From Farms to Tables: Quantifying the Effect of Emissions Pricing on Canadian Food Prices*

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Abstract

This paper examines the effect of emissions pricing on Canadian food prices. We describe emissions pricing policies relevant to the agriculture and food sectors and the differing design details of various provincial systems and the federal *Greenhouse Gas Pollution Pricing Act*. To quantify the potential effect of such policies on food prices, we use a detailed input-output model of Canada's economy to estimate both the direct and indirect cost increases across sectors. We also explore how exemptions and policy design can mitigate what would otherwise be larger effects. In particular, imported inputs, generous exemptions for most direct emissions in primary agriculture, and special provisions for large industrial emitters all dampen the effect. Overall, we find that emissions pricing at $80 per tonne could potentially increase prices of domestically-produced food by approximately 0.8 percent on average. Combined with imported food that is not directly affected by emissions pricing, we find an average effect of approximately 0.5 percent. While we abstract from general equilibrium responses, our analysis suggests emissions pricing in Canada has only a modest effect on food prices.

JEL Classification: Q18, Q54, Q58, D57

Keywords: Emissions pricing; food prices; Canadian agriculture; climate policy; input-output analysis

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1 Introduction

Canadian inflation rose considerably in recent years, peaking at 8.1 percent in June 2022. While inflation has since declined, nearing relatively normal levels of around two percent by mid-2024, the overall price level remains high. In May 2024, consumer prices were 18.2 percent higher than in May 2019.[1] Had inflation been maintained at the Bank of Canada's two percent target, consumer prices would have increased by nearly half that amount. Food prices have been a significant driver of this trend, rising 26.3 percent over the same period. Understanding the underlying causes of such increases is important, and specifically the role of government policy. Indeed, there is broad concern that government policies in general, and emissions pricing in particular, are substantial drivers of Canada's recent food price increases. Approximately one in four Canadians, for example, believe the federal government is primarily to blame (Leger, 2024). To shed light on this issue, we provide a detailed description of emissions pricing policies in Canada relevant to food and agriculture. We also quantify the potential effects of these emissions policies on food prices, including impacts throughout the food supply chain. We find that emissions pricing has only a modest effect on food prices, with an $80 CAD per tonne price raising the cost of domestically produced food by approximately 0.8 percent. Including non-pricing of imports, we find food prices rise by an average of 0.5 percent.

As with most goods and services, a variety of complex factors contribute to food price changes. Chief among these are agricultural production costs. In fact, we estimate that Statistics Canada's food input price index (lagged by six months) accounts for nearly two-thirds of the variation in the annual change in grocery prices. We illustrate this strong relationship in panel (a) of Figure 1. Understanding the drivers of farm input cost changes is therefore important for understanding why food prices rose so much in recent years. To that end, we estimate the contribution of selected farm inputs to changes in the total farm input price index in panel (b) of Figure 1. Fertilizer costs overwhelmingly account for the acceleration in 2022, especially following Russia's invasion of Ukraine. Machinery fuel is also an important contributor. Historically, variations in the costs of these two inputs account for most of the variation in total farm input costs. Emissions pricing therefore naturally raises concerns for agricultural production costs, as such policies directly affect fuel prices and potentially influence fertilizer prices due to the emissions-intensive nature of its manufacturing process. While countless other factors may also have contributed to rising food prices in recent years (Pentz et al., 2024), our analysis focuses here and quantifies the effect of emissions pricing and food prices in Canada. Importantly, we include the potential for cascading effects throughout the food supply chain using detailed data on input-output linkages.

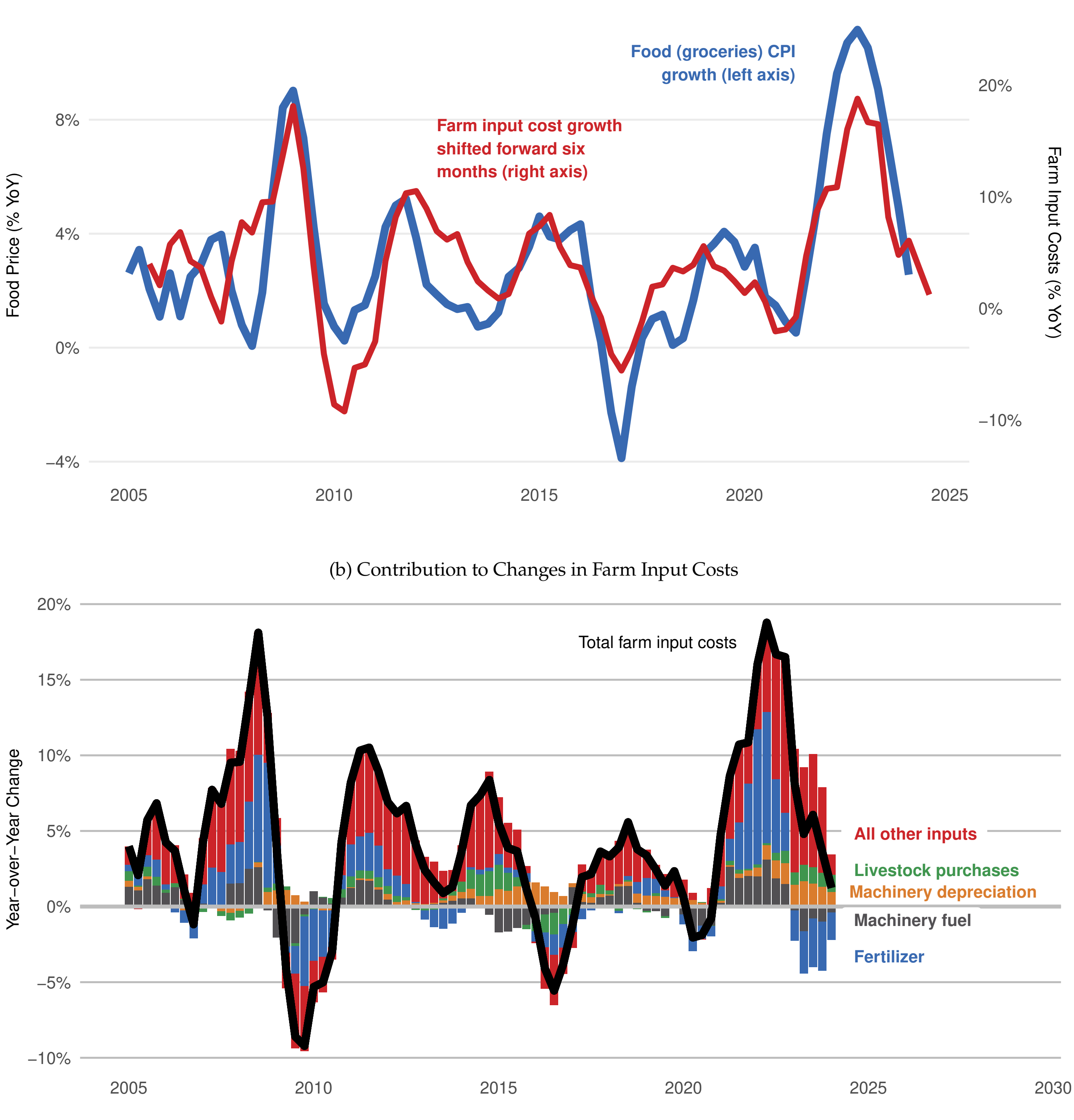
These intersectoral linkages are critical for capturing the full effect of emissions pricing. As we will demonstrate, food product manufacturers have relatively low direct emissions intensity. However, many of the inputs they purchase from other sectors embody significant upstream emissions. For instance, primary agriculture, which is a crucial supplier to food manufacturers, has an order of magnitude higher emissions intensity. For farmers, it is also essential to capture the effect of emissions pricing on the cost of producing inputs such as natural gas and fertilizers, both of which are produced by emissions-intensive sectors. The effect of policy-induced changes in the cost of petroleum refining, chemical manufacturing, primary agriculture, food manufacturing, truck transportation, and then extending to retail grocery stores, can potentially be large.

[1]Source: Authors' calculations using Statistics Canada data table 18-10-0004-01.

Figure 1: Changes in Consumer Grocery Prices and Farm Input Prices, 2005-2024

(a) Grocery Prices and Farm Input Costs

(b) Contribution to Changes in Farm Input Costs



Note: Panel (a) displays the year-over-year change in the "food purchased from stores" component of the consumer price index and the year over year change in Statistics Canada's farm input price index. Panel (b) displays the contribution of selected items to the annual change in farm input costs.

Source: Authors' calculations using Statistics Canada data tables 18-10-0004-01, 18-10-0258-01 and 32-10-0049-01.

To undertake this analysis, we compile detailed data on emissions, production, trade, and input-output linkages between 110 sectors that encompass the entire Canadian economy. Using this data, we apply standard methods from the input-output analysis literature to estimate greenhouse gas emission intensities and attribute them to specific products purchased by final buyers (Miller and Blair, 2022). These indirect emissions estimates, also known as scope 3 emissions, include both the direct emissions associated with each sector's production, emissions embodied in inputs purchased from other sectors, and emissions embodied in the inputs of those inputs, and so on. Applying emissions pricing to these estimates provides an upper bound on the effect on pricing. We find that full pricing of all emissions at $80 per tonne would increase food prices by an average of nearly four percent, with crop and animal production experiencing up to a 13 percent increase. However, policy design is crucial. We show that policies often exempt a substantial share of direct agricultural emissions from emissions pricing, which dampens the downstream effect on food prices. The treatment of large industrial emitters further mitigates this effect via lowering the average costs of emissions through free allocations of emissions permits. Food processing and food manufacturing activities are consistently included in large-emitter systems, dampening emissions pricing effects in food production. The large emitter systems also limits how emissions pricing raises the cost of many important emissions-intensive farm inputs, particularly fertilizers. When all such exemptions, large emitter treatments, and non-pricing of imported inputs, we find an $80 per tonne emissions price would increase food prices in Canada by approximately 0.5 percent on average.

