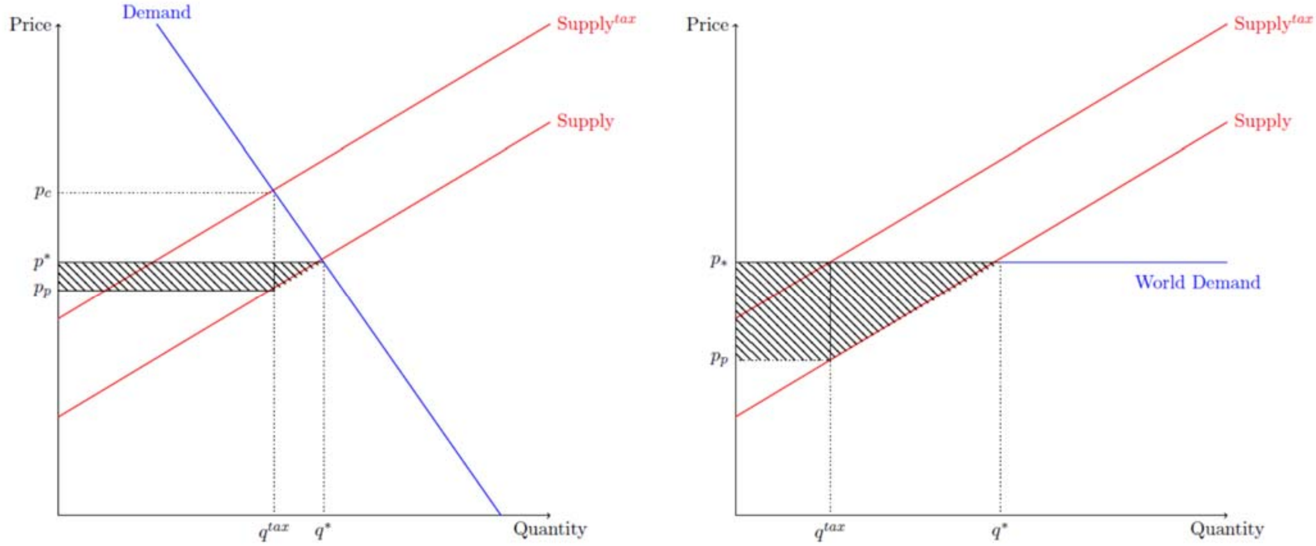
The structure of this report is as follows. The remainder of the introduction provides a very brief overview of the economics of carbon pricing. The second section reviews Canada's carbon pricing policies, emphasizing the federal backstop, while mentioning the highlights of the existing schemes in Alberta, British Columbia, Ontario and Quebec. Two of these provincial policies have existed for several years. As a result, econometric evidence on their actual effect on the cattle sector is presented in the third section. Section four establishes the inability of Canadian feedlots and cow-calf operations to influence global prices. Modelling of the effect of carbon pricing on cow-calf production is then discussed, followed by an analysis of feedlot sector. Other relevant considerations including a theoretical analysis of the interactions of carbon taxes and business risk management programs are contained in section six. Discussion of revenue recycling mechanisms and safety values is next. An extensive technical Appendix accompanies this report. This Appendix includes a description of the econometric models along with additional statistical tests and tables of results.

## (Very) Basic Economics of Unilateral Carbon Pricing

$CO_2e$ emissions are an environmental externality that arise because of a missing market: emitters of $CO_2e$ are using the atmosphere as a “free input” in production. In a perfect system, just like in any other market, emitters of $CO_2e$ would pay a market price for the right to release emissions into the atmosphere. This missing market motivates governments to intervene to curb greenhouse gas emissions. Broadly speaking governments can employ two methods to reduce emissions. They can regulate emitters by creating and imposing new rules and regulations on technologies, product availabilities and consumer choices. Alternatively, they can attempt to use market-based mechanisms to provide incentives for firms and households to reduce their emissions. Both carbon taxes and cap-and-trade policies are market-based mechanisms. *The overwhelming consensus is that market-based programs, such as carbon taxes or cap-and-trade systems, are the most cost effective policies available to governments to reduce $CO_2e$ emissions.* Market-based policies achieve the greatest overall reductions in pollution at the lowest total cost to society. Through their use of prices, market-based policies send signals to economic decisions makers, business people such as feedlot operators and cow-calf farmers, to reduce their energy use. Rather than forcing these businesses to use potentially inefficient technologies, prices provide incentives to find the least cost method to improve environmental performance.

The typical partial equilibrium analysis of a carbon tax is depicted in Figure 1a. (Pricing under a cap-and-trade system works identically.) The initial, competitive equilibrium is at price p* and quantity q*. A carbon tax, levied on producers – feedlots or cow-calf enterprises – vertically shifts the supply function. Post-tax, producers receive ($p^*-p_p$) less per cow, while consumers pay ($p_c-p^*$) more. Total quantity declines from q* to $q^{tax}$ and the demand response ensures that the effect of the tax is split between consumers and producers. The incidence of the carbon tax – i.e., the relative burden of tax that falls, respectively, on consumers or producers – is determined by the relative elasticities of demand and supply.

This conventional analysis can be compared with the scenario in Figure 1b, where producers sell into a global commodity market. The demand channel disappears in this scenario as a single jurisdiction such as Canada is too small to influence global trade in cattle. In this second situation, producers now receive ($p^*-p_p$) less per cow, an amount equal to the full amount of the tax. More importantly, the output response is larger, equaling ($q^*-q^{tax}$). This larger output response results from the absence of a demand response. Farmers bear the full burden of the tax.




(a) Effect of a Carbon Tax with a Demand Response

(b) Effect of a Unilaterally Implemented Carbon Tax

**Figure 1: The Effect of Carbon Taxes on Demand and Supply of Cattle**

This report measures the private costs of carbon pricing and these private costs (as opposed to social costs) are measured as the change in producer surplus. Producer surplus is a standard measure of economic welfare that captures the difference between the market price of an output and variable costs. Producer surplus is a producer's contribution to fixed costs and net margins. Measuring producer surplus requires establishing what is known as a counterfactual scenario. In this context, a counterfactual scenario is the hypothetical outcome for the cattle market in the absence of an intervention like carbon pricing. The term counterfactual is similar to the notion of a "but for" scenario. That is, the report takes as its baseline a Canadian cattle market that is identical "but-for" the introduction of a carbon policy. Lost producer surplus is shown by the thatched regions in Figure 1. The practical aspects involved in calculating the area of these regions reflect the need to estimate both the magnitude of the cost increase due to carbon pricing (i.e., the effective carbon tax) and the change in quantities for that given change in cost (i.e., the elasticity of supply). While conceptually straightforward, in practice, care is required to aptly evaluate these changes.

# Overview of Carbon Pricing Policies in Canada

Canada does not have a uniform carbon pricing policy. Each province and territory is expected to implement its own system. The Federal Government has committed to a "Federal Carbon Pricing Backstop", a policy that sets the minimum stringency for the provincial programs. To date, Alberta and British Columbia have implemented carbon taxes, while Ontario and Quebec have cap-and-trade programs. Basic economic theory illustrates that these two policies are equivalent in an ideal setting. Key differences emerge in practice however. This section outlines key features of the three sets of policies: the Federal Carbon Pricing Backstop, the carbon tax frameworks of Alberta and British Columbia and the cap-and-trade system of Ontario and Quebec. Each policy has unique aspects; however, it turns outs, that provinces that applied one of the broad categories – carbon taxes or cap-and-trade – have similar details.

## Federal Carbon Pricing Backstop

As part of its the Pan-Canadian Framework on Clean Growth and Climate Change , the Government of Canada presented the details of the Federal Carbon Pricing Backstop in its 2017 Technical Paper.[4,5] This carbon pricing framework commits Canada to a country-wide price on CO2e emissions starting in 2018 and includes guaranteed increases in stringency over the subsequent five years. Central to this commitment is a two-pronged implementation strategy. The first prong delegated carbon pricing authority to the provincial and territorial governments. Provinces would have the flexibility and authority to price carbon either by levying a tax or by introducing a cap-and-trade system (or what is referred to as a "hybrid" system, which is in reality a tax with a specific revenue recycling mechanism). Provinces are then permitted to use all collected revenues (either tax revenue or revenue from permit auctions) as each deems appropriate. This delegation of authority was accompanied by a second, and more important, prong, one that is outlined in the Technical Paper. The federal government established a *minimum* stringency and established a backstop that would guarantee a minimum price for CO2e emissions. This backstop adds teeth of to the government's commitments on climate change. It is what makes the framework economically meaningful to the Canadian cattle industry.

The backstop instrument used by the federal government mimics the Albertan policy. It combines a direct carbon levy applied to fossil fuels with an output-based allocation system for facilities that emit above a certain threshold. Virtually no cattle operations would be subject to output based allocation, so the Canadian cattle sector would effectively face a carbon price on direct and indirect inputs net of any output-based subsidy for other sectors. Provinces who fail to implement their own pricing system will adopt the federal backstop by default. The Federal Government has pledged to return direct revenues to the jurisdiction where they were collected.

The federal carbon pricing backstop starts at $10/tCO2e in 2018 and increases by an additional $10/tCO2e each year for five years, reaching $50tCO2e in 2022. Table 1 illustrates the progression of taxes on four

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[4] "Pan-Canadian Approach to Pricing Carbon Pollution" http://news.gc.ca/web/article-en.do?nid=1132169.
[5] https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html.

prominent fuel types. The tax on diesel, for instance, starts at 2.74¢ per litre (L) in 2018. Increases of another 2.74¢/L occur each January 1st, until the tax reaches 13.69¢/L in 2022. Similar charges apply to gasoline, propane and natural gas according to their carbon content.

**Table 1: Carbon Price on Prominent Fossil Fuels under Federal Backstop Policy**

| Fuel | Unit | 2018 ($10/tCO2e) | 2019 ($20/tCO2e) | 2020 ($30/tCO2e) | 2021 ($40/tCO2e) | 2022 ($50/tCO2e) |
|---|---|---|---|---|---|---|
| **Gasoline** | ¢/L | 2.33 | 4.65 | 6.98 | 9.30 | 11.63 |
| **Diesel** | ¢/L | 2.74 | 5.48 | 8.21 | 10.95 | 13.69 |
| **Natural gas** | ¢/ $m^3$ | 1.96 | 3.91 | 5.87 | 7.83 | 9.79 |
| **Propane** | ¢/L | 1.55 | 3.10 | 4.64 | 6.19 | 7.74 |

The price of other inputs will also increase. When constructing the carbon pricing scenarios used in the cow-calf and feedlot analysis, a combination of enterprise budgets, estimates from the economics literature and computable general equilibrium modelling is used to evaluate the cost increase for inputs. For example, electricity in Alberta, a province with significant coal-fired generation, is expected to increase by 21% at a price of $20/tCO2e (Brown et al., 2017). At the same $20/tCO2e, fertilizer costs are expected to increase by 3.4% (Rivers, 2017) and total feed cost will go up by $1.56/cwt.

As stated, the Federal Carbon Pricing Backstop, like Alberta's carbon tax system, contains an output-based pricing system. The objective of this output-based allocation is to minimize the risk of carbon leakage and to offset competitiveness concerns for high emitting and trade exposed sectors.

## Tax Base of the Backstop Policy

The costs of any carbon pricing policy are determined by two factors: the rate or price and the tax base or coverage. The tax rate has already been discussed, but it turns out that the tax base is substantially more important for the agricultural sector.

Canada's existing carbon pricing policies focus on emissions from the combustion of fossil fuels. In total, approximately 70% of emissions are covered. The current formulation of the backstop policy – and the existing carbon pricing policies in Alberta and British Columbia – exempt fuel intended for on-farm use. Relief from the federal carbon levy is granted to "gasoline and diesel fuel used by registered farmers in certain farming activities".[6] This exemption normally applies to dyed fuels used in on-farm production. The vast majority of cattle operations in Canada are covered by this exemption, implying that the carbon levy will not have a consequential impact their gasoline and diesel costs. As mentioned however, provinces are free to introduce tailored carbon pricing systems. Whether a provincial or territorial government includes a farm fuel exemption

[6] Technical Paper on the Federal Carbon Pricing Backstop, pg.12.

will be determined on a case-by-case basis. Currently, both British Columbia and Alberta exempt dyed fuels, while Ontario and Quebec do not.

All Canadian carbon pricing policies also exempt emissions from enteric fermentation. Enteric fermentation is the largest unpriced source of greenhouse gas emissions in many countries, including Canada. (Globally, no country levies a fee on enteric fermentation.) Internationally, livestock production contributes 7.1 GtCO2e, or 14.5% of all anthropogenic GHG emissions, with cattle representing 65% of this total. In Canada, agriculture contributed 1.7% to gross domestic product but 8.4% of its total emissions (ECCC, 2015). Applying a $30/tCO2e tax on enteric emissions alone – not including any other costs – would translate into more than a $16/cwt increase in costs. $16/cwt is larger than the margin on the majority of cattle operations in the country. Thus, while exemptions such as the one on marked fuels provide relief to the industry, the implicit exemption embedded in the definition of the tax base is of much greater economic relevance. It is worth noting that similar "process" exemptions are offered to other sectors. For instance, process emissions from the cement industry, one of the largest emitters on an intensity basis (i.e., tCO2e/$ output), comprise 60% of the sector's total emissions, but only combustion emissions are priced under the backstop policy (i.e., process emissions are exempted).

## Carbon Taxes: Alberta and British Columbia

British Columbia has an explicit carbon pricing system, whereas Alberta refers to its program as a hybrid system that levies a fee and then uses output-based rebates for its electricity sector. In practice, both systems are accurately referred to as carbon taxes.

British Columbia introduced its carbon tax on July 1, 2008. Starting at $10/tCO2e, the tax increased at a rate of $5 per year until 2012 when it reached $30 tCO2e. The Climate Leadership Plan was initially revenue neutral and involved recycling all carbon tax revenues back to households and firms via reductions in personal and corporate income tax rates. British Columbia's policy also reduced school property taxes for land classified as "farm" and, among other things, provided transfers to northern and rural homeowners (BC Ministry of Finance, 2012). British Columbia's carbon tax covers between 70 to 77% of the province's emissions, excluding fugitive emissions from soils and landfills as well as enteric fermentation (BC Ministry of Finance, 2011). Starting in 2012, the province also exempted fuel used for agricultural purposes.

Alberta introduced a carbon tax of $20/tCO2e on all fuels that emit greenhouse gases in 2017. The tax will increase to $30/tCO2e in January 2018. Marked gas and diesel used on-farm are exempt from the levy and large industrial emitters, such as electricity generation, will continue to be regulated under a separate output-based allocation system. "Agriculture is the only economic sector with a levy exemption" (Alberta, 2017a). Alberta's carbon pricing model is expected to cover 70 to 90% of emissions. Most Alberta households will also receive a rebate to offset the average cost of the carbon levy.

The three large sources of agricultural emissions in Alberta are from fuel use, electricity consumption and from methane due to livestock digestive processes (emissions from soils are another major source). Under Alberta's Climate Leadership Plan, fuel and enteric fermentation are exempted and electricity is covered under the output-based allocation approach. The output-based allocation works to reduce the increase in electricity costs (while still providing incentives for emissions reductions). The government has also committed a modest $10M to assist farmers to reduce their energy bills through energy efficiency upgrades. Overall, Alberta's carbon levy system has adopted a light touch attitude towards the agricultural sector.

## Cap-and-Trade: Ontario and Quebec

Both Quebec and Ontario have cap-and-trade systems. Cap-and-trade systems require covered facilities – i.e., large emitters – to provide an allowance or permit for each tCO2e emitted. Cow-calf operators and feedlots do not directly participate in either Quebec or Ontario's cap-and-trade system. Likewise neither province offers any sector-specific relief that is targeted at beef production.

Quebec launched its cap-and-trade system in 2013 and linked it with California's carbon market in 2014. Prior to this, Quebec established a small carbon tax of approximately $3/tCO2e on fuels in 2007. Quebec's cap-and-trade system covers 74 emitters, each of whom releases at least 25,000 tCO2e per year. In total, 83 MtCO2e are covered, less than half of Ontario's 170Mt (2013 values). This equals roughly 85% of the province's emissions (Quebec, 2014). Permit prices traded at roughly $11/t in 2013, increasing to $15 in 2016.

Ontario's cap-and-trade system was announced in April 2015 and received royal assent in May 2016.[7] Ontario's system covers 148 facilities and approximately 82% of provincial emissions. Facilities that emit more than 25,000 tCO2e are obligated to participate in the market as are natural gas distributors and fuel suppliers. Facilities that emit between 10,000 and 25,000 tCO2e can voluntarily participate in the market. Both mandatory and voluntary participants have the opportunity to receive free allowances during the initial compliance periods. Free allowances provide a strong incentive for voluntary participation because these allowances can be sold on the secondary market (if firms are able to reduce their emissions). Ontario's emissions cap starts at 142.3 MtCO2e in 2017 and declines to 124.7 MtCO2e by 2020. Further, Ontario will join Quebec and California in their emissions management systems in 2018.

[7] On May19, 2016, the regulations governing the cap-and-trade system were released. O.Reg 144/16 covers the cap-and-trade system, while O.Reg 143/16 replaces O.Reg 452/09 and outlines the rules on quantification, reporting and verification of greenhouse gas emissions. Since 2009, O.Reg 452/09 required facilities emitting more than 10,000 tCO2e per year to report their emissions since 2009.

# Econometric Evidence from British Columbia and Quebec

The provinces of British Columbia and Quebec have pre-existing carbon pricing policies. Given these extant policies, it is possible to perform *ex post*, or after-the-fact, analysis to evaluate the implications of these policies on the cattle sector. The advantage of this after-the-fact analysis is that it is possible to estimate and observe the actual ramifications of carbon pricing on the cattle sector against a counterfactual scenario where neither province levied its price. Nonetheless, for several reasons, caution should be exercised when interpreting these results. For example, the analysis is limited by data availability. It is only possible to determine the implications for variables that are obtainable. These variables include cattle inventories and head slaughtered. Second, neither British Columbia nor Quebec provide an "ideal" setting with which to econometrically evaluate the effect of carbon pricing on the sector. There are several reasons for this. Both provinces had relatively small cattle sectors compared with the Prairie Provinces and Ontario. Second, Quebec had a notable pre-trend in its sector prior to the introduction of its policy. Finally, both provinces' policies coincide with the 2008 financial crisis.[8] To the extent possible, econometric adjustments are made for each of these disadvantages, but it is still likely that the estimates will over-estimate the true effect of carbon pricing on the cattle sector.

Despite these cautions, this after-the-fact analysis yields revealing estimates of the implications of carbon taxes and cap-and-trade systems on the sector. British Columbia introduced its broad-based carbon tax on July 1, 2008. Starting in 2007, Quebec had a small carbon tax of approximately $3/tCO2e, but formally launched their cap-and-trade system in January of 2013. Table 2 shows the implications of these carbon pricing policies.

**Table 2: Implications of British Columbia and Quebec Carbon Pricing Policies on the Cattle Sector[9]**

| | Inventories | Head Slaughtered |
|---|---|---|
| Carbon Price | -4.384*** | -0.717 |
| | (1.441) | (0.920) |
| Farm Fuel Exemption | 79.329*** | 32.120* |
| | (20.741) | (14.605) |
| Number of | 340 | 340 |
| Time FE | Yes | Yes |
| Province FE | Yes | Yes |

[8] Another formal econometric assumption, known as the stable unit treatment value assumption or SUTVA, also needs to be satisfied if one wishes to make causal claims. SUTVA is not a testable assumption but it is highly unlikely to hold in this case.

[9] Throughout the report, asterisks represent statistical significance with *** indicating significance at a 0.1% level, ** indicating significance at a 1% level and * representing significance at a 5% level.

This table presents the estimated coefficients from a difference in differences econometric model. The parameters describe the implications of the British Columbia and Quebec carbon charges on provincial cattle inventories and head slaughtered. The other provinces are used as the control group. Dependent variables are measured in thousands of animals. Additional results examining robustness to specification and alternative dependent variables are contained in the Appendix. Heteroskedasticity robust standard errors are in parentheses.

The estimates in the inventories column are statistically significant at a 1% level. These parameters suggest that a \$25/tCO2e carbon price yields an approximate 100,000 head reduction in the number of cattle in the province. The farm fuel exemption reverses the majority of this effect however. By exempting dyed fuels used on-farm, 80,000 head are restored to the provincial herd, implying that the farm fuel exemption does provide meaningful, but not complete, relief to the sector.

The results on head slaughtered are not statistically robust. It is not possible to claim that the carbon prices have an effect on provincial slaughter rates that is different from zero. This is perhaps not surprising as Canada's largest packers are in Alberta and Ontario, not in British Columbia or Quebec (Rude et al., 2010). Still, the signs on the point estimates do corroborate the estimates on the inventories regression.