Our analysis contributes to the growing literature exploring how emissions pricing affects consumer prices. In Canada, Statistics Canada regularly produces estimates embedded within its Social Policy Simulation Database and Model (SPSD/M) microsimulation tool. For example, the latest estimate for 2024 from version 30.0 of this tool reports that food prices in British Columbia have increased by just over 0.3 percent due to emissions pricing. These estimates are based on projections from the broader Supply and Use Tables, which can be used to estimate embodied taxes across various goods and services. To illustrate, using this data and the methods described later in this paper, we estimate that BC's carbon tax added approximately 0.8 percent to grains and other crop product prices in 2020 (Statistics Canada, 2020). While informative, these estimates have limitations in scope and coverage. For instance, Québec's cap-and-trade system is not captured by these data as it is not a commodity tax. Additionally, it does not account for important features of large emitter systems, which may lead to increased production costs for firms without explicit commodity tax payments. Our analysis instead estimates the effect of emissions pricing by relying on embodied emissions estimates and approximations of policy design details.

In the academic literature, while there is considerable empirical research on carbon taxation in general (Köppl and Schratzenstaller, 2023), there is very little exploration of its effect on food prices in particular. Early modeling work in Canada found that a carbon tax of just over $100 per tonne would increase agricultural producer prices by between 0.8 and 1.3 percent (Hamilton and Cameron, 1994). More recently, empirical research examining whether the agricultural sector in British Columbia experienced a decline in international competitiveness—which would indicate significant cost increases—found little evidence of such an effect (Rivers and Schaufele, 2015). Our paper is one of the first systematic examinations of the potential effect of emissions pricing on food prices in Canada. Most comparable to our work is Wu and Thomassin (2018), a working paper that uses similar input-output analysis methods, although it abstracts from details of policy design. Most recently, Winter, Dolter, and Fellows (2023) estimate the distributional costs of carbon pricing across households that, in part, incorporates input-output estimates for many items, including agriculture and food, although that is not an explicit focus of their methods.

Before proceeding to our analysis, some caveats are in order. Our estimates are not empirical observations of actual effects. Instead, they are based on a comprehensive model of Canada's economy that supposes production cost changes are fully passed through to consumers. If cost changes are not fully passed through, our estimates will overstate the effect. This is especially relevant in highly trade exposed sectors, where international prices will tend to prevail. Conversely, if cost changes are more than fully passed through, our estimates will understate the effect. We also do not account for changes in production techniques and technologies that emissions pricing may induce. Despite these caveats, our estimates are nonetheless informative and suggest that emissions pricing has only a modest effect on food prices.

2 Climate Policy Affecting Canadian Agriculture and Food Production

Climate policy in Canada generally takes three forms: mandatory instruments such as pricing or regulation, abatement support incentives, and indirect policies such as enabling legislation or information-provision (Scott et al., 2024). Importantly, there are currently very few policy initiatives to regulate or reduce agricultural emissions. Here, we focus on pricing systems relevant to the agricultural and food manufacturing sectors. While there are numerous abatement support incentives and other initiatives to reduce emissions in the agricultural sector (Scott et al., 2024), describing them all is beyond our scope and not directly relevant to the main purpose of the paper, quantifying the effect of emissions pricing on food prices. We begin with a brief primer on the basics of emissions pricing design, then turn to the specifics of the different pricing systems. We organize this section by jurisdiction, starting with federal policies.

2.1 A Brief Primer on Canadian Emissions Pricing

Emissions pricing in Canada generally takes two parts. The first is large-emitter systems that target combustion emissions and industrial process emissions for industrial facilities above a certain annual emissions threshold. The second is pricing on combustion emissions from households and non-industrial sectors such as transportation. The two-part systems are by design, to address competitiveness concerns from emissions pricing and affordability concerns via revenue return to households (Winter, 2024). The exception is Quebec, with a cap and trade system for industrial emissions and fuel distributors. While there is some variation in design, the majority of large-emitter systems combine emissions pricing with a tradeable performance standard that includes free allocation of emissions permits. The allocation of emissions permits is generally tied to output, called output-based rebating.[2] The effect of this design feature is to lower the average cost of emissions while maintaining the marginal price signal via subsidizing output. Facilities' compliance options include lowering emissions via decreasing output or changing production inputs, purchasing earned emissions credits from facilities with emissions below the performance standard, purchasing recognized offset credits from non-regulated entities, or paying for emissions above the performance standard.

[2]Output-based or other rebating is common globally; for a discussion of alternatives, see Böhringer, Fischer, and Rivers (2023).

The Government of Canada sets a minimum standard for coverage and stringency of emissions pricing, called the federal benchmark, with separate tests for large-emitter systems and non-industrial pricing. Provinces and territories whose systems meet the federal benchmark criteria by demonstrating equivalent emissions reductions maintain their own systems. Jurisdictions that fail this benchmark test have the federal system imposed, called the backstop. The backstop consists of an output-based pricing system for large industrial emitters and the federal fuel charge on combustion of fossil fuels (Environment and Climate Change Canada, 2024b). Provinces and territories regularly switch back and forth between having their own systems and the backstop (Winter, 2024). As of July 2024, BC, Northwest Territories, and Quebec have their own systems in full; Yukon, Nunavut, Manitoba[3] and Prince Edward Island have the federal system applying in full; and Alberta, Saskatchewan, Ontario, New Brunswick, Nova Scotia, and Newfoundland and Labrador have the federal fuel charge and individual provincial large emitter systems in place (Environment and Climate Change Canada, 2024b).

2.2 Canada

The federal fuel charge applies to combustion emissions from fossil fuels. It currently applies in Alberta, Saskatchewan, Manitoba, Ontario, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, Yukon and Nunavut (Environment and Climate Change Canada, 2024b). It has several exemptions for agricultural activities, including on-farm fuel use in combustion engines and fuel used in fishing vessels. Natural gas and propane used on farms is not exempt, though starting in the 2021/22 fiscal year the Government of Canada introduced a refundable tax credit for natural gas and propane use on farms in backstop provinces at a rate per $1000 in farming expenses for farms with total expenses above $25,000 (Environment and Climate Change Canada, 2024d). This rate differs by year, and in the 2023 tax year it was 0.186 percent in Alberta, Saskatchewan, Manitoba and Ontario and 0.14 percent in the Atlantic provinces (Canada Revenue Agency, 2024). For greenhouses (NAICS 1114), there is a partial exemption for propane and natural gas used in heat and carbon dioxide production, lowering the fuel charge to 20 percent of the prevailing rate. In all fuel charge (backstop) provinces, light fuel oil used for heating a "home, building or similar structure" (except for heat generation for an industrial process) is fully exempt from the fuel charge until March 31, 2027 (Canada Revenue Agency, 2023; Department of Finance Canada, 2023).[4]

The federal OBPS, effective in 2019, currently applies in Yukon, Nunavut, Manitoba and Prince Edward Island (Environment and Climate Change Canada, 2024b). It sets a performance standard for facilities producing a regulated product with annual emissions at or above 10,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions below 10,000 t CO_2e. The federal OBPS exempts activities by default unless the specified industrial activity is listed in the *Output-Based Pricing System Regulations* Schedule 1 or included in a list of recognized industrial activities. The intent of the federal OBPS is to implement emissions pricing while protecting competitiveness and limiting leakage; by rebating based on output it lowers the average cost of emissions while keeping the marginal cost at the prevailing rate. Specific food sectors identified at risk of competitiveness and leakage risk are sugar and confectionery product

[3] Manitoba also has an emissions tax of $10 per tonne on coal and petroleum coke (Manitoba, 2015).

[4] The regulations are still in draft form, but deemed to be in effect as of November 2023 (Department of Finance Canada, 2023).

Table 1: Canada's OBPS Regulated Food Manufacturing Activities and Requirements

	Performance Std.		Tightening	GHGs Regulated by Type		
Activity	Std.	Units	Rate	Stationary	On-site transport	Wastewater
Industrial potato proc.	0.102	t potatoes	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O
Industrial oilseed proc.	0.0481	t oilseed	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O
Alcohol prod.	1.11	kL alcohol	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O
Wet corn milling	0.0991	t corn	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O
Citric acid prod.	0.479	t citric acid	1%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	
Sugar refining	0.102	t refined sugar	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	
Confectionery products		t finished prod.	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	
Canned, pickled or brined fruits & veg		t output	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	
Pig slaughtering, pork prod.		t pork prod.	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	
Plant protein isolate prod.		t dry protein	2%	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	

Source: Authors' interpretation of *Output-Based Pricing System Regulations* and Environment and Climate Change Canada, 2023; Environment and Climate Change Canada, 2024f.
Notes: Food manufacturing activities without a performance standard were added to the list in 2023 with the first compliance year of 2024. These activities are included in a facility's emissions limit but we could not find public performance standards.

manufacturing (NAICS 3113); fruit and vegetable canning, pickling and drying (NAICS 31142); animal (except poultry) slaughtering (NAICS 311611); and miscellaneous food manufacturing (NAICS 3112, 3118, 3119) (Environment and Climate Change Canada, 2024h). The OBPS also applies to numerous important inputs into agriculture, fishing, and food product manufacturing, such as the energy sector and fertilizer production.

A facility's annual emissions limit (AEL) under the federal OBPS is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot S_p - \left[S_p \cdot TR \cdot (y - 2022) \right] \right\}, \tag{1}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$ denotes production in year y, S is the product's emissions intensity standard in tonnes of CO_2e per unit, and TR is the annual tightening rate for allowable emissions. Facilities can emit up to the annual emissions limit without financial penalty.

The performance standards for industrial activities are largely set at 80 percent of national production-weighted average emissions intensity for that activity (Canada, 2019). Environment and Climate Change Canada adjusted this upward to 90 percent and 95 percent for some sectors based on assessed competitiveness risk, including nitrogen fertilizers (Canada, 2019). The OBPS includes a tightening rate on the performance standards to gradually increase the stringency and lower allowable emissions. For regulated food products, the tightening rate is two percent except for citric acid production with a tightening rate of one percent. The output-based standards, tightening rates, and regulated emissions for regulated food manufacturing activities are detailed in Table 1.