In sum, the main result from the econometric analysis is that the carbon levies in British Columbia and Quebec led to large reductions in herd sizes, but that the farm fuel exemption lessened the greater part of the effect. It is worth reiterating, however, that it is not possible to make causal statements based on these econometric models.

# Econometric Evidence on Pass-through of Unilateral Tax Increases

A common claim is that the beef cattle sector, like much of agriculture, is trade dependent and subject to international competition. The corollary to these statements is that the beef sector will be unable to pass-through unilaterally imposed carbon costs. That is, if a government imposes a carbon price on cattle farmers, these operations must bear the entire cost of these levies because international competition in cattle markets implies that domestic Canadian producers have no capacity to influence global prices.

Despite these claims, supporting evidence has been scant. This is because country- or region-specific shocks are needed to statistically identify the potential for unilateral pass-through and these types of shocks are rare. Generally, shocks, such as increases in fertilizer or oil prices, are global in nature. Normal propagation of shocks from, say, increases in the price of oil affects the entire cattle industry. This includes producers in Canada, but also operations elsewhere in the world.

The important characteristic of Canada's carbon pricing policy, however, is that it is unilateral. This means that it will only change the cost structure of Canadian enterprises while leaving producers in the rest of the world unaffected.

Table 3 uses changes in Albertan and Ontarian provincial excise fuel taxes to investigate Canadian producers' ability to unilaterally pass-through cost shocks. Like carbon pricing, fuel taxes have both direct and indirect effects on agricultural operations. More importantly, the tax changes are unique to Alberta and Ontario – i.e., they only change prices in one province at a time – so have idiosyncratic region-specific statistical variation that enables identification of tax pass-through rates for the highly-traded beef industry.

**Table 3: Pass-through of Canadian-Specific Diesel Taxes to Cattle Prices**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | *Fed Cattle Prices* | | *Feeder Cattle Prices* | | *Fed Cattle Prices* | |
| Diesel tax pass-through | -0.016 | 0.023 | -0.107 | -0.107 | | |
| | (0.056) | (0.056) | (0.947) | (0.957) | | |
| Feeder*Diesel pass-through | | | | | -0.011 | -0.004 |
| | | | | | (0.006) | (0.019) |
| Province fixed effects | Y | Y | Y | Y | Y | Y |
| Year fixed effects | Y | Y | Y | Y | Y | Y |
| Month fixed effects | Y | Y | Y | Y | Y | Y |
| Province-specific trend | N | Y | N | Y | N | Y |
| Number of observations | 528 | 528 | 480 | 480 | 480 | 480 |

Table 3 shows that provincial excise taxes on fuels have no economically or statistically meaningful effect on cattle prices. Columns (1) and (2) consider the pass-through rate from diesel taxes to fed cattle prices, showing small point estimates that are not statistically distinguishable from zero. Equally, columns (3) and (4) examine the effect of diesel taxes on calf prices, similarly finding no meaningful results.

Finally, columns (5) and (6) consider the implications for fed cattle prices from the interaction of feeder cattle prices with diesel taxes. These models consider a slightly different issue. They ask what the effect on fed cattle prices is from a unilateral shock to Canadian feeder cattle prices. These models examine a different channel – namely, whether domestic feedlot operators are able to pass-through shocks to domestic cow-calf operations (or vice versa) or whether international arbitrage opportunities at both levels of the market discipline prices. Again in this instance, there are no meaningful effects. This suggests that competitive international markets play a role for both weaned calf prices and for fed cattle prices. In sum, Table 3 provides evidence that it is exceedingly unlikely that Canadian producers – at either the feedlot or cow-calf levels of the market – have any ability to pass-through carbon price cost increases. Rather, each will bear the majority of the carbon charge independent of the effects at other stages of the supply chain.

# Carbon Pricing and Cow-calf Operations

Beauchemin et al. (2010) found that 80% of the beef sector's total emissions, from both production and enteric fermentation, came from the cow-calf system with the remaining 20% from the feedlot system. So, understanding the role of carbon pricing on the cow-calf level of the market is especially important.

As discussed, a carbon price creates two costs for cow-calf enterprises: a direct technical cost effect and an output effect, the cost arising from reduced production. Figure 2 graphically presents the intuition underlying the key results in this study. The top panel is a structurally estimated supply function for Canadian cow-calf farmers. As described in the Appendix, this figure is constructed by combining farm-level data on input and output prices and quantities with assumptions on firm cost minimization to recover firm-specific marginal costs.

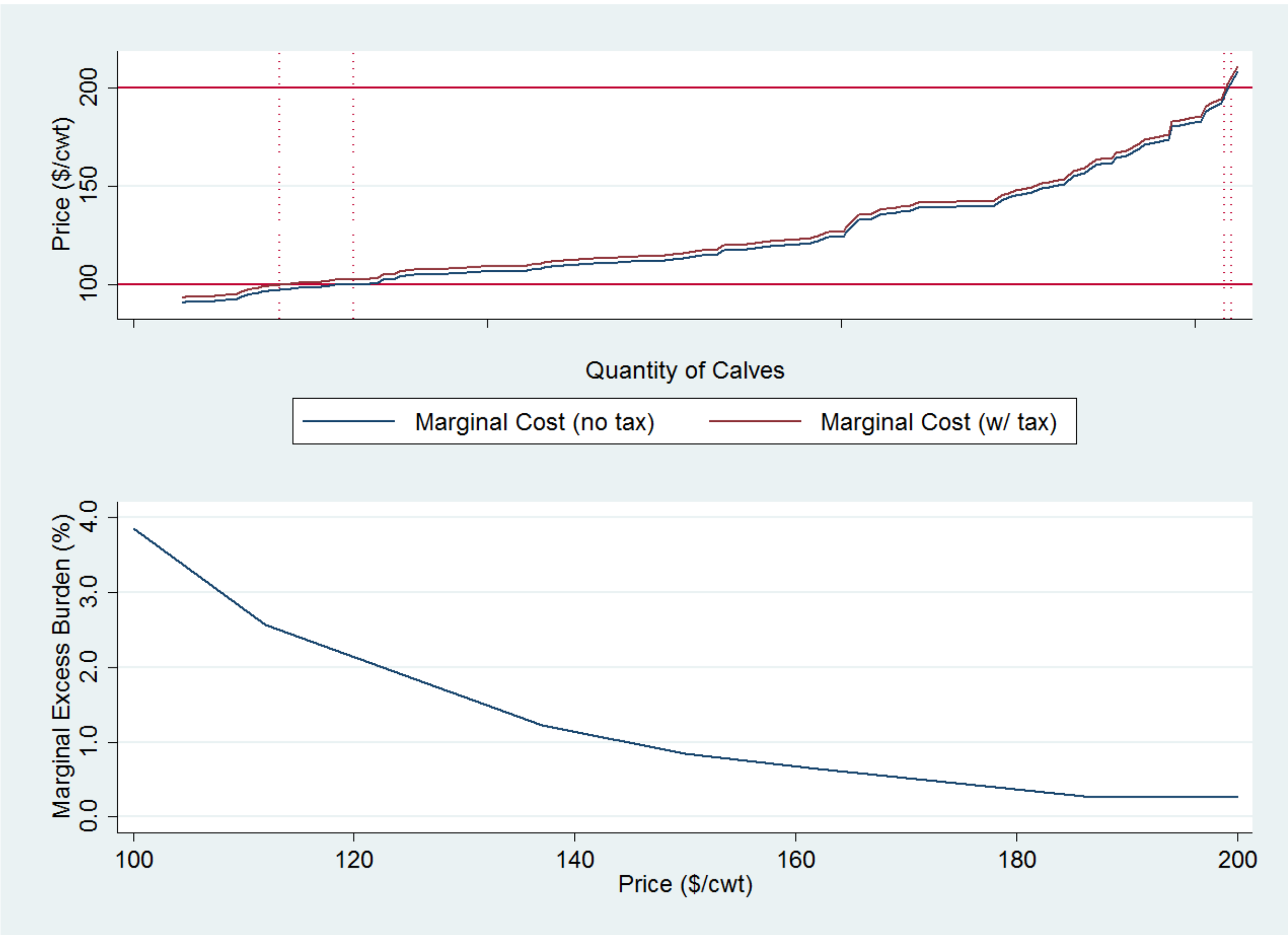


**Figure 2: Implications of a $40/tCO2e Carbon Tax on Alberta's Cow-Calf Industry**

The blue curve in Figure 2 illustrates the pre-carbon price, short-run supply curve for cow-calf producers. The red curve, then, represents a counterfactual scenario with fixed per unit carbon price. This post-levy supply curve is for a $40/tCO2e price without farm fuel exemptions scenario described below. Carbon prices have two effects on the sector. First, there is the per unit "technological" cost. Carbon pricing make inputs such as fuel and feed more expensive. This cost is proportional to a firm's direct and indirect carbon emissions and is modeled as a tax-induced upward shift in the supply curve. In Figure 2, the blue curve "shifts up" to become the red supply function as farmers now pay a higher price for essential inputs. This carbon price reduces farmers' producer surplus at all output levels. Of course, while the shift of the supply function will affect producers' net returns, this cost effect is not considered an "economic cost" as revenue in proportion to input use is recovered by the government. In principle, this revenue could be recycled back to producers via lump-sum transfers, reductions in other taxes or through alternative policies.

The second effect of a carbon tax is the output response. The output response is an economic cost as it reflects the (private) deadweight loss associated with the climate policy. Emissions and output are cost complements in cattle production, so reducing emissions involves reducing output in the short-run. The law of one price applies to agriculture, so output prices are extra-jurisdictionally determined via global competition. The magnitude of the domestic output response is determined by the domestic elasticity of supply. When output prices are high, as shown by the horizontal line at $200/cwt, the marginal cost function is nearly vertical and output responses are negligible. The bottom panel of Figure 2 depicts the marginal excess burden or marginal deadweight loss from the carbon price. Marginal excess burden is the economic cost arising from the output effect. When calves sell for $200/cwt, economic costs are tiny, equalling 0.26%. This is because the elasticity of supply is small in this circumstance as shown by the steepness of the blue and red supply curves. As prices decline however, the supply curve becomes increasingly elastic (flatter) and the output response grows rapidly and nonlinearly. At $100/cwt, the marginal excess burden in this scenario is 3.85%. So, even though prices only fell by 50%, the marginal burden increased nearly 15 fold.