Offset production and credit registration are enabled under the *Canadian Greenhouse Gas Offset Credit System Regulations* and its accompanying protocols. There are no currently active protocols relevant to the agriculture sector, though there is a protocol for reducing emissions from refrigeration systems, relevant for food manufacturing and retail food stores.[5] There are three active registered projects under this protocol, all grocery stores (Environment and Climate Change Canada, 2024a). A draft protocol for reducing enteric methane emissions from beef cattle — via improved management, diet change, feed additives, growth

[5]The two other active federal protocols are for landfill methane and forest management on private forest lands.

promotion, or other strategies — is under development (Environment and Climate Change Canada, 2024c). Protocols are subject to strict additionality requirements, where "emission reductions generated by the project must not occur as a result of federal, provincial or territorial regulations, legal requirements, municipal by-laws, or any other legally binding mandates" (Canada, 2022), excluding priced emissions from facilities regulated under a provincial or federal large-emitter system from accessing the protocols. Canada does recognize BC's and Alberta's offset programs — though not all protocols[6] — enabling facilities regulated under the federal OBPS access to additional offset markets (Environment and Climate Change Canada, 2024g).

2.3 British Columbia

BC has two provincially-implemented emissions pricing systems: a carbon tax levied on combustion emissions from energy fuels and a system for large industrial emitters with annual emissions at or above 10,000 tonnes of CO_2e, called the BC OBPS. Facilities subject to the OBPS are exempt from the carbon tax. There are numerous exemptions from the carbon tax for agricultural activities, including coloured fuel for on-farm use and propane. The exception is natural gas, which is fully subject to the carbon tax. Similar to the federal government, there is a partial exemption for greenhouses (NAICS 1114), lowering the carbon tax to 20 percent of the prevailing rate on natural gas and propane.

The BC OBPS explictly excludes the agricultural sector (NAICS 11). Currently regulated food manufacturing activities are only sugar manufacturing (NAICS 311310) and meat rendering and processing (NAICS 311614). As of 2022, BC only has industrial food manufacturing facilities in these two sectors (Environment and Climate Change Canada, 2024e). Other food products explicitly not regulated are cannabis-growing areas; eligible plants-growing areas; and fat, oil, and grease refining and storage.

A facility's annual emissions limit (AEL) under the OBPS is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{p,y} \cdot S_p \cdot \left[RF - \left(1 - \frac{IP_{p,y}}{CE_{p,y}} \right) \cdot TR \cdot (y - y_i) \right] \right\}, \tag{2}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$ denotes production in year y, S is the product's production-weighted average emissions intensity in tonnes of CO_2e per unit, RF is the sectoral reduction factor, IP is industrial process emissions and CE is compliance emissions allocated to the product[7], TR is the annual tightening rate for compliance emissions, and $y_i = 2024$ (the first compliance year).

For regulated food products, the annual tightening rate on emissions is one percent, the annual tightening rate on industrial process emissions is zero percent, and the reduction factor is 65 percent (Government of British Columbia, 2024b).[8] This means the output-based allocation of emissions for a given facility is 65 percent of the sectoral average emissions intensity in 2024, and decreases by one percentage point per year. The production-weighted average emissions intensity for regulated products

[6] Canada currently only recognizes the following protocols from Alberta: aerobic composting, aerobic landfill bioreactors projects, emissions reductions from pneumatic devices, reducing emissions from fed cattle, and breeding programs for low residual feed intake in beef cattle (Environment and Climate Change Canada, 2024g).

[7] industrial process emissions are a subset of compliance emissions

[8] BC's reduction factor is more generous for cooper mining (80 percent), lead-zinc smelting (85 percent), cement, chemical processing, and lime products (90 percent), and aluminum smelting (95 percent).

are: rendering and meat processing, 0.3862 tonnes CO_2e per tonne protein and fat; liquid sugar, 0.2593 t CO_2e per t solid sugar content; solid sugar, 0.2369 t CO_2e per t solid sugar. There are numerous regulated industrial activities that supply inputs to agriculture, such as lime manufacturing and natural gas processing that are also subject to the OBPS, limiting the emissions pricing exposure to agricultural inputs.

BC also has a carbon offset market providing indirect regulatory coverage with two active protocols available to the agriculture sector, forestry and methane from organic waste. The forestry protocol includes afforestation or reforestation of agricultural land and avoided conversion of forested land to agricultural land. The methane protocol includes anaerobic digestion of solid waste or manure. It allows for credit generation from avoided methane emissions and displacement of more carbon-intensive fuel. As of July 2024, there are no active registered projects for either protocol related to agriculture (Government of British Columbia, 2024a).

2.4 Alberta

The federal fuel charge applies in Alberta, and so the only provincially-run emissions pricing is the large emitter system, the *Technology Innovation and Emissions Reduction Regulation* (TIER) and the supporting offset market. TIER regulates facilities via a performance standard for facilities with annual emissions at or above 100,000 t CO_2e or that has annual imports more than 10,000 t of hydrogen. There is an opt-in provision for facilities with annual emissions at or above 2,000 t CO_2e; these facilities must compete with a regulated facility or be in a sector designated as emissions-intensive and trade-exposed.[9] Facilities regulated under TIER are exempt from the federal fuel charge.

TIER excludes agriculture, but includes support activities for crop and animal production (NAICS 1151). Relevant regulated activities are agroindustry (biodiesel; crude and refined canola oil; ethanol; flour; gluten; malt; refined vegetable oil) and food processing (finished frozen potato products; fresh and frozen beef and veal; liquid and refined sugar) (Alberta Environment and Protected Areas, 2023). Relevant food sectors designated as emissions-intensive and trade-exposed are support activities for crop and animal production (NAICS 1151); animal food manufacturing (3111); grain and oilseed milling (3112); sugar and confectionery product manufacturing (3113); seafood product preparation and packaging (3117); bakeries and tortilla manufacturing (3118); other food manufacturing (3119); breweries (31212); and wineries and distilleries (31213) (Alberta Environment and Protected Areas, 2023). As with other systems, TIER also regulates industrial activities that supply inputs to agriculture and food manufacturing, including oil and gas production and refining, fertilizer manufacturing, and electricity.

A facility's annual emissions limit (AEL) under TIER is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot S_{p,y} - \left[\left(B_{E,y} \cdot I_{E,y} \right) + \left(B_{Hy,y} \cdot I_{Hy,y} \right) + \left(B_{He,y} \cdot I_{He,y} \right) \right] \right\}, \tag{3}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$

[9] The emissions intensity test is emissions intensity at or above one percent and trade exposure at or above 10 percent, or emissions intensity at or above three percent, or trade exposure at or above 80 percent. Emissions intensity is measured by sectoral full emissions pricing costs divided by gross valued added. Trade exposure is measured by the ratio of sectoral exports plus imports to production plus imports.

denotes production in year y, $S_{p,y}$ is the product's emissions intensity standard[10] in tonnes of CO_2e per unit for year y, $B_{E,y}$ is the benchmark for electricity, $I_{E,y}$ is the facility's imported electricity, $B_{Hy,y}$ is the benchmark for hydrogen, $I_{He,y}$ is the facility's imported hydrogen, $B_{He,y}$ is the benchmark for industrial heat, and $I_{He,y}$ is the facility's imported industrial heat.

Facilities can have either an activity-specific or a facility-specific emissions intensity standard; the majority of regulated activities have a facility-specific standard (Alberta Environment and Protected Areas, 2023).[11] Sector-specific standards are determined by the average emissions intensity of the 10 percent of facilities with the lowest emissions intensity, and a two percent annual tightening rate starting in 2023 (Alberta Environment and Protected Areas, 2023). Facility-specific standards are set relative to past emissions intensity, and initially set at 90 percent of production-weighted average emissions intensity for non-industrial process emissions and 100 percent of production-weighted average emissions intensity for industrial process (IP) emissions (Alberta Environment and Protected Areas, 2023). The tightening rate on non-IP emissions was initially one percent per year, then two percent per year starting in 2023.

Alberta's offset system is one of the most-developed in Canada, with 18 active protocols (Government of Alberta, 2024). Offset protocols directly relevant to agriculture and food production include aerobic composting, agricultural nitrous oxide emission reductions, biofuel and biogas production, energy generation from biomass waste combustion, reducing emissions from fed cattle, and breeding programs for low residual feed intake in beef cattle. Other relevant offsets are distributed renewable energy generation and energy efficiency projects. There are also several withdrawn protocols applicable to agriculture, including conservation cropping, emissions reductions from dairy cattle, edible oils in cattle feed, swine feed and swine manure practices, reducing age at harvest of beef cattle, reducing days on feed of beef cattle, and nitrous oxide abatement from nitric acid production. As of July 2024, there are four active offset projects for reducing emissions from cattle and three active projects for reducing agricultural nitrous oxide emissions (Alberta Carbon Registries, 2024).

2.5 Saskatchewan

The federal fuel charge applies in Saskatchewan, and so the only provincially-run emissions pricing is the large emitter system, called the Saskatchewan OBPS. The Saskatchewan OBPS came into effect in 2019, and expanded to include electricity generation in 2023 (Winter, 2024).[12] Facilities subject to the OBPS are exempt from the federal fuel charge. Regulated facilities are those with with annual emissions at or above 25,000 t CO_2e and electricity generation facilities with annual emissions at or above 10,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions below the respective thresholds (Saskatchewan, 2023). Saskatchewan's OBPS is unique in that it has no minimum threshold for voluntary participation. Saskatchewan also allows for creation of aggregate facilities from individual facilities with annual emissions below 25,000 t CO_2e, but this is currently only applicable to the upstream oil and gas sector (Government of Saskatchewan, 2024b). It explicitly excludes some sectors in accompanying guidance: agriculture; transportation (other than on-site transportation); distribution pipelines; landfills; public institutions; and district heating (Government of Saskatchewan, 2024c). Regulated emissions are

[10] Alberta uses benchmark instead of standard.

[11] Only electricity, hydrogen, and industrial heat have sector-specific standards set in regulation; others are set by ministerial order (Alberta, 2019).

[12] Saskatchewan's electricity sector was subject to the federal OBPS between 2019 and 2022.

stationary fuel combustion (CO_2, CH_4, N_2O), industrial process emissions (CO_2, CH_4, N_2O, SF_6, HFCs, PFCs), industrial product use emissions (SF_6, HFCs, PFCs), fugitive emissions (CO_2, CH_4, N_2O), on-site transportation emissions (CO_2, CH_4, N_2O), and waste and wastewater emissions (CO_2, CH_4, N_2O). Currently, there are five food processing facilities with emissions above the threshold and one below the threshold (Environment and Climate Change Canada, 2024e).

The Saskatchewan OBPS explicitly excludes agriculture (Government of Saskatchewan, 2024c), but includes food and agricultural products processing. Performance standards are sector-specific, with required improvements relative to a facility's baseline emissions intensity. A facility's annual emissions limit (AEL) under the OBPS is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{p,y} \cdot \left[S_{p,k} \cdot \left(B_{p,b} - \frac{IP_{p,b}}{q_{p,b}} \right) + \frac{IP_{p,b}}{q_{p,b}} \right] \right\}, \tag{4}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility; $q_{p,y}$ denotes production in year y; $S_{p,k}$ is the product's emissions intensity standard in tonnes of CO_2e per unit for compliance year k; $B_{p,b}$ is the product's baseline emissions intensity in baseline year b, measured in tonnes of CO_2e per unit of product p; $IP_{p,b}$ is industrial process emissions from producing product p in baseline year b; and $q_{p,b}$ denotes production in baseline year b.

The performance standard is a function of the reduction period rather than years since the regulation came into effect, and applies as soon as a facility becomes subject to the regulation (Government of Saskatchewan, 2024c). This means facilities in the same economic sector may have different performance standards. The performance standard for most sectors is 0.9875 in the first compliance period, decreasing by 0.0125 per year until it reaches 0.85 in the 12th compliance year (Saskatchewan, 2023). In 2024, the performance standard is 0.9250, assuming a facility became regulated when the OBPS came into effect and is in its sixth compliance year. Saskatchewan's performance standard is equivalent to the output-based allocation rate. Like several other systems, Saskatchewan grants industrial process emissions an 100 percent allocation rate, but this is set to the facility's baseline emissions intensity for industrial process emissions. Agricultural sectors explicitly granted performance standards in the regulations are food and beverage processing and grain and oilseed processing; the regulation also has an "other sectors" performance standard so facilities meeting the emissions thresholds in non-listed sectors are also granted free allocations. Relevant activities that are inputs to agrifood sectors with performance standards are agricultural and industrial equipment manufacturing; chemical manufacturing; fertilizer manufacturing; electricity generation; petroleum refining; oil and gas production; and natural gas transmission.

Lastly, Saskatchewan has indicated it will develop an offsets program, but there is no indication is has advanced past initial engagement since 2021 (Government of Saskatchewan, 2024a).

2.6 Ontario

The federal fuel charge applies in Ontario, and so the only provincially-run emissions pricing is the large emitter system, called the Ontario Emissions Performance Standards (EPS) program. The Ontario EPS came into effect in 2022 (Government of Ontario, 2024a). Regulated facilities are those with with annual emissions at or above 50,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions at or above 10,000 t CO_2e (Ontario, 2019). Facilities subject to the EPS are exempt from the federal fuel charge. The Ontario EPS only explictly includes specific industrial activities, detailed in Schedule 2 of the *Emissions Performance Standards Regulation*. It excludes agricultural activities but includes some food and agricultural products processing: industrial processing of potatoes or oilseeds; producing ethanol for use in alcoholic beverages; wet milling of corn; citric acid production; refined sugar production; and specific NAICS activities, including grain and oilseed milling (3112); sugar and confectionery product manufacturing (3113); fruit and vegetable preserving and specialty food manufacturing (3114); dairy product manufacturing (3115); meat product manufacturing (3116); bakeries and trortilla manufacturing (3118); other food manufacturing (3119); and beverage manufacturing (3121) (Ontario, 2019).

The Ontario EPS has a mix of sector-specific performance standards and facility-specific performance standards. Food product manufacturing activities are all subject to a facility-specific performance standard (Government of Ontario, 2024b). A facility's annual emissions limit (AEL) under the EPS is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot \left(S_{p,y,FPE} + S_{p,y,nFPE} \right) \right\} - \left(I_{E,y} \cdot 0.063 \cdot SF_{y,nFPE} \right), \tag{5}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$ denotes production in year y, $S_{p,y,FPE}$ is the product's emissions intensity standard for fixed process emissions (FPE) in tonnes of CO_2e per unit for year y, $S_{p,y,nFPE}$ is the product's emissions intensity standard for non-fixed process emissions in tonnes of CO_2e per unit for year y, $I_{E,y}$ is the facility's imported thermal energy, and $SF_{y,nFPE}$ is the facility's stringency factor for non-fixed process emissions. Fixed process are those from industrial processes, and non-fixed process emissions are all other regulated GHGs (Government of Ontario, 2024b). The performance standard for both fixed process emissions and non-fixed process emissions is the facility's baseline emissions intensity for the emissions source multiplied by the respective stringency factor. Stringency factors have a set schedule, and for fixed process emissions were 1.0 in 2022 and 0.961 in 2024 (Government of Ontario, 2024b). These translate to an output-based allocation rate of emissions permits that is 100 percent of the facility's baseline emissions in 2022 and 96.1 percent of the facility's baseline emissions in 2024. The stringency factor for non-fixed process emissions is 0.761 for dairy products and 0.881 for food products manufacturing in 2024 (Government of Ontario, 2024b), implying output-based allocation rates of emissions permits of 76.1 percent and 88.1 percent respectively.

As with other systems, the Ontario EPS also regulates industrial activities that supply inputs to agriculture and food manufacturing, including oil and gas processing and refining, fertilizer manufacturing, and electricity. Ontario has no provisions for creating an offset market in its regulations.

2.7 Quebec

Quebec is the only province with a cap and trade system, which came into force in 2013. Quebec's system is deemed equivalent to the federal benchmark and so federal pricing does not apply. The cap and trade system applies to industrial facilities with annual emissions at or above 25,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions at or above 10,000 t CO_2e (MELCCFP, 2024f). It also applies to fuel distributors that distribute 200 litres or more per year and electricity imports with attributable emissions at or above 25,000 t CO_2e per year (Quebec, 2024). Covered sectors are defined in the regulation and are mining, quarrying and oil and natural gas extraction (NAICS 211 and 212); electric power generation, transmission and distribution (NAICS 2211); natural gas distribution (NAICS 2212 and 488990); steam and air conditioning production for industrial purposes (NAICS 22133); manufacturing (NAICS 31, 32, 33); and pipeline transportation (NAICS 486 and 488990) (Quebec, 2024).

The cap and trade system is linked to California, with declining annual emissions caps and a minimum price. Quebec's system is unique in that a compliance period is over three years, rather than one, allowing for intertemporal substitution of activity (MELCCFP, 2024f). The current compliance period covers 2024 through 2026. In 2024, Quebec's cap is 52.55 million tonnes and the minimum price is \$22.93 CAD,[13] with the cap declining by 2.34 percentage points per year to 44.14 million tonnes in 2030 and the minimum price increasing by five percent plus inflation per year (Gouvernement du Québec, 2017; Gouvernement du Québec, 2023; MELCCFP, 2024h).

Similar to other Canadian pricing systems, firms with specific industrial activities identified as emissions-intensive and trade exposed (EITE) are given free allocation of emissions permits.[14] These activities are prescribed in the regulation, and are mining and quarrying (except oil and gas), (NAICS 212); specific contracted electric power generation (NAICS 2211); steam and air conditioning production for industrial purposes (NAICS 22133); and manufacturing (NAICS 31, 32, 33) (Quebec, 2024). Free allocations (FA) are granted according to the following formula:

$$FA_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot S_{p,y} \cdot \left[AF - MEE_y \right] \right\}, \tag{6}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$ denotes production in year y, $S_{p,y}$ is the product's emissions intensity standard in tonnes of CO_2e per unit for year y, AF is the facility's assistance factor and MEE_y is the minimal expected effort to reduce emissions (MELCCFP, 2024a). Intensity targets are a function of past emissions and are generally facility-specific, but are sector-specific for aluminum, lime, and cement production (MELCCFP, 2024a). Assistance factors are a function of carbon leakage risk: 90 percent for low EITE risk, 95 percent for medium EITE risk, and 100 percent for high EITE risk, and is 60 percent for (Quebec, 2024; MELCCFP, 2024a). Agrifood has an assistance factor of 90 percent, except for sugar and oilseed processing with assistance factors of 100 percent (Quebec, 2024). The minimal expected effort is one percentage point per year; a firm's reductions above this are converted into permits for auction. For an agrifood facility operating since the system's inception in 2013, the free allocation rate in 2024 is 79 percent when the assistance factor is 90 percent and 89 percent when the assistance factor is 100 percent.

A portion of the free allocation is assigned to the firm as free emissions permits, according to the formula:

$$FA_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot S_{p,y} \cdot \left[AF - CDF_y - RF - TMF \right] \right\}, \tag{7}$$

where other parameters are as above and CDF_y is the cap decline factor (2.34 percentage points per year), RF is a reduction factor based on leakage risk, and TMF is a trajectory modulation factor. The

[13] Linking with California means that both jurisdictions have a minimum price and the exchange rate determines which binds (MELCCFP, 2024h).

[14] The EITE test is emissions intensity at or above 0.1 kt CO_2e per million dollars GDP, or trade exposure at or above 10 percent. Emissions intensity is measured by the ratio of emissions to GDP for sectors and firms. Trade intensity is measured by the ratio of imports plus exports to domestic production plus imports.

reduction factor is activity-specific and varies from -0.272 to 1.36 percentage points, and is a function of the emissions intensity of production, defined as kt CO_2e per million dollars of GDP. Agrifood is designated as "risk level 1", with low emissions intensity and the reduction factor is 1.36 percentage points. The trajectory modulation factor is set in the regulation and is negative for 2024 through 2019, reducing the required reductions and increasing the free allocation — this is a deliberate policy choice to "preserve competitiveness" (MELCCFP, 2024a). For an agrifood facility operating since the system's inception in 2013, the free allocation rate for emissions permits in 2024 is 86.76 percent with an assistance factor of 90 percent and 96.78 percent with an assistance factor of 100 percent.