This explicit representation of the cattle supply function enables a direct determination of the private costs of carbon levies on the sector at different global price levels. The private economic costs of a carbon price are measured as the total excess burden *plus* the technical cost effect. Supply elasticities are nonparametrically calculated as arc elasticities. Excess burden is a measure of the deadweight loss of a tax. Because carbon prices are unit charges, rather than *ad valorem* taxes, the marginal excess burden of a carbon price, and hence the private costs of the policy, increase disproportionately as output prices decline. This is illustrated in the bottom panel of Figure 2. This panel shows a curve mapping the marginal excess burden of a constant per unit output carbon price to different output price levels.

There are two reasons why an identical $40/tCO2e carbon price yields a larger excess burden when prices are low compared to when prices are high. First, the *ad valorem*-equivalent of the per unit carbon charge is larger at lower prices compared to higher prices. This influences the deadweight loss calculation. Second, as Figure 2 shows, the supply curve becomes more elastic at lower prices. This increased elasticity is driven by the sector's underlying technology, which is highly dependent on land quality and weather. The combination of these two factors produces the marginal excess burden curve in the bottom panel, where the marginal excess burden (i.e., the economic cost per dollar of carbon levy) equals 3.85% at a price of $100/cwt, but only 0.26% at $200/cwt. The combination of the percent increase in the carbon charge plus the greater elasticity of the supply function implies that carbon pricing has a feedback effect on producer surplus. Private economic costs grow nonlinearly as output prices decline.

## Cost of Production Models versus Marginal Costs

Both the Canadian Cattlemen Association and AAFC typically use a "cost of production" method to evaluate the costs of new policies. A variant of this approach is used to estimate the technical cost effect in this report as well. Cost of production analysis takes average costs at a given level of output. It then adds or subtracts the policy-induced per head cost change as follows:

$$\text{Cost of carbon tax per cwt} = AC(\tilde{q}) + P_{CO_2e} CO_2^{\tilde{q}} e$$

Cost of production analyses are incomplete representations of total costs, because they ignore the output effect. This is especially precarious in this circumstance as a primary abatement channel for beef cattle is a contraction of output – i.e., a main effect of a carbon price is to reduce output. As cost of production models use average costs rather than marginal costs, most tend to treat output as fixed. Marginal costs are not reported on cash flow or income statements. While the price of a specific input is observable, the underlying marginal cost of output is typically not.

Economic decision-making depends on the marginal costs of production not on average costs. Producers focus on the implications of the next cow produced. For example, consider two producers: Alan and Betty. Let Alan and Betty both have a fixed amount of grazing land. Alan's is rated at 1 animal unit months (AUM), while Betty's is rated at 1.2AUM. Let both stock at the optimal rate – i.e., Alan will have one head per acre-month, while Betty will have 1.2 head per-acre month. This stocking rate implies that Alan and Betty will have the same average number of animals per AUM, but Betty will have more head per acre. In other words, Betty can maintain a larger herd because her marginal cost per acre of grazing land is lower than Alan's. It is these differences in marginal costs that motivate Betty to increase her herd size relative to Alan.

Canada's federal ministry, Agriculture and Agri-Food Canada, uses the average operation in a province to evaluate the implications of carbon pricing on the sector. If prices remain stable and variable costs are constant, these models will yield reasonable estimates. If prices change, sizable biases will emerge. Cost changes, such as those due to a carbon policy, move an industry along its marginal cost curve. This means that the total private cost of a carbon charge varies with the output response. As is apparent in this analysis, the output response is nearly as large as the technological costs embedded in the cost of production analysis.

As mentioned, marginal costs are fundamentally unobservable to analysts. They must be estimated using a combination of data and assumptions about producer behaviour. In this report, producers are assumed to be cost minimizers, a standard assumption in agricultural economics. The Appendix outlines a "production function" methodology that is used to recover marginal costs. This combines the Ackerberg et al. (2015) control function approach with the De Loecker (2011), De Loecker and Warzynski (2012) and Ganapati et al. (2017) method. Control function estimation of the production function is usually viewed as superior to alternatives such as least squares or panel data methods because unobserved firm-specific productivities influences the choice of inputs. Ignoring these unobserved productivities, as is done in ordinary least squares, implies that estimated elasticities will be biased and inconsistent. Similarly, fixed effects panel data methods assume that all farm-specific unobservables, including productivities, are time invariant. (See the Appendix for additional details.)

## Constructing Carbon Pricing Scenarios and Estimating Cost Effects

Four carbon pricing scenarios are considered for each of Alberta and Ontario (eight scenarios in total). These scenarios are combined with the structurally estimated supply function, as shown in Figure 2, to determine the consequences of the carbon pricing policy on cow-calf producers.

Table 4 outlines the four scenarios. As repeated throughout this report, carbon prices have two effects on producers: a cost effect and an output effect. These scenarios represent the cost effect of different carbon pricing schemes. These estimates are direct analogues to the cost of production analysis completed by AAFC.[10]

A series of models and estimates were combined in order to calculate these costs. First, Rivers (2017) developed a computable general equilibrium model of the Canadian economy to investigate the carbon policy induced price changes of specific agricultural inputs. The most important inputs are fertilizer (ammonia) and agro-chemicals. At $20/tCO2e, Rivers (2017) forecasts that fertilizer prices will increase by approximately 3.5%, while chemical prices are expected to increase by 0.1%. Feed is the largest single cost for Canadian cattle enterprises. So the cost increases for fertilizer and chemicals were incorporated into a several enterprise budgets to calculate the expected increase in feed costs. This increase in feed costs is an indirect effect of a carbon price for feedlots and cow-calf operations. These enterprise budgets are from the Alberta Ministry of Agriculture and Forestry and the Ontario Ministry of Agriculture, Food and Rural Affairs. Fuel is another major cost in these crop and forage budgets, so the exemption or non-exemption of on-farm fuel use has a central role in determining a cow-calf operation's indirect cost increases through inputs: that is, if farm fuel is exempt, the increase in the cost of feed is smaller than if it is not exempt.

Next, the potential increase in electricity prices due to carbon pricing may be large, especially in Alberta and Saskatchewan. A substantial share of Albertan and Saskatchewan electricity is from coal-fired generation. This means that carbon levies have the potential to dramatically increase utility costs. Other jurisdictions in Canada do not face similar pressures as they have substantial hydroelectric or nuclear power. Determining how much the price of electricity will increase is challenging. Several factors need to be acknowledged such as the fuel mix of existing generation (natural gas or coal) and the potential for incumbent players to exert market power by acting non-competitively. These factors must then be considered alongside the proposed output-based rebate system in the backstop carbon pricing policy. Fortunately, Alberta has clearly articulated how its output-based allocations will apply to its electricity sector and it appears highly probable that the federal government will adopt a system that is identical to Alberta's. Brown et al. (2017) developed a detailed model of Alberta's electricity sector that incorporates each of these elements: output-based allocations, market power and fuel mix. They forecast that a $20/tCO2e tax will cause a 21% increase in Alberta electricity prices. This estimate is

[10] The scenarios considered here make different assumptions than both the AAFC analysis and other reports, such as the one commissioned by the Canadian Canola Association. For instance, the Canadian Canola Association report assumes that there is no pass-through on increased fertilizer costs. This report, in contrast, uses computable general equilibrium modelling to inform the cost increase. Key differences with the AAFC report are discussed below.

used in the Alberta scenarios. Carbon pricing-induced increases in Ontario's electricity prices are expected to be much smaller and are obtained from Rivers (2017).

The final step in developing the carbon price cost estimates is to include the feed cost into a per-animal cow-calf cost of production model. These cost of production models were provide by Canfax for Alberta and Ontario.[11] The baseline Alberta model assumes a 550lb calf and a feed ration that is 85% alfalfa and hay and 15% barley. Of note, two estimates were developed based on different assumptions of fuel usage in the Alberta scenarios. The first, and the results presented in this report, uses the cost estimates as presented in the actual cost of production model. An alternative scenario was also developed where 100L of diesel fuel is used per calf. This latter assumption appears inconsistent with the estimates in the cost of production model and is viewed as less reliable. For Alberta, the equivalent of roughly 45L of diesel fuel is used both directly and indirectly for each 550lb calf. Ontario's model is based on a 610lb calf and a feed ration that is 71% silage and 29% hay. Producers in Ontario are assumed to use 30L diesel in the direct production of each calf. Alternative assumptions about days on feed, feed rations and fuel-use were explored. These had minor implications for the cost estimates. The results presented reflect the most likely cases given these assumptions.

**Table 4: Dollar Increase in Cattle Production Costs per Hundredweight Calf Produced**

| | $20/tCO2e | $40/tCO2e |
|---|---|---|
| Alberta | | |
| No farm fuel exemption | 1.91 | 2.58 |
| With farm fuel exemption | 1.55 | 1.87 |
| Ontario | | |
| No farm fuel exemption | 1.19 | 2.37 |
| With farm fuel exemption | 0.71 | 1.38 |

Table 4 shows the expected cost increases from the four carbon pricing scenarios. Under Alberta's current carbon price system of $20/tCO2e and with a farm fuel exemption the cost increase is $1.55/cwt. Table 5 shows, based on the 5 year average costs of a cow-calf operation of $119.05/cwt in Alberta, this is equivalent to a 1.3% increase in total operating costs. Identical policy parameters in Ontario yield a smaller $0.71/cwt cost increase, equal to 0.4% of operating costs given the average cost per cwt in Ontario is $198.00/cwt. Ontario does not exempt dyed fuels for on-farm use, however. Eliminating the farm fuel exemption increases this estimate for

[11] As a check on the reliability of the estimates, the AgriProfits model provided by the Alberta Ministry of Agriculture and Forestry was also used as was a model developed by the Ontario Ministry for Agricultural, Food and Rural Affairs. Results in the text are based on the Canfax model.

Ontario by $0.48.[12,13] Table 5 shows that a $40/tCO2e tax implies a 1.4% increase in total costs for Albertan operations and a 1.2% increase for Ontario, as Ontario does not exempt farm fuel.

**Table 5: Percent Increase in Operating Costs due to Carbon Pricing**

| | $20/tCO2e | $40/tCO2e |
|---|---|---|
| Alberta | | |
| No farm fuel exemption | 1.61 | 1.99 |
| With farm fuel exemption | 1.31 | 1.39 |
| Ontario | | |
| No farm fuel exemption | 0.60 | 1.20 |
| With farm fuel exemption | 0.36 | 0.70 |

## Total Cost of Carbon Pricing for Cow-Calf Operations

The main cow-calf results are in Table 6. Table 6 shows the total costs of the carbon tax including both the technical cost effect from Table 4 plus the output effect.

The total costs of carbon taxes for cow-calf producers are measured by adding the cost increases from Table 4 to the total excess burden from the tax. Combined, these two effects capture the foregone producer surplus. Excess burden, in single market's price-quantity space, is calculated as:

$$EB = \frac{1}{2} t^2 \frac{dQ}{dt}$$

As illustrated in Figure 2, the change in quantity supplied per unit tax, or the elasticity of supply, depends on the price level at which it is measured. The change in quantity supplied is larger at $100/cwt than at $200/cwt because the elasticity of supply is greater at former price level. Table 6 presents the estimated total decrease in producer surplus at different price levels. Under Alberta's existing policy, the total cost of the carbon tax is $2.70/cwt at a price of $100/cwt. This value falls to $1.71 at a price of $200/cwt. In 2021, when the carbon tax is

[12] A key point worth emphasizing is that fertilizer and chemicals are not typically applied to forage crops and are not included in the enterprise budgets. As such, in the Alberta scenario, for instance, these cost increases apply exclusively to the barley share of feed and not to alfalfa and hay. These underlying assumptions about the feed, as well as electricity, are an important factor driving the some of the cost differences between Alberta and Ontario and between the $20 and $40/tCO2e scenarios.

[13] Alberta's combination of rapidly changing electricity generation fuel mix with market power and the output-based allocation system imply that a $40/tCO2e carbon tax, as comes into effect in 2021, is forecast to produce a disproportionately smaller increase in the price of electricity. Due to distinct generation fuels, this effect is not material to Ontario's situation.

mandated to reach $40/tCO2e, the total costs to producers, at these two price levels, corresponds to $3.61/cwt and $2.04/cwt. The bottom panel of Table 6 shows the magnitude of the output effect under the four scenarios. Given Alberta's current farm fuel exemption, as output prices fall from $200/cwt to $100/cwt, the output response has the potential to increase by more than a dollar per cwt. The size of the output effect ranges from from $0.16 with a $20/tCO2e tax and$200/cwt price to $1.22/cwt at a tax of $40/tCO2e and a $100/cwt price.

Over this period, Alberta's AgriProfits model predicts gross margins of $5.80/cwt. After adjusting for unpaid labour, these decline to $4.60/cwt. These estimates are based on an average price of $182/cwt of weaned calf production. This means that *even with the farm fuel exemption* a $40/tCO2e carbon tax will reduce gross margins by approximately 1/4 to 1/3. Moreover, these shares could increase rapidly if output prices fall.

**Table 6: Total Costs and Economics Costs to Producers from Carbon Price Scenarios**

| Carbon Tax | | $20/tCO2e | | $40/tCO2e | |
|---|---|---|---|---|---|
| Output price | | $100/cwt | $200/cwt | $100/cwt | $200/cwt |
| *Total Cost to Producers from the Carbon Tax ($/cwt)* | | | | | |
| Alberta | | | | | |
| | No farm fuel exemption | 3.32 | 2.11 | 4.32 | 2.82 |
| | With farm fuel exemption | 2.70 | 1.71 | 3.61 | 2.04 |
| Ontario | | | | | |
| | No farm fuel exemption | 2.07 | 1.31 | 4.11 | 2.61 |
| | With farm fuel exemption | 1.23 | 0.78 | 2.40 | 1.52 |
| *Excess Burden from the Carbon Tax ($/cwt)* | | | | | |
| Alberta | | | | | |
| | No farm fuel exemption | 1.41 | 0.20 | 1.74 | 0.24 |
| | With farm fuel exemption | 1.15 | 0.16 | 1.22 | 0.17 |
| Ontario | | | | | |
| | No farm fuel exemption | 0.88 | 0.12 | 1.74 | 0.24 |
| | With farm fuel exemption | 0.52 | 0.07 | 1.02 | 0.14 |

The estimates for Ontario are similar to Alberta's, albeit slightly smaller in value. Of course, Ontario does not offer a farm fuel exemption. With a $20/tCO2e carbon price and an output price of $100/cwt, Ontarian producers will see a $2.07/cwt loss in producer surplus. With the same price and a $40/tCO2e charge, this estimate balloons to $4.11. If prices are at $200/cwt, the consequences are less stark. At $20/tCO2e, total costs increase by $1.31/cwt, while at $40/tCO2e they go up by $2.61 against a counterfactual of no carbon price.

The Additional Tables section at the end of this report contains Table 12. Table 12 represents the dollar-valued estimates from Table 6 as *a percent of total pre-carbon price operating costs*. Using average baseline pre-carbon policy operating costs of $119.05/cwt for Alberta and $198.00/cwt for Ontario, these percent of operating costs range from 0.66% in Ontario with high output prices to 2.41% of operating costs in Alberta with a $40/tCO2e tax and low output prices. Caution is needed in interpreting these numbers however. The entire point of the output response is that marginal, and hence average, costs will change. But it is not obvious how the total operating costs will change with an evolving industry structure.

# Carbon Pricing and the Feedlot Sector

The impact that carbon prices will have on feedlots depends on the extent to which the sector responds by shrinking output. As with the cow-calf analysis, both the cost effect and the output effect are important. Analysis of the implications of carbon pricing on the feedlot sector proceeds in three steps. First, the long-run relationship between feeder cattle, fed cattle and oil prices is estimated.[14] This relationship is inherently interesting and is useful for establishing a potential counterfactual scenario where the majority of cattle producing countries adopt a carbon price; however, as shown above, these models do not provide insight into country or region-specific pass-through rates. Rather they illustrate pass-through when there is a global shock to a market. Next, the cost increase estimates for feedlots are presented. An identical multi-model methodology to that used in the cow-calf sector is applied. Finally, the total costs of a carbon price are calculated. Data limitations prevent a replication of the full supply function analysis as is found in the cow-calf section. Instead, it is only possible to estimate a single "average" elasticity of supply. Still, estimating this parameter is not straightforward and instrumental variable methods are required to obtain an unbiased coefficient.

## Long-run Relationship between Feeder Cattle, Fed Cattle and Oil Prices

Analysis is completed on the relationship between oil and fed cattle prices and between feeder and fed cattle prices. Understanding the long-run relationship between the prices of oil and fed cattle is useful for three reasons. First, the natural pass-through rate of energy cost shocks is inherently valuable for understanding the links between the distinct commodity markets. Second, the pass-through rate of oil to fed cattle prices establishes a prospective counterfactual scenario where other countries in the world adopt climate policies similar to Canada's. Finally, pass-through rates provide a means to calculate an "average" marginal cost of weight gain that can be used as a check on easier-to-obtain accounting information – i.e., to see whether the average costs in the TRENDS cost of production model match the implied marginal costs from market transactions.

Cost pass-through depends on a range of economic factors including the shape of the demand curve, market structure, trade policy and the level of competition from competing products. Normally, it is not possible to derive simple theoretical conditions to forecast the effect on prices from a carbon charge. Instead an empirical model is required. This analysis focuses on the long-run relationship between prices. For there to be a long-run relationship between the price of fuel and cattle, the variables must be "cointegrated". Formally, the term cointegration means that there is a statistically stationary linear combination on nonstationary random variables. The intuition underlying the concept is natural: it simply means that over short periods of time cattle prices and, say, oil prices might appear random, but over longer periods they are connected, because fuel is an essential input into the feedlot sector. Changes in the commodity costs of fuel will eventually lead to changes in

[14] All the analysis was also completed using diesel prices instead of oil prices. The results are similar. The discussion focuses on oil because of the saliency of oil prices. Fluctuations in the global price of oil are common across regions, whereas local supply disruptions may cause idiosyncratic volatility in regional diesel prices.

fed calf production and in turn changes in fed calf prices. Of course the same reasoning applies to the relationship between feeder and fed cattle prices.

An autoregressive distributed lag (ARDL) reparameterization of a vector error correction model is applied to determine the long-run relationships between fed cattle prices and the price of oil and between feeder and fed cattle prices. Several features of the ARDL model make it appropriate in this context. First, the main data series are typically believed to be subject to the "law of one price". The law of one price implies that there should be minimal cross-sectional variation in prices across regions. An implication, one that is demonstrated above, is that Canadian firms will have minimal ability to pass-through any unilateral carbon price-related cost increases. Any attempt to charge a higher price for Canadian beef will open opportunities for other suppliers to arbitrage away these premiums. Second, it means that the econometric models can focus directly on the direct effect of shocks to oil and feeder prices on fed cattle prices as there is no systematic variation in the basis (i.e., it is random noise). ARDL models also allow for the reduced-form estimation of both short-run and long-run relationships between sets of variables. While the focus of this report is the long-run implications, understanding the short-run dynamics clarifies the short- to long-run adjustment process. Finally, as demonstrated in the Appendix, the price series demonstrate non-stationary behaviour. Unless this non-stationarity is addressed, as with the ARDL reparameterization, the statistical models may produce spurious, or meaningless, results.

Table 7 shows the main results from the price analysis. Two models for each province are presented. The first column shows the relationship between oil prices and fed cattle prices. In Alberta, every $1 increase in oil prices leads to an $0.85 increase in fed cattle prices in the long-run. For Ontario, the pass-through rate is slightly smaller at 0.79. Interestingly, the short-run dynamics of oil price shocks indicate that initially fed cattle prices decrease slightly before eventually incorporating the higher oil prices. The relationship between prices at different levels of supply chain follows a similar pattern, but the magnitudes of the pass-through effects are distinct. The long-run pass-through rate from feeder to fed cattle prices is actually smaller than the oil to fed cattle pass-through rate. The price pass-through coefficient is 0.71 in Alberta and 0.52 in Ontario.[15] At the same time the short-run response is negative and larger for both provinces, equaling -0.18 and -0.22 in Alberta and Ontario, respectively.

[15] Models were also estimated that simultaneously included oil and feeder prices. The results showed that the pass-through rate for feeders increased while the rate for oil decreased in these specifications. This suggests that the main channel through which oil prices influence fed cattle prices is through feeder prices.