The remainder of each facility's free allocation is consigned to auction, and the revenues are placed in a fund specific to the firm to be used for studying "the technical and economic potential of GHG emission reduction" and investing in "emission reduction projects in their establishments or in research and development projects aimed at reducing greenhouse gas emissions" (MELCCFP, 2024g).

Firms' failure to reduce emissions or purchasing insufficient credits to meet their compliance obligation faces an administrative penalty requiring them to surrender three emissions permits for each outstanding permit (MELCCFP, 2024b).

Quebec's offset market has seven active protocols (MELCCFP, 2024c). Offset protocols directly relevant to agriculture and food production are carbon sequestration through afforestation or reforestation on private land, which includes agricultural lands; methane destruction by covering manure storage facilities; and anaerobic digestion of manure. Quebec is also developing protocols for fuel substitution in maritime transport; agricultural fertilizer application practices; and afforestation or reforestation on public land (MELCCFP, 2024e). As of July 2024, there are no active registered projects for either protocol related to agriculture (MELCCFP, 2024d).

2.8 New Brunswick

The federal fuel charge applies in New Brunswick, and so the only provincially-run emissions pricing is the large emitter system, called the New Brunswick OBPS. New Brunswick's OBPS came into effect in 2021. Facilities subject to the OBPS are exempt from the federal fuel charge. The New Brunswick OBPS only explicitly includes manufacturing and processing; mining, quarrying and oil and gas extraction; and electricity generation, though it does have provisions for inclusion of other industrial activities (New Brunswick, 2018). It sets a facility-specific performance standard for facilities with annual emissions at or above 50,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions at or above 10,000 t CO_2e. Regulated emissions are stationary fuel combustion (CO_2, CH_4, N_2O), industrial process emissions (CO_2, CH_4, N_2O, SF_6, HFCs, PFCs), industrial product use emissions (SF_6, HFCs, PFCs), fugitive emissions (CO_2, CH_4, N_2O), on-site transportation emissions (CO_2, CH_4, N_2O), and waste and wastewater emissions (CO_2, CH_4, N_2O). Currently, there are two food manufacturing facilities that meet the 10,000 t CO_2e threshold (Environment and Climate Change Canada, 2024e).

A facility's annual emissions limit (AEL) under the New Brunswick OBPS is determined by the equation:

$$AEL_y = \sum_{p=1}^{n_p} \left\{ q_{y,p} \cdot S_{p,y} \right\}, \tag{8}$$

where p is a regulated product, n_p is the number of regulated products produced at the facility, $q_{y,p}$ denotes production in year y and $S_{p,y}$ is the product's emissions intensity standard in tonnes of CO_2e per unit for year y. For industrial activities (excluding electricity generation[15]), the emissions intensity standard $S_{p,y}$ is given by the equation:

$$S_{p,y} = \left[\left(BEI_p - \frac{IP_{p,y} + EC_{p,y}}{q_p} \right) \cdot TR_k + \frac{IP_p + EC_p}{q_p} \right] \cdot RF_k \cdot BF_k \tag{9}$$

where BEI_p is the benchmark emissions intensity for product p, $IP_{p,y}$ is the facility's industrial process emissions from product p in year y, $EC_{p,y}$ is the facility's stationary combustion from electricity produced on-site, TR_k is the annual tightening rate on the performance standard in reduction period k, RF_k is the risk-adjustment factor for a facility, and BF_k is the biomass adjustment factor.[16] The performance standard is a function of the compliance year of a given facility, starting with the third year of operation. The tightening rate is one percent for the first two reduction years (years three and four of operations), and two percent annually for reduction years three through ten (New Brunswick, 2021). This effectively means the output-based allocation of emissions permits is 99 percent of a facility's baseline emissions in the first reduction year, decreasing to 82 percent in reduction year 10. Assuming all regulated facilities were in operation prior to the OBPS' implementation in 2021, the output-based allocation rate in 2024 is 94 percent.

Finally, New Brunswick's *Climate Change Act* allows for facilities to purchase offset credits, but it has not yet enabled its offset market through additional regulation.

2.9 Nova Scotia

The federal fuel charge applies in Nova Scotia, and so the only provincially-run emissions pricing is the large emitter system, called the Nova Scotia OBPS. The first compliance year for the NS OBPS was 2023 (Government of Nova Scotia, 2024). Facilities subject to the OBPS are exempt from the federal fuel charge. The Nova Scotia OBPS only explicitly includes manufacturing and processing; mining, quarrying and oil and gas extraction; and electricity generation, though it does have provisions for inclusion of other industrial activities. It sets a facility-specific performance standard for facilities with annual emissions at or above 50,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions at or above 10,000 t CO_2e. Currently, there are no agricultural facilities or food manufacturing facilities that meet the 10,000 t CO_2e threshold (Environment and Climate Change Canada, 2024e), and mandatory and opted-in facilities are all non-food or non-food-processing activities (Government of Nova Scotia, 2024). As the OBPS does not apply to agriculture or food sectors and it is substantively similar to the New Brunswick OBPS (New Brunswick Department of Environment and Local Government, 2022; Nova Scotia Environment and Climate Change, 2023), we do not describe it further. However, it is worth noting that the Nova Scotia OBPS applies to inputs to agri-food, mainly through electricity (Nova Scotia Environment and Climate Change, 2023).

[15]The performance standard for electricity is prescribed in the *Reduction of Greenhouse Gas Emissions Regulation*.

[16]The risk adjustment factor is 1.045 for lime manufacturing (NAICS 327410) and unity for all other regulated facilities. The biomass adjustment factor is 1.045 for facilities where at least 91 percent of energy used in cogeneration for steam is biomass and unity otherwise (New Brunswick Department of Environment and Local Government, 2022).

2.10 Newfoundland and Labrador

The federal fuel charge applies in Newfoundland and Labrador, and so the only provincially-run emissions pricing is the large emitter system, called the Newfoundland and Labrador Carbon Pricing System for Large Industry (Government of Newfoundland and Labrador, 2024); we will use OBPS. The first compliance year for the Newfoundland and Labrador OBPS was 2019. Facilities subject to the OBPS are exempt from the federal fuel charge. The NL OBPS only explicitly includes manufacturing and processing; mining, quarrying and oil and gas extraction; and electricity generation. It sets a facility-specific performance standard for facilities with annual emissions at or above 25,000 t CO_2e, with opt-in for facilities in regulated sectors with emissions at or above 15,000 t CO_2e. Currently, there are no agricultural facilities or food manufacturing facilities that meet the 15,000 t CO_2e threshold (Environment and Climate Change Canada, 2024e). As the OBPS does not apply to agriculture or food sectors, we do not describe it further. However, it is worth noting that the Newfoundland and Labrador OBPS applies to inputs to agri-food, mainly through electricity (Newfoundland and Labrador, 2016).

3 Quantifying the Effect of Emissions Pricing on Consumer Prices

With these policy details in hand, we proceed to quantify the effect of emissions pricing on food prices. In this section, we first introduce an input-output model of Canada's economy to provide a foundational understanding of the rich web of interconnections between sectors. With this framework, we then proceed to explore both the direct and indirect effects of emissions pricing under a scenario where each tonne of greenhouse gas emissions are fully priced (regardless of type or source) and fully passed through to consumers. This provides an upper bound on the potential effect. Finally, we demonstrate how various aspects of policy design dampen these effects dramatically.

3.1 An Input-Output Model of Canada's Economy

Input-output tables provide valuable data on how goods and services flow through the economy within and between sectors. The intuition behind these tables is also straightforward. Each sector's total output can either be used by itself or other sectors as an intermediate input into the production of yet some other good or service, or it can be sold directly to final buyers either domestically or abroad. The term "final demand" refers to this final consumption and investment. These data can also be useful to examine how changes in the cost of certain inputs for one item, say transportation fuel or natural gas, affects the final price of goods and services throughout the economy.

To illustrate, we present an aggregated version of the latest data from Statistics Canada in Table 2 for 2019, the latest pre-COVID year that we base our later analysis on. The rows represent different industries such as agriculture, forestry, and fishing; resources, utilities, and construction; food manufacturing; other manufacturing; and services. These industries are listed as sellers, indicating the goods and services they provide to others. The columns represent the same industries as buyers, showing how much each industry purchases from every other industry to produce its own goods and services. For example, the agriculture, forestry, and fishing sector sells \$17.4 billion worth of goods to itself, \$1.1 billion to the resources, utilities, and construction sector, \$31.8 billion to the food product manufacturing sector, and so on. The table also

Table 2: Canada's Symmetric Input-Output Data (2019, Billions of Dollars)

Seller	Buyer: Ag., Forestry, Fishing	Resources, Util., Const.	Food Mfg.	Other Mfg.	Services	Final Demand	Total Output
Ag., Forestry, Fishing	17.4	1.1	31.8	10.3	1.9	37.6	100.1
Resources, Util., Const.	4.6	39.3	2.1	59.3	65.0	453.7	624.1
Food Manufacturing	5.6	0.7	14.2	1.1	20.4	86.0	128.0
Other Manufacturing	8.5	71.1	5.8	102.4	59.9	385.5	633.3
Services	14.7	117.5	21.1	86.0	703.2	1,637.4	2,580.0
Imports	9.4	66.5	17.5	186.3	146.4		
Value Added	39.9	327.8	35.6	187.8	1,583.1		
Total Output	100.1	624.1	128.0	633.3	2,580.0		

Source: Authors' calculations using Statistics Canada's 2019 symmetric input-output tables (catalogue 15-207-X) using link-1961 classification.

includes imports and the final demand, the former of which are purchases by Canadian producers from suppliers abroad and the latter of which is the total consumption by households, businesses, government, and foreign buyers. The value-added row represents the additional value created by each sector after accounting for the cost of intermediate inputs, which more intuitively may be thought of as the income generated by each sector for workers, capital owners, land owners, and so on. The final column, total output, shows the total production of each sector, combining all intermediate and final goods and services. Notice that spending by any sector on intermediate inputs plus imports and value added always equals total output (i.e., sales). Each dollar must go somewhere, after all. Also notice that sales by every sector equals total purchases by all other sectors and by final buyers. Total imports plus domestic value added also equals total final demand.