**Table 7: Time Series Relationship between Feeder Cattle, Oil and Fed Cattle Prices**

| *Alberta* | | |
|---|---|---|
| | Oil Prices | Feeder Cattle |
| Short-run adjustment | -0.037** | -0.178*** |
| | (0.011) | (0.031) |
| Long-run pass-through | 0.846*** | 0.707*** |
| | (0.214) | (0.035) |
| Number of Observations | 368 | 332 |
| *Ontario* | | |
| | Oil Prices | Feeder Cattle |
| Short-run adjustment | -0.040*** | -0.221*** |
| | (0.011) | (0.034) |
| Long-run pass-through | 0.786*** | 0.515*** |
| | (0.189) | (0.022) |
| Number of Observations | 368 | 272 |

## Inferring Unit Costs from Pass-Through Estimates

It is possible to use the pass-through rates for the oil price series to back-out the mean unit cost per cwt of fed cow. As discussed, accounting data are used in most cost of production models such as Canfax's TRENDS model. Accounting data provide information on average costs, while marginal costs are used for economic decision-making. Unit costs at the mean can loosely be considered as a happy medium between these two concepts. They are not as informative as marginal costs, but contain information encapsulated in producer decision-making. It is possible to use output price times the ratio of the absolute pass-through rate divided by the pass-through elasticity to infer these unit costs:

$$\text{Unit Cost} = P * \frac{\text{Absolute Pass - Through Rate}}{\text{Pass - Through Elasticity}}$$

Table 8 displays the implied unit costs for feedlot operations using two specifications. In Alberta, the implied costs per cwt are $134.34 and $181.42/cwt. In Ontario, these values equal $145.03 and $186.80. The comparable realized value in the TRENDS model for May 2015 through April 2016 is $180.67/cwt for a steer calf. This suggests that the TRENDS "average cost" estimates closely match the implied marginal costs from the pass-through analysis. Hence, it is likely that the average and marginal cost curves are relatively flat.

**Table 8: Implied Unit Costs ($) per cwt of Feedlot Weight Gain**

| | Alberta | Ontario |
|---|---|---|
| Specification 1 | 134.34 | 145.03 |
| Specification 2 | 181.42 | 186.80 |

## Estimating the Elasticity of Supply of Fed Cattle

The elasticity of cattle supply is required to calculate lost producer surplus and total costs to feedlots of climate policy. The usual method to infer an elasticity of supply would be to run a regression with quantity of animals supplied as the dependent variable and fed cattle prices as the independent variable. This regression would likely yield incorrect parameters however. Supply elasticities from standard regression models are prone to substantial bias due to an econometric issue known as simultaneity. Loosely, simultaneity refers to the difficulties in separating demand from supply responses. To overcome this problem in this report, an instrumental variable model is estimated where a demander shifter is used as an instrument for the potentially problematic price variable. The Canadian experience with the bovine spongiform encephalopathy crisis provides a credibly exogenous and strong instrumental variable, enabling identification of an unbiased and consistent estimate of the supply elasticity.

The estimated elasticities of supply are in Table 9. Two values are found 0.74 and 0.67 from slightly different models. These elasticities are similar to others found in the literature. Azzam (1997), for example, estimates an own-price elasticity of cattle supply equal to 0.84. This is the value used by Rude et al. (2010) in their analysis of packer market power. Given their similarity, the subsequent analysis uses a value of 0.71 to evaluate the output response arising from carbon pricing (i.e., the midpoint of the two estimates).

**Table 9: Elasticities of Supply for the Alberta Feedlot Sector**

| | Levels | Logs |
|---|---|---|
| Elasticity of supply | 0.74 | 0.67 |
| Second-stage | 1.36*** | 0.67*** |
| | (0.45) | (0.25) |
| Number of | 204 | 204 |
| First-stage F-stat | 20.61 | 13.40 |

## Total Cost of Carbon Pricing for the Feedlot Sector

The costs of carbon pricing for the feedlot sector are determined in a two-step process. First, using the same basic methodology as in the cow-calf analysis, the cost effect is calculated per cwt. Next, the excess burden or output effect of a carbon levy is calculated and the total costs are presented. Again this uses the excess burden formula presented and applied in the cow-calf section. Unlike the previous analysis however, it is not possible to evaluate the differential output responses at high versus low output prices – i.e., the elasticity of supply is constant for the feedlot sector where it varied in the cow-calf model. (Data limitations prevent estimating a similar supply function to the one presented in Figure 2.)

Four scenarios are considered. These match those above: two carbon prices – \$20 and \$40/tCO2e – with and without a farm fuel exemption. Table 10 presents the estimated cost increase for the feedlot sector. These cost increases are determined by using the computable general equilibrium model, the crop enterprise budgets and Canfax's TRENDS model. Average projected costs for the 2016 model, based on a steer entering at 550lb and exiting at 1375lbs, is used as the benchmark. A key assumption, one that is supported by the results in Table 3, is that feedlots are not able to squeeze cow-calf margins by reducing the price paid for weaned calves. Likewise, feedlots do not face higher calf prices due to the carbon charge. Instead, this analysis considers only those direct and indirect costs incurred at the feedlot level of the market.

**Table 10: Cost Increases for Feedlot Sector due to Carbon Pricing**

| | \$20/tCO2e | \$40/tCO2e |
|---|---|---|
| Dollar value (\$/cwt) | | |
| No farm fuel exemption | 1.11 | 1.87 |
| With farm fuel exemption | 0.81 | 1.35 |
| Percent of costs (%/op. costs) | | |
| No farm fuel exemption | 0.76 | 1.28 |
| With farm fuel exemption | 0.55 | 0.92 |

Table 10 shows that at \$20/tCO2e feedlots in Alberta, where there is a farm fuel exemption, are estimated to see a \$0.81/cwt increase in costs. Without the exemption, as is the case in Ontario and Quebec, a \$20/tCO2e carbon price will yield a \$1.11/cwt cost increase. These, respectively, represent 0.55% and 0.76% of total operating costs. At \$40/tCO2e, the costs increase to \$1.35/cwt, or 0.92% of costs, with the farm fuel exemption and \$1.87/cwt, or 1.28% of costs, without it.

A key point on these cost increases is that they assume that there is no change in feeding practices. In the crop enterprise budgets, the percent increase in the cost of barley is greater than that for silage. Firms are able to substitute across different inputs. Substitution possibilities are perceived to be small in the feedlot (and cow-calf) industries, yet they do exist.[16] Altering feed shares seems like a probable area for substitution and the possibility for these types of substitution implies that these cost estimates will be an upper bound or over-estimate of the true effect.

Table 11 presents the total costs to the feedlot sector after incorporating the excess burden from the output effect. Without a farm fuel exemption and at a $20/tCO2e carbon levy, feedlots will incur total costs of $1.50/cwt. At $40/tCO2e, the estimate is $2.53/cwt. Exempting dyed fuels reduces these estimates to $1.10/cwt and $1.83/cwt, respectively.

**Table 11: Total Costs ($/cwt) of Carbon Pricing for the Feedlot Sector**

| | $20/tCO2e | $40/tCO2e |
|---|---|---|
| No farm fuel exemption | 1.50 | 2.53 |
| With farm fuel exemption | 1.10 | 1.83 |

Like in the cow-calf section, the excess burden or output effect can be calculated by subtracting the cost effect from these total costs. Further, Table 13 in the Additional Tables section contains the percent increase in benchmark costs due to carbon pricing. At $20/tCO2e, feedlots will see a 0.75% and 1.03% increase in operating costs with and without the fuel exemption. At $40/tCO2e the corresponding values are 1.25% and 1.73%.

These estimates represent the total costs to the feedlot sector if Canada unilaterally implements climate policy without other cattle producing countries introducing comparable schemes. The path to global carbon pricing is uneven, but, following on the Paris 2015 agreement, consequential international progress has been made (Ecofiscal, 2016). Prospects for multi-nation carbon pricing are a real possibility. Cattle producers still have private costs under a global pricing system, yet, as described in the Introduction, a share of these costs would be borne by consumers. It is possible to adjust the estimates in Table 11, using the coefficients from Table 7, to evaluate a separate counterfactual scenario, one where there is global carbon pricing. In this global carbon pricing scenario, it is possible to pass-through increased costs to consumers. Using the mid-point oil to fed cattle pass-through rate from Table 7, 0.816, the values in Table 11 can be multiplied by (1 – 0.816) to obtain the expected increase in costs from this global carbon pricing scenario. Without a farm fuel exemption, the total cost increases for feedlots from carbon pricing at $20 and $40/tCO2e, respectively, are $0.28 and $0.47. If all players were on a level playing field, the implications of Canada's backstop policy would be small. This suggests that the cattle sector has a vested interest in advocating for international carbon pricing policies. Not only does coordinated international carbon pricing eliminate competitiveness concerns, it enables the global industry to split the burden with consumers.

[16] A simple example highlights this. As Ontario's electricity prices increased in 2016-17, feedlot operators were more judicious with their water heaters during the winter months. Anecdotally several opted to actively managed their equipment, rather than treat the heaters as always-run. This implies substitution between (potentially uncompensated) labour and energy. An increase in labour hours – active management – took the place of energy-usage - electricity in this context.

# Other Considerations

Several additional factors related to carbon pricing and the beef cattle industry are considered in this section. These include interactions between carbon taxation and business risk management programming, the importance of enteric fermentation and a comparison of the report's results to modelling completed by AAFC.

## Carbon Pricing, Risk-taking and Business Risk Management Programming

Carbon pricing has the potential to interact with a wide-range of existing agricultural policies. The most important of these is the suite of business risk management (BRM) programs within Growing Forward 2. BRM programs, such as AgriStability, provide protection against potential drops in market income and help to manage a volatile primary agriculture sector. Currently, federal, provincial and territorial governments are negotiating the parameters of what will become Growing Forward 3. Growing Forward 3 is expected to be released in early 2018. So, given the coincident timing of the backstop carbon pricing policy and the Growing Forward 3 negotiations, it is useful to consider the interaction of these two policies.

Theoretical analysis presented in the Appendix demonstrates that carbon taxes may interact with BRM programming in unexpected ways. Taxation is often believed to discourage risk-taking because it confiscates part of the return to risky activities. However, a classic economic result by Domar and Musgrave (1944) demonstrates that this is not always the case. Taxation may increase risk-taking because, when losses are subsidized, taxes convert the government into a sleeping partner in the enterprise.

There are two relevant theoretical results in the Appendix. They are given by the formulas labelled (21) and (25). The first equation, (21), states that *because of the carbon tax* producers now have a greater incentive to pursue riskier endeavours. Therefore, we should expect the variance of profits to increase. The result in equation (25) shows that producers' private valuation of BRM programming should increase with carbon taxation and that this valuation increases proportionately with the variance of profits. Plainly, this means that AgriStability becomes more valuable to individual producers due to the carbon pricing policy.

## Emissions from Enteric Fermentation

Internationally, cattle production contributes 4.6 GtCO2e of greenhouse gas emissions (FAO, 2017). A large share of these is due to digestive processes or enteric fermentation. Typically, digestive emissions from beef are pegged at 300kg CO2e/kg protein or 12kg CO2e/kg live weight. As mentioned, at $30/tCO2e, the tax on enteric emissions alone – not including any other costs – would be roughly $16/cwt.

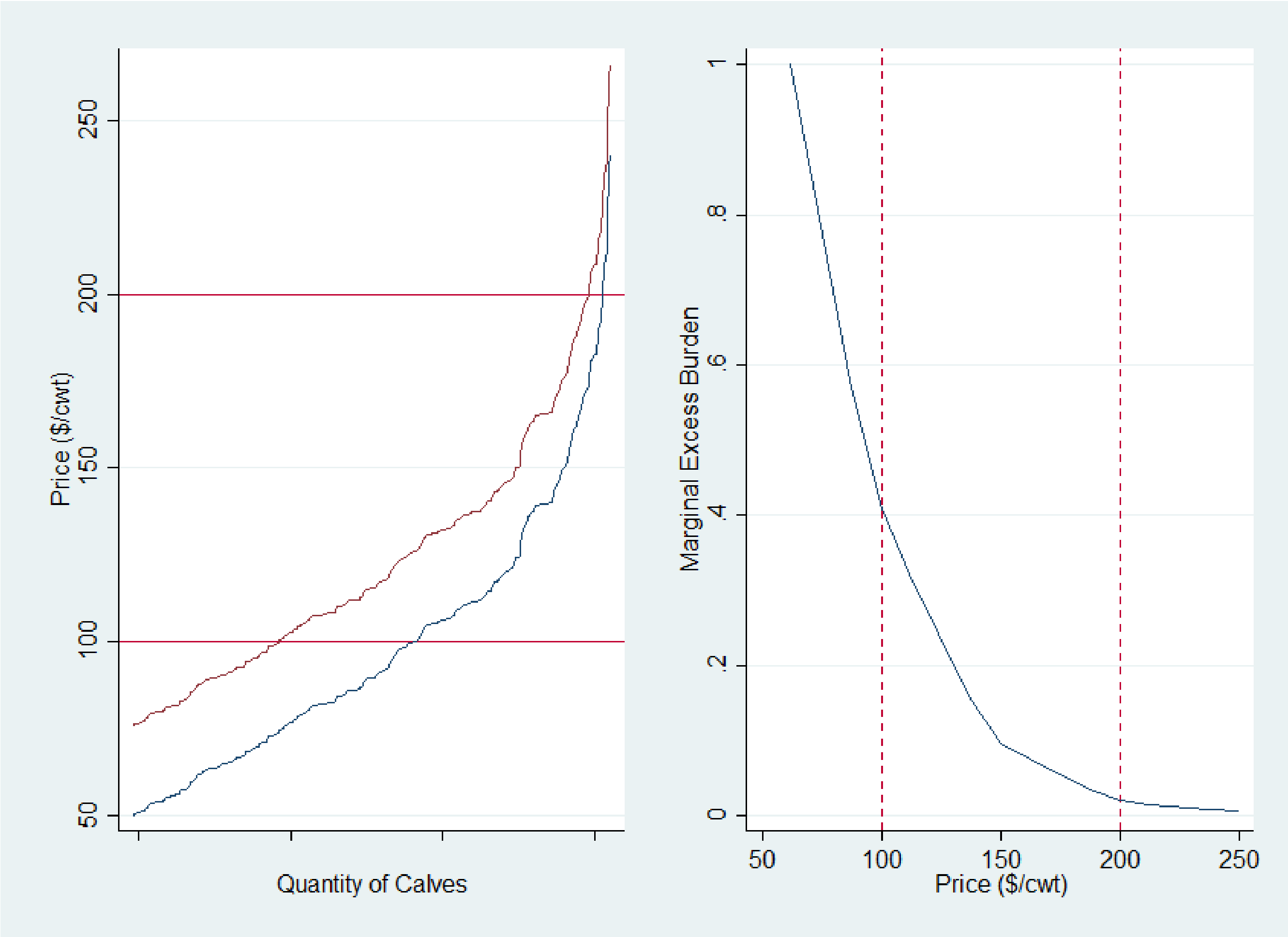


**Figure 4: Implications of a $40/tCO2e including Digestive Emissions**

Enteric fermentation poses both a risk and an opportunity for the Canadian beef industry. The risks are unmistakable. The sector must heed the prospect of creeping regulation and future per animal charges on digestive emissions. These emissions are likely the largest unpriced source of greenhouse gases under the federal backstop policy. Although no jurisdiction in the world currently prices these emissions, the potential for eventual taxes on non-fossil fuel emissions poses a much larger risk to the Canadian cattle sector than does the existing carbon pricing systems.

Figure 4 replicates Figure 2, from the cow-calf analysis, for a $40/tCo2e carbon tax, but includes digestive emissions in the tax base. Visually, the effect of expanding the tax base is dramatic. Instead of having moderate implications for Canadian cattle producers, taxing enteric emissions would imply a massive shift in the supply function. Both the cost and output effects increase considerably. In fact, it is likely that the industry would shrink to a fraction of its size at otherwise reasonable output prices if the tax base was expanded to include digestive processes.

While there is substantial risk from the potential to include digestive methane within the tax base of future climate policies, enteric fermentation may also provide the Canadian industry with an opportunity. Active management systems enable producers to reduce emissions from digestive processes. For example, ensuring good herd health, effective grazing and more efficient feed management all reduce methane emissions (Alberta , 2017b). Indeed the environmental effects can be large, reducing emissions by 19-30% (Schneider and McCarl, 2006). Increasing research on emissions-reducing techniques should continue to be a strategic priority for the sector.

The downside of both research and active management is that these activities are costly and hence may further squeeze already thin margins. Yet, the sector could attempt to offset a portion of these costs by differentiating Canadian beef through a low carbon branding exercise. Product differentiation has the potential to enable the sector to obtain price premiums on its product in specific niche sectors. While it is unlikely to be broadly appealing, "low emissions" beef may be attractive to key customers. Of course, pursuit of a differentiation strategy must be pursued in a transparent, meaningful and honest fashion. Even under active management to reduce digestive methane, protein from beef will remain more emissions-intensive than alternatives such as fish or chicken. Attempting to differentiate Canadian beef based on its environmental footprint, therefore, poses its own risks. Still, similar to key oilsands firms' embracing of carbon pricing (e.g., Suncor, Shell, etc.), the sector should continue to be proactive and actively engage in reducing its whole greenhouse gas footprint.

## Comparing these Results to AAFC's Analysis

AAFC completed analysis of the federal carbon pricing backstop policy. Their analysis focused on the impacts on input costs and the potential benefits of revenue recycling. They concluded that "while the impacts on certain input costs can be significant, the overall effects on operating expenses are expected to be modest" (AAFC, 2017b). For Alberta, at $50/tCO2e, operating expenses are expected to increase by 1.67%. In Ontario and Saskatchewan, the same effective tax will lead to a 1.03% and 1.60% increases, respectively. Nationally, average operating costs are projected to go up by 1.20%. AAFC stresses that their estimates do not include exemptions or alternative rebates such as those granted for on-farm fuel use in Alberta and British Columbia. Once these exemptions are incorporated, Alberta's cost increase is only 0.5%, while the increase in British Columbian operating costs falls from 0.9% to 0.5%. Finally, AAFC states that cross-provincial differences are mainly due to electricity generation technologies; coal-fired power is common in Alberta and Saskatchewan, for example, while hydroelectric power is baseload in British Columbia, Manitoba and Quebec.

AAFC's analysis likely has a vital role in the policy development process, so it is useful to compare their results with those in this report. While there are many differences between the analyses, four key points are highlighted.

First, AAFC's analysis is for a representative, "typical or average farm". Their calculations do not reflect commodity-specific effects from carbon pricing. For instance, it is likely that the percent increase in net costs is very different between, say, small beef cattle enterprises compared with large crop operations. These differences may be meaningful in certain contexts.

Second, AAFC's analysis finds smaller effects than those reported in this study. For example, this analysis estimates that at $40/tCO2e Albertan producers will experience a 1.39% increase in costs (not 0.5%), even after accounting for the farm fuel exemption. For Ontario, the estimate is 1.20% which can be comparted with AAFC value of 1.03%. The difference could be due to either different methodologies or due to the fact that this report considers a specific commodity. Importantly, as discussed in the cow-calf analysis, depending on the state of the global market, average cost modelling may paint a distorted picture of the implications of carbon pricing on farm decision-making and these values deliberately exclude the output effect.

Third, compared to the scenarios used in this analysis, there are small differences in cost increases applied to the AAFC projections. Cost increases for this report's scenarios result from combining several models. As an example, AAFC forecasts that the cost of electricity in Alberta at $50/tCO2e will be 43% higher than the no carbon tax counterfactual. It is not obvious how they arrived at these estimates. In contrast, the cost increase used in this analysis is from the structurally constructed and estimated model developed by Brown et al. (2017). The Brown et al. model yields a more precise characterization of the underlying structure of the province's electricity market. Likewise, for the scenarios in this paper, computable general equilibrium models are used in combination with enterprise budgets to develop estimates of the increases in feed costs, whereas, again, it appears as though AAFC simply inflated costs according to rules-of-thumb from pre-defined benchmark.

Finally, the AAFC estimates concentrate exclusively on input costs. The main refrain of this report is that carbon prices have two effects on agricultural markets. There is a cost effect and an output effect. AAFC's analysis only considers the cost effect. As is demonstrated, the output effect can be large, especially when output prices are low. The output effect arises from the interaction of carbon prices with globally determined output prices. Ignoring the output effect has the potential to generate large biases in the estimated costs of carbon policy for agricultural producers. A $40/tCO2e tax at $100/cwt implies that total costs to Albertan cow-calf producers are actually 1.46% greater than under the cost of production scenario. Of course, if prices increase to $200/cwt, cost of production models only underestimate the total costs by 0.20%.

Taken together, these four limitations imply that AAFC should work towards developing a more complete picture of how carbon pricing may influence highly-traded sectors such as beef cattle and other agricultural commodities.