For our analysis to come, it is convenient to represent these input-output flows mathematically. To begin, one can divide output into goods for final consumption and intermediate goods used in production. This can be written as

$$Y^j = C^j + \sum_{k=1}^{J} M^{kj}, \tag{10}$$

where C^j is consumption and M^{kj} are goods from sector j used to produce output in sector k. This equation ensures that the supply of goods matches demand. Importantly, this expression is for *quantities* of each item, rather than value. But to relate this to input-output data, in particular data produced by Statistics Canada that we will provided in Table 2, we must capture the flow of value between sectors. To achieve this, multiply both sides of the above equation by the price of sector j's goods, P^j. With some algebraic manipulation, we have

$$P^jY^j = \beta^j \boldsymbol{I} + \sum_{k=1}^{J} \sigma^{kj} P^k Y^k, \tag{11}$$

where $\boldsymbol{I}$ is total household income, $\beta^j = P^jC^j/I$ is the share of total income allocated to final demand of sector j's output, and $\sigma^{kj} = P^jM^{kj}/P^kY^k$ is the share of sector k's total sales (which, in the case of perfectly competitive sectors, is equivalent to total input purchases by sector k) allocated to the purchase of intermediate inputs produced by sector j. In the data, the total output of food product manufacturers in 2019, for example, was $128 billion. Of this, $86 billion went to satisfy final demand and $42 billion to intermediate inputs purchased by other producers. One may also derive the input shares σ^{kj} and final demand shares β^j from the data in Table 2. The share of food manufacturing purchases sourced from from agriculture, forestry, and fishing, for example, is 24.8 percent (from 31.8/128).

More than just mathematically capturing the data, this expression can also be used to relate total output of each sector to total final demand. If input shares and final demand shares are fixed, then one can solve the above expression in matrix form as

$$\boldsymbol{\gamma} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \boldsymbol{\beta}, \tag{12}$$

where $\boldsymbol{\gamma}$ is the vector of sector sales relative to the economy's total income (such that $\gamma^j = P^j Y^j / I$), $\boldsymbol{A}$ is the matrix of intermediate input shares (also known as the Direct Requirements Matrix), and the vector $\boldsymbol{\beta}$ summarizes the distribution of final demand across sectors. The term $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is known as the Leontief Inverse Matrix, and it shows how much output from each sector is needed to satisfy one unit of final demand for a given sector. Given the data in Table 2, the Leontief Inverse Matrix is

$$(\boldsymbol{I} - \boldsymbol{A})^{-1} = \begin{bmatrix} 1.24 & 0.01 & 0.35 & 0.03 & 0.01 \\ 0.09 & 1.09 & 0.06 & 0.13 & 0.04 \\ 0.08 & 0.00 & 1.15 & 0.01 & 0.01 \\ 0.15 & 0.16 & 0.12 & 1.22 & 0.05 \\ 0.32 & 0.31 & 0.37 & 0.27 & 1.40 \end{bmatrix}, \tag{13}$$

which means 1.24 units of agricultural output is required to satisfy one unit of final demand for that sector. Continuing down the first column, this also means 0.09 units of resources, utilities, and construction, 0.08 units of food product manufacturing, 0.15 units of other manufactured goods, and 0.32 units of services are all required to satisfy one unit of final demand for agricultural goods. In total, this means nearly 1.9 units of total output is required across all sectors for each unit of final demand for agriculture. This is a critical object in the analysis to come. It will be central to quantifying how a shock to an upstream sector (say, through emissions pricing raising the cost of energy inputs) can affect downstream sectors, including those not directly energy-intensive.

While not immediately obvious, one can use this simple framework to trace the effect of a cost change in one sector onto price changes in any other. But certain additional assumptions regarding the production technologies are required. In particular, if production exhibits constant returns to scale and if the share of total costs accounted for by each input is constant, then changes in the price of that input will affect marginal costs in proportion to that input's share. One example of this is if production can be summarized by a Cobb-Douglas function. In this case, changes in the marginal cost of production in sector j are

$$\hat{c}^j = \frac{\hat{\tau}^j}{\hat{\varphi}^j} \prod_{n=1}^{N} (\hat{w}^n)^{\alpha^{jn}} \prod_{k=1}^{J} \left(\hat{P}^k\right)^{\sigma^{jk}}, \tag{14}$$

where hats denote relative changes (that is, $\hat{x} \equiv x'/x$, so that a ten percent increase in x is $x' = 1.1 \times x$)

and α^{jn} and σ^{jk} are the input shares for each of the N primary factors purchased by sector j and for the intermediate inputs purchased by sector j from each of the economy's J sectors. In this expression, $\hat{\tau}^j$ are policy-induced changes in sector j's production costs, $\hat{\varphi}^j$ are changes in sector j's total factor productivity, $\hat{w}^n$ are changes in the price of any of the N primary inputs (such as labour, capital, and land), and $\hat{P}^k$ are changes in the price of goods or services from sector k. If each sector is also perfectly competitive, then changes in marginal cost will equal changes in output prices. That is, $\hat{c}^j = \hat{P}^j$ for all sectors. It is then straightforward for one to show that

$$\ln \hat{\boldsymbol{P}} = (\boldsymbol{I} - \boldsymbol{A}')^{-1} \left(\ln \hat{\boldsymbol{\tau}} + \sum_{n=1}^{N} \boldsymbol{\alpha}^n \ln \hat{w}^n - \ln \hat{\boldsymbol{\varphi}} \right), \tag{15}$$

where bold variables denote vectors of changes for each variable across sectors. If total factor productivity is held constant, and if we abstract from general equilibrium effects of policy changes on wages, capital returns, and so on, then the change in the cost of emissions in any sector will affect the production costs and therefore prices charged by every other sectors to an extent captured fully by the Leontief Inverse Matrix. In this way, one can quantify the full direct and indirect effect of emissions pricing on, goods and services throughout Canada's economy since such policies would affect $\hat{\tau}^j$ in the above.[17] The direct effect in sector j would simply be $\ln \hat{\tau}^j$ itself. A policy-induced cost increase equivalent to one percent of total costs would raise prices by one percent. Indirect effects, meanwhile, add to this by an amount summarized by the column sum of the Leontief Inverse Matrix. That sum for crop and animal production (excluding cannabis), for example, is approximately 2.5. For a sector that purchases no intermediate inputs at all would have a value for this sum of 1.0, so a value of 2.5 indicates potentially large indirect effects.

Before turning to our quantitative analysis, it is worth appreciating how emissions pricing policies will affect $\hat{\tau}^j$ in the above expressions. Emissions are generated through energy use and other processes both by firms and by households directly. The total emissions in the economy can therefore be well approximated by a simple expression

$$E = E^f + \sum_{j=1}^{J} e^j P^j Y^j, \tag{16}$$

where E^f represents the emissions by households through their direct use of fossil fuels and e^j represents the emissions intensity in tonnes per dollar of output in sector j. A policy that fully prices emissions at P^e per tonne will therefore raise household costs by $P^e E^f$ and the production costs of sector j output by $P^e e^j P^j Y^j$. The change in costs for sector j relative to no emissions pricing is therefore $\hat{\tau}^j = P^e e^j$. Data on emissions intensity is therefore all that is required. And combined with the result in equation 15, the effect of emissions pricing on the output price for each sector in Canada's economy is therefore

$$\ln \hat{\boldsymbol{P}} = (\boldsymbol{I} - \boldsymbol{A}')^{-1} \ln P^e \boldsymbol{e}, \tag{17}$$

where $\boldsymbol{e}$ is the vector of direct emissions intensities e^j of each sector. This can further distinguish between the direct effect of emissions pricing (captured by $\ln P^e \boldsymbol{e}$ alone) and all of the indirect effects that are due to the cascading cost changes that ripple through the rich web of interconnections between sectors,

[17] Although presented and derived differently, this approach is equivalent to the cost-push pricing model that is common in input output analysis (Miller and Blair, 2022).

which amplify the direct effects by $(\boldsymbol{I}-\boldsymbol{A}')^{-1}$. To the extent that both consumers and producers change behaviour in response to emissions pricing by shifting expenditures away from items with relatively high price increases, then the estimates derived from equation 17 will overstate the effect.

3.2 Direct and Indirect Effects Under Full Pricing

To fix ideas, we begin with a simple example based on the crop and animal production (excluding cannabis) sector in Canada. In 2019, this sector produced approximately \$72.7 billion in output. Total greenhouse gas emissions of this sector was just under 70.3 megatonnes. The emissions intensity of production was therefore 0.97 tonnes per thousand dollars in output.[18] Now imagine a policy that priced all of these emissions in full, with no compensating rebates or other complexities. At \$80 per tonne, the cost would be just over \$82 per thousand dollars in output—equivalent to a 7.7 percent increase in total costs, or $\hat{\tau} = 1.077$ for this sector. But this is just the direct effect of such a pricing policy. If there was full and economy-wide pricing of all emissions, then inputs used by this sector would also experience direct cost increases in proportion to their respective $\hat{\tau}^j$. And such increases up the supply chain would multiply geometrically in a manner summarized by the Leontief Inverse Matrix. The total direct plus indirect effect of emissions pricing would be captured by $(\boldsymbol{I}-\boldsymbol{A}')^{-1}\ln\hat{\boldsymbol{\tau}}$. For the crop and animal production (excluding cannabis) sector, we estimate this value at 1.62 tonnes per thousand dollars in output in 2019.[19] At \$80 per tonne economy-wide, the total direct plus indirect cost for this sector would increase from the 7.7 percent direct effect to 13 percent.