# Safety Valves and Revenue Recycling Mechanisms

As the empirical analysis demonstrates, carbon pricing, especially under unfavourable global market conditions, has the potential to introduce notable costs on highly-traded sectors such as beef cattle. These costs jeopardize the competitiveness of the industry and can cause significant emissions leakage. Recognition of these risks has led to the design of different safety valves and revenue recycling mechanisms in an attempt to mitigate some of these carbon pricing pitfalls. The concept of a "safety valve" was introduced by Roberts and Spence (1976). Safety valves draw an analogy to pressurized vessels. The idea is that if the costs of carbon pricing get too high then there is some trigger to relieve some of the pressure. Revenue recycling mechanisms are often considered in conjunction with safety valves. Revenue recycling broadly refers to the complementary policies associated with the revenues collected from carbon taxes or permit auctions. Revenue recycling is viewed as a central component of well-designed carbon pricing policies.

Safety valves and revenue recycling tend to focus on two issues: fairness and competitiveness (Ecofiscal Commission, 2016). Fairness looks at the distribution of the burden of carbon pricing across households and firms. The focus of the cattle industry is on the competitiveness features of revenue recycling and safety valve schemes. The preceding analysis emphasized that recycling policies need to appreciate the cattle sector's underlying structure and the important role in cost heterogeneity when thinking through the best methods to potentially provide relief to the sector.

## Review of Mechanisms

Four key mechanisms are discussed: exemptions, lump-sum rebates, output-based allocations and offset credits.

**Exemptions.** It has been common to pair carbon taxes with sector-specific exemptions. For example, Norway does not charge a carbon tax on coal used in its cement industry (Ekins and Speck, 1999), the UK's Climate Change Levy provides conditional exemptions to a range of industries (Martin et al., 2014) and most manufacturers have reduced rates on other existing European carbon taxes (Ekins and Speck, 1999). Alberta, British Columbia and the federal backstop policy have likewise adopted exemptions for the agricultural sector. Dyed fuels for on-farm use are not included in the carbon tax base. Agriculture is the only sector that has been granted an exemption.

Exemptions tend to be politically popular. They are transparent and the connection between the exemption and net returns from operating is salient. Still, most economists consider them to be economically inefficient. Exemptions, in many cases, are not a cost-effective method for achieving the dual goal of reduced carbon emissions and maintained competitiveness. They contravene the equi-marginal principle, which states that the lowest cost method of reducing emissions is to have a uniform price across all sectors. Further, using a computable general equilibrium model, Bohringer et al. (2012) find that exemptions can manage distributional issues but may not be effective at reducing leakage. Hoel (1996) shows, theoretically, that, when border adjustments are available to policy-makers, sector exemptions are inferior to alternative mechanisms. Of course, the legality of border adjustments – tariffs and subsidies – is still in dispute and important practical features such as the mechanism for precisely calculating the required adjustments are not immediately obvious.

**Lump-sum rebates.** Direct sector-specific payments are another method to alleviate competitively disadvantaged sectors. These rebates can be lump-sum or conditional on some other behaviour. Lump-sum rebates are transfers from government to farmers. They maintain the incentive to reduce emissions, because the transfers are independent of a farm's emissions footprint. Ideally, a lump-sum rebate would make the farmer "whole" by compensating them for the cost of the policy. Often lump-sum rebates are temporary and are treated as transitional support (Ecofiscal Commission, 2016).

Goulder et al. (2010) found that lump-sum transfers equal to only 15% of carbon payments were required to make firms in the US whole. Moreover, they found that a 100% lump-sum transfer over-compensated industries. Providing free allowances or emissions permits in a cap-and-trade system is equivalent to providing a lump-sum transfer. The key characteristic is that the rebate cannot influence firm decision-making. It must simply be a transfer mechanism.

**Output-based rebates.** For key sectors, both Alberta and the federal carbon pricing backstop have adopted an alternative to lump-sum transfers known as output-based allocations. Output-based rebates establish some benchmark technology and then measure performance against that standard. In Alberta's electricity industry, for example, allocations will be based on a "best gas" technology standard. Generators that meet or beat this benchmark in terms of emissions intensity will receive a subsidy.

Conditional rebates are a form of output-base allocation, where rebates to a sector depend on a firm's performance. With this mechanism, sectors receive an allocation of carbon revenues that reflects a predetermined percentage of aggregate carbon tax payments. Distribution of funds to firms then is based on shares of physical output (e.g., bushels of barley produced). Firms therefore have two incentives with this program. They have an incentive to reduce emissions because they pay the carbon price. However, as they receive a subsidy that is contingent on their share of the sector's output, there is an incentive to increase output.

Fischer and Fox (2012) model output-based rebates and find that "[f]or Canada, [output-based rebates are] across the board the most effective at avoiding lost production" (p. 211). Yet, their analysis does not consider agricultural production. Indeed, it is not obvious how an output-based allocation system could be practically designed for agriculture. Benchmarks or standards are needed to operationalize output-based schemes. Output-based rebates work best when there is a "best in class" technology which firms can adopt. Best in class technologies in agriculture usually reflect differences in natural endowments such as land quality and climate. It is implausible that producers could replicate a best in class technology by altering their land quality, rainfall or summer temperatures. Moreover, there is uncertainty on how to scale an output-based system to an industry with thousands of firms that enter and exit frequently.

**Offset credits.** One recommendation that has received special attention in the agricultural community is the potential for offset credits. The idea is that producers could undertake costly activities to reduce emissions. By making investments in soil sequestration via reduced tillage and manure management, among other projects, farmers would earn credits. These credits could then be sold to other firms in the economy, reducing a share or all of the cost from the initial emissions-reducing investment.

Most carbon credit programs draw a line between activities that are undertaken for economic reasons and those that are referred to as "additional". Low tillage cropping for instance is largely viewed as economically advantageous irrespective of its environmental benefits. Farmers benefit regardless of any potential carbon credit. Additionality requires making investments that would not otherwise be made without the payment. Low tillage practices, for example, may not qualify for offset credits, but investing in improved manure management systems (e.g., anaerobic digesters) might.

## Exemptions are (Probably) a Good Policy for the Beef Sector

Fundamentally, it is difficult to correct the negative competitive effects arising from unilaterally implemented carbon pricing. Options available are sensitive to both political and practical pressures. In general, output-based subsidies are viewed as more economically efficient when compared with exemptions – at least from a social welfare perspective. Yet, designing an output-based allocation system for the agricultural sector may prove exceedingly difficult. Emissions and output are cost complements and several major challenges confront policy-makers attempting to scale a system designed for large emitters to a heterogeneous farm sector. Among the issues with output-based systems in agriculture is determining the appropriate benchmark or baseline technology. Production – and emissions from production – depends on hard-to-manage factors such as land quality and weather. Tying compensation to long-standing natural endowments or factors that are susceptible to random shocks will likely distort the goals of the program. While output-based allocations may be desirable for many Canadian industries, they are unlikely to work for agriculture.

In reality, the option that is likely best suited to the cattle industry is the one used in Alberta and British Columbia. Given the pre-existing combination of design and political constraints, exemptions are probably the best safety valve mechanism for the beef sector. Exemptions are popular within the industry, but unpopular outside of it. Negative views are generally due to the perceived inefficiency and inequity of sector-specific exemptions. Yet, limited exemptions, such as those on specific inputs such as fuel used on-farm, may be tolerable to critics.

Provinces that are unwilling to adopt full exemptions could, instead, design price-contingent exemptions. As this report demonstrated, the (private) economic costs of carbon pricing are small at high prices, but large at low prices. Jurisdictions that do not currently exempt farm fuel may want to remove their carbon charges on dyed fuels, but only if output prices decline below some pre-defined threshold. That is, exemptions would be triggered when competitiveness effects are particularly large. These output price-contingent exemptions would provide relief from carbon pricing exactly when it's needed the most.

Finally, lump-sum transfers in the form of transitional support are an option for provinces reluctant to embrace exemptions. Lump-sum transfers maintain the incentive to reduce emissions, but are a means to keep farmers and ranchers whole. Modelling is needed to determine the appropriate compensation and duration of funding, but lump-sum transfer programs would be straightforward to establish. For example, the previous three years' production could be used to determine a baseline for decoupled transfers that last for the next three years. Of course, the perennial challenge with lump-sum transfer mechanisms is that they typically face substantial political opposition and, hence, are rarely used.

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# Additional Tables of Results

Two additional tables of results are presented.

Table 12 provides the *percent increase in total costs and excess burden relative to operating costs* for cow-calf enterprises. These are found by dividing the estimated dollar value increase in costs per cwt as presented in Table 6 by the average cost of production *in the pre-carbon price scenario*. These average costs equal $119.05/cwt in Alberta and $198.00/cwt in Ontario.

**Table 12: Percent Change in Total Costs Relative to a Pre-Carbon Price Baseline Scenario, Cow-Calf**

| Carbon Tax | | $20/tCO2e | | $40/tCO2e | |
|---|---|---|---|---|---|
| Output price | | $100/cwt | $200/cwt | $100/cwt | $200/cwt |
| *Total Cost to Producers from the Carbon Tax (% of total cost)* | | | | | |
| Alberta | | | | | |
| | No farm fuel exemption | 2.79 | 1.77 | 3.45 | 2.19 |
| | With farm fuel exemption | 2.27 | 1.44 | 2.41 | 1.53 |
| Ontario | | | | | |
| | No farm fuel exemption | 1.05 | 0.66 | 2.08 | 1.32 |
| | With farm fuel exemption | 0.62 | 0.39 | 1.21 | 0.77 |
| *Excess Burden from the Carbon Tax (% of total cost)* | | | | | |
| Alberta | | | | | |
| | No farm fuel exemption | 1.18 | 0.16 | 1.46 | 0.20 |
| | With farm fuel exemption | 0.96 | 0.13 | 1.02 | 0.14 |
| Ontario | | | | | |
| | No farm fuel exemption | 0.44 | 0.06 | 0.88 | 0.12 |
| | With farm fuel exemption | 0.26 | 0.04 | 0.51 | 0.07 |

Table 13 repeats the analysis of Table 12, but for the feedlot sector. It takes the dollar-valued estimates from Table 11 and divides them by the average cost per cwt needed to produce a fed calf. This average cost for 2016 equals $146.28/cwt.

**Table 13: Percent Change in Total Costs Relative to a Pre-Carbon Price Baseline Scenario, Feedlots**

| | $20/tCO2e | $40/tCO2e |
|---|---|---|
| No farm fuel exemption | 1.03 | 1.73 |
| With farm fuel exemption | 0.75 | 1.25 |