Producing such estimates for several sectors relevant for agriculture and food in Canada is possible. Using detailed input-output, production, and emissions data for 110 sectors, we provide estimates of emissions intensity by sector in Table 3, showing both direct emissions and total emissions. The first row is the crop and animal production sector (excluding cannabis) that we just discussed. Fishing, hunting, and trapping have direct emissions of 0.26 tonnes per thousand dollars in output and total emissions of 0.46. Animal food manufacturing shows a low direct emissions intensity at 0.05, but a much higher intensity for total emissions, at 0.77. For this sector, this indicates significant supply chain emissions from the production and transportation of raw materials upstream. The same is true for nearly all food product manufacturing sectors. The remaining sectors, such as breweries, wineries and distilleries, wholesale trade, and retail trade, show varying levels of direct emissions but generally lower total emissions compared to the agricultural and food manufacturing sectors. In the final two rows, we report the emissions intensity of wholesale and retail trade to very roughly approximate the features of distribution and retail sales relevant for the food sector. More detailed information on subsectors within these broad categories, such as grocery stores, is not available.

Sectoral emissions intensities are informative to get a sense of how emissions pricing may affect production costs and therefore consumer prices. If all emissions are priced, then as described for cop and animal production, one can simply multiply the relevant intensities by the emissions price. In Table 4, we

[18]Source: Authors' calculations using Statistics Canada's symmetric supply and use tables at the L97 aggregation combined with data table 38-10-0097-01.

[19]Source: Authors' calculations using Statistics Canada's symmetric supply and use tables at the link-1961 classification assuming that imported inputs have the same emissions intensity as the corresponding domestically produced inputs in the same supplier sector. Statistics Canada produces its own direct plus indirect emissions intensity estimates in data table 38-10-0098-01, which we do not use directly in this analysis. Our estimates are nearly identical, with a correlation of 0.996 and a mean absolute difference of 0.02 between the two series across sectors.

Table 3: Direct and Total Emissions Intensity, by Sector (2019)

Sector	Emissions Intensity (tonnes per $000)		
	Direct Intensity	Indirect Intensity	Total (Direct + Indirect) Intensity
Crop and animal production (except cannabis)	0.97	0.66	1.62
Fishing, hunting and trapping	0.26	0.20	0.46
Animal food manufacturing	0.05	0.72	0.77
Sugar and confectionery product manufacturing	0.09	0.42	0.51
Fruit and vegetable specialty food manufacturing	0.06	0.51	0.57
Dairy product manufacturing	0.03	0.90	0.93
Meat product manufacturing	0.04	0.95	0.98
Seafood product preparation and packaging	0.02	0.48	0.50
Miscellaneous food manufacturing	0.06	0.64	0.70
Soft drink and ice manufacturing	0.03	0.30	0.33
Breweries	0.06	0.26	0.32
Wineries and distilleries	0.07	0.31	0.38
Wholesale trade	0.06	0.11	0.17
Retail trade (except cannabis)	0.05	0.10	0.15

Source: Authors' calculations using Statistics Canada's symmetric supply and use tables at the link-1961 aggregation combined with data table 38-10-0097-01.

report the upper bound marginal cost effect of emissions pricing at $80 per tonne. This is calculated by multiplying each sector's emissions intensity from Table 3 by the carbon price, although it represents an upper bound since not all emissions are priced, which is a point we will turn to shortly. As previously discussed for the crop and animal production sector (excluding cannabis), direct costs increase by 7.7 percent and if total emissions are priced economy-wide, then costs increase by 13 percent. Fishing, hunting, and trapping see cost increases of 2.1 percent due to direct effects of pricing but this rises to 3.7 percent with all indirect effects included. For most food product manufacturing sectors, these indirect upstream effects are considerably larger. Animal food manufacturing, for example, exhibits a direct cost increase of 0.4 percent but a higher total cost increase of 6.2 percent, underscoring the importance of supply chain emissions. These estimates, to be clear once again, assume that every tonne of emissions—both direct and indirect, regardless of the supplier's sector or location—are priced in full and passed through to consumers. But this is not the case for several reasons that we explore next.

3.3 The Dampening Effect of Trade and Sectoral Exemptions

Domestic emissions pricing affects only inputs purchased from suppliers within Canada subject to such policies. Therefore, higher levels of imported intermediates dampen the extent to which pricing affects costs. We estimate that crop and animal production includes ten cents of imported intermediate inputs for each dollar in sales. Among food product manufacturers, nearly 14 cents of imported intermediates are embodied within each dollar in sales. Quantifying the effect of domestic pricing alone is straightforward and involves setting the price levied on imported emissions to zero. Previously, we implicitly assumed that the emissions intensity of imports from each sector matched that of their domestic counterparts.

Table 4: Upper Bound Marginal Cost Effect of Emissions Pricing at $80/tonne, by Sector (2019)

Sector	Percent Increase (%)		
	Direct Effect	Indirect Effect	Total (Direct + Indirect) Effect
Crop and animal production (except cannabis)	7.7	5.2	13.0
Fishing, hunting and trapping	2.1	1.6	3.7
Animal food manufacturing	0.4	5.8	6.2
Sugar and confectionery product manufacturing	0.7	3.4	4.1
Fruit and vegetable and specialty food manufacturing	0.5	4.1	4.6
Dairy product manufacturing	0.3	7.2	7.4
Meat product manufacturing	0.3	7.6	7.9
Seafood product preparation and packaging	0.2	3.8	4.0
Miscellaneous food manufacturing	0.5	5.1	5.6
Soft drink and ice manufacturing	0.2	2.4	2.6
Breweries	0.5	2.1	2.6
Wineries and distilleries	0.6	2.5	3.1
Wholesale trade	0.5	0.9	1.4
Retail trade (except cannabis)	0.4	0.8	1.2

Source: Authors' calculations based on emissions intensity values reported in Table 3.

In addition, and as described in Section 2, agricultural producers receive exemptions from various emissions pricing policies in all jurisdictions in Canada. For example, coloured farm fuel is typically not subject to such policies, nor are process emissions. Methane produced by cattle is also exempt from emissions pricing. Similarly, fuel used directly by fishers is normally exempt. However, not all activities are exempt. Natural gas used for certain agricultural activities is subject to pricing, although this represents a minor expense for the agricultural sector as a whole. In 2019, for instance, spending on natural gas (including liquids, related products, and distribution margins) was only 0.4 percent of total costs for crop and animal production.[20] Overall, the fraction of emissions covered by emissions pricing in primary agriculture is closer to zero than to 100 percent. Without quantifying the precise share of emissions subject to pricing, we quantify the implications of primary agricultural emissions being fully excluded from pricing policies. This represents a lower bound that contrasts with the upper bound effect quantified in the previous section. Agricultural producers still face additional costs from emissions pricing embodied within goods and services purchased from suppliers, which our estimates will capture.

Such an exemption has significant implications for food product manufacturers across the economy. We estimate that animal food manufacturing, for example, uses approximately 32 cents of inputs from crop and animal production for each dollar in sales. This figure includes not only direct purchases from that sector but also all embodied purchases made by suppliers throughout the economy that sell inputs to animal food manufacturers. It also encompasses all subsequent inputs in the supply chain, summarized by $(\boldsymbol{I} - \boldsymbol{A})^{-1}$. Meat product manufacturing, meanwhile, uses nearly 63 cents of inputs from crop and animal production per dollar in sales. Not all food product manufacturers rely heavily on inputs from crop and animal production. For instance, sugar and confectionery product manufacturing uses less than

[20]Source: Authors' calculations using Statistics Canada's 2019 supply and use tables (catalogue 15-602-X). This value excludes taxes on natural gas. Including such product taxes increases the share spent on this input to just under 0.6 percent.

Table 5: Policy Design and the Marginal Cost Effects of Emissions Pricing at $80/tonne, by Sector (2019)

Sector	Percent Increase (%)			
	Total with Full Pricing	Domestic Pricing Only	+ Exempting Primary Agr.	+ Large Emitter OBAs
Crop and animal production	13.0	11.2	1.5	0.7
Fishing, hunting and trapping	3.7	2.8	0.6	0.4
Animal food mfg.	6.2	4.0	1.6	0.9
Sugar and confectionery mfg.	4.1	1.7	1.4	0.9
Fruit, vegetable, and specialty mfg.	4.6	2.3	1.6	1.1
Dairy product mfg.	7.4	6.1	1.5	0.8
Meat product mfg.	7.9	6.4	1.5	0.8
Seafood product preparation	4.0	2.4	1.0	0.6
Miscellaneous food mfg.	5.6	3.6	1.6	0.9
Soft drink and ice mfg.	2.6	1.3	1.2	0.8
Breweries	2.6	1.5	1.4	0.9
Wineries and distilleries	3.1	1.5	1.3	0.9
Wholesale trade	1.4	1.0	1.0	0.8
Retail trade (except cannabis)	1.2	0.9	0.9	0.7
Average Effect	3.9	3.1	1.1	0.8

Source: Authors' calculations based on emissions intensity values reported in Table 3 combined with calculations using Statistics Canada national symmetric domestic and imports input output data (catalogue 15-207-X) using the link-1961 classification. The overall average is a sales-weighted average across all sectors. Exempting primary agriculture's direct emissions includes crop and animal production and fishing, hunting and trapping.

5 cents per dollar in sales. However, on average, we estimate that for each dollar in sales from the seven food product manufacturing sectors for which we have data, 32 cents are purchased as inputs from crop and animal production. Therefore, exempting most direct primary agricultural emissions from pricing policies will have significant downstream effects.

With these adjustments, we provide estimates of the effects of both exemptions for direct emissions in primary agriculture and fishing, as well as domestic-only pricing in Table 5. As before, we report the marginal cost effect of emissions pricing at $80 per tonne across these different scenarios. The first column are the results from Table 4 for full emissions pricing. In the second column, we present updated estimates based on domestic-only pricing. Overall, the effect on prices decreases from 3.9 percent with full pricing to 3.1 percent with domestic-only pricing. The reduction in the magnitude of the effect on marginal costs is particularly large for food product manufacturers, where it falls nearly by half. In the third column, we report the effect on marginal costs when also exempting direct crop and animal production and direct fishing emissions. We estimate that the cost increase for crop and animal production drops significantly from 11.2 percent to 1.5 percent, highlighting the heavy burden of direct emissions in this sector. Of the 1.5 percent increase, nearly one-third is due to a roughly ten percent increase in the price of outputs from the pesticide, fertilizer, and other agricultural chemical product manufacturing sectors. Other sectors also see reduced cost increases, such as dairy product manufacturing (from 6.1 percent to 1.5 percent) and meat product manufacturing (from 6.4 percent to 1.5 percent). Across all sectors, we estimate that the average effect of pricing on consumer prices declines from 3.1 percent with domestic-only pricing to 1.1 percent with these direct production emissions excluded—barely more than one-quarter of the full pricing effect.

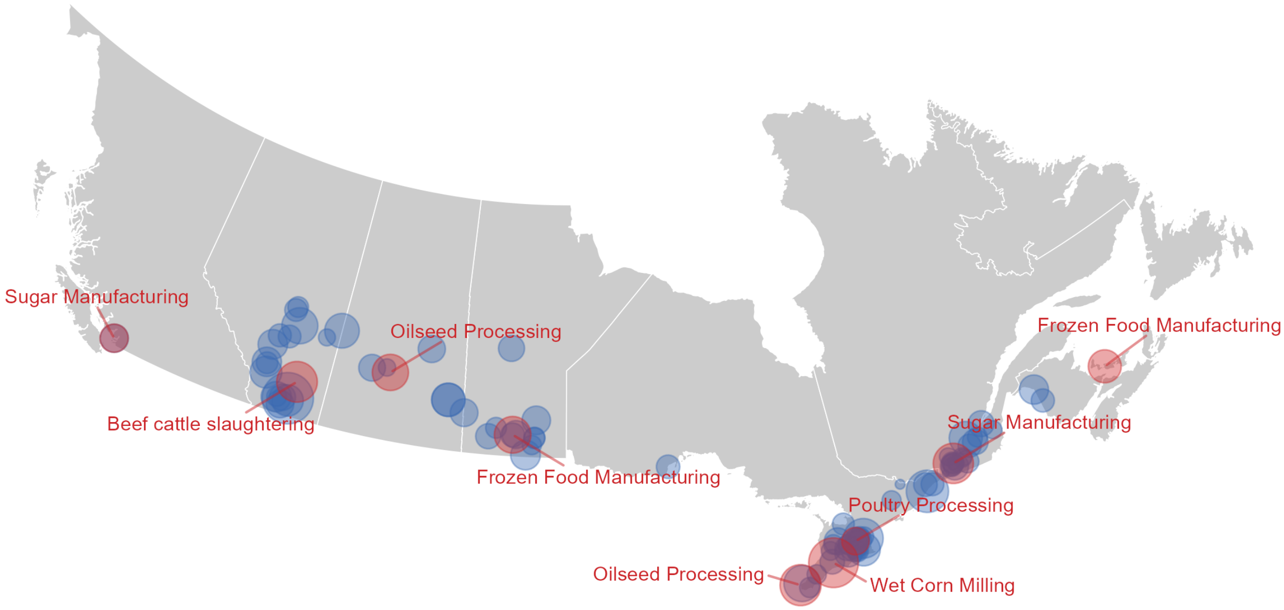
While these estimates reflect a full exemption of direct emissions in crop production and fishing, even smaller reductions in direct costs for these sectors still significantly dampen the overall effect of emissions pricing. If 80 percent of direct costs are eliminated for these two sectors, similar to the treatment received by greenhouses, we estimate the average effect on marginal costs would be 1.5 percent, with the maximum increase among food product manufacturers being 2.5 percent for meat producers.

3.4 The Dampening Effect of Large Emitter Treatment

A considerable portion of food product manufacturing is accounted for by a relatively small number of large facilities. Since emissions pricing policies differ for large emitters compared to small ones, incorporating such design details into our estimates is important. In Figure 2, we plot the locations of major food, beverage, and tobacco manufacturing facilities as of 2022.[21] Different types of manufacturing facilities are labeled, including sugar manufacturing, beef cattle slaughtering, oilseed processing, frozen food manufacturing, poultry processing, and wet corn milling. The size of the circle represents the emissions produced by each facility, as reported by the federal government's Greenhouse Gas Reporting Program (Environment and Climate Change Canada, 2024e). The map highlights clusters of these manufacturing facilities across various regions in Canada, with notable concentrations in Ontario, Quebec, Alberta, and British Columbia. Large facilities have access to what are effectively free emissions permits, or "output-based allocations," as described in a previous section of the paper.

[21] We do not plot larger emitters in crop production (mainly greenhouses), as these facilities typically receive an 80 percent reduction in their emissions price and in our lower bound estimates presented in the previous section, their direct emissions are excluded already.

Figure 2: Emissions of Major Food, Beverage, and Tobacco Manufacturing Facilities (2022)



Note: Displays the location and sector of 97 major food, beverage, and tobacco product manufacturing facilities (NAICS 311 and 312) included in Canada's Greenhouse Gas Reporting Program in 2022. The size of each dot is proportional to each facility's total emissions.

Source: Authors' calculations using Environment and Climate Change Canada's GHGRP database.

These selected large emitters within the food product manufacturing sector account for a considerable share of total emissions. In fact, we estimate that these 97 facilities account for approximately half of the sector's total emissions. If the average OBA received by these facilities is equivalent to 80 percent of total emissions, which corresponds to treatment under the federal system described earlier, then the average effect of pricing on consumer prices for the sector as a whole falls by 40 percent, assuming the sector's emissions not accounted for by these facilities receives no targeted support. Not all large facilities covered by reporting regulations have access to output-based allocations within emissions pricing systems. The federal threshold for mandatory inclusion into the output based pricing system is 50 kilotonnes per year. Of the 97 facillities illustrated in Figure 2, only 14 exceed that amount. But there is scope for voluntary participation by facilities below this threshold. In what follows, we provide only illustrative estimates of the potential effect of large emitter systems. In addition to large emitters within the food product manufacturing sector itself, a key input supplier to primary agriculture is chemical fertilizer manufacturing. Nearly all emissions in this sector is accounted for by large facilities. We assume the average OBA received by these firms is equivalent to 90 percent of their emissions, consistent with the federal system. Finally, we also assume an 80 percent OBA level for the electricity generation, oil and gas extraction, petrochemical manufacturing, and chemical manufacturing sectors, which are also important input suppliers for food and agriculture and this rate is also broadly consistent with the federal system.

Output subsidies provided to large emitters directly affects these producers and indirectly affects the production costs of any other downstream sector purchasing their output as an input, such as retail trade (i.e., grocery stores). We report the results of this in the final column of Table 5. While the dampening effect of the special large-emitter treatment is modest relative to the effect of exempting most primary

Table 6: Household Final Consumption Expenditures and Average Price Effect, by Sector (2019)

Sector	Consumption Expenditures: Millions of Dollars: Domestic	Imports	Percent (%): Import Share	Average Price Effect
Crop and animal production	4,151	7,853	65.4	0.2
Fishing, hunting and trapping	894	248	21.7	0.3
Animal food mfg.	1,689	1,134	40.2	0.6
Sugar and confectionery mfg.	1,653	2,060	55.5	0.4
Fruit, vegetable, and specialty mfg.	4,207	3,615	46.2	0.6
Dairy product mfg.	9,649	1,045	9.8	0.7
Meat product mfg.	11,734	2,409	17.0	0.7
Seafood product preparation	715	1,473	67.3	0.2
Miscellaneous food mfg.	12,489	6,267	33.4	0.6
Soft drink and ice mfg.	2,629	1,110	29.7	0.6
Breweries	3,567	676	15.9	0.8
Wineries and distilleries	1,263	3,313	72.4	0.2

Note: Display household final consumption expenditures on domestically produced and imported items for selected sectors in 2019. The average price effect presumes that domestic marginal cost increases reported in Table 5 are fully passed through to consumers and that the effect of emissions pricing on imports is zero.
Source: Authors' calculations using Statistics Canada national symmetric domestic and imports input output data (catalogue 15-207-X) using the link-1961 classification.

agricultural emissions, it further reduces the potential effect of carbon pricing on production costs and therefore consumer prices. The effects are now entirely bounded between a 0.6 and 1.1 percent increase for all food product manufacturing subsectors. The average effect on marginal costs across all listed sectors declines from 1.1 percent to 0.8 percent. This further suggests that the effect of emissions pricing on Canadian food prices is modest.

3.5 Imported Final Consumption

The preceding sections examined the potential effect of emissions pricing on domestic marginal costs of production in various sectors. Canadian households, however, import a substantial share of their total expenditures on food. Imports of primary agricultural products, for example, was nearly \$7.9 billion in 2019 while spending on domestically produced items from this sector was less than \$4.2 billion. So, even if domestic production cost increases are fully passed through to consumers, imported items will not experience any price increase as a result of domestic emissions pricing in Canada except through the indirect effects of transportation and trade margins.

Accounting for imported final consumption is more relevant for some food products than others. In Table 6 we report the distribution of household final consumption expenditures across domestic purchases and imports. Dairy products have limited imports as a consequence of high trade barriers, with an average import share of less than ten percent. Crop and animal production and seafood, meanwhile, have import shares of roughly two-thirds. Across all sectors listed in the table, the average household imports 36 percent of total consumption expenditures.

The effect of domestic emissions pricing on average consumer prices will therefore be larger in sectors where import shares are low and smaller in sectors where import shares are high. We estimate the average price effect by taking the final estimates of emissions pricing on marginal production costs reported in Table 5 and multiplying these by share of household final consumption expenditures accounted for by domestic producers. We report this in the final column of Table 6. We find emissions pricing increases the average consumer price by 0.5 percent. As before, this likely overstates the effect as buyers would shift consumption to imported items. Estimates of the elasticity of international trade flows for food items, for example, are relatively high, averaging more than -8 across the more than 700 agriculture and food items reported by Fontagné, Guimbard, and Orefice (2022).

4 Discussion

Several important caveats to our analysis are worth making explicit. First, our analysis does not cover how emissions pricing might affect the broader competitiveness of Canadian farmers or food producers. And we did not look at the potential for leakage, where efforts to reduce emissions in Canada could lead to higher emissions in other countries because production moves to places with weaker climate policies. Higher costs for Canadian farmers and food producers might lower their incomes if exports decline, as their products become less competitive internationally. This effect is potentially minor, however, since the scale of exemptions for direct emissions in primary agriculture are broad. Additionally, consumers might turn to more imports if domestic prices rise. Although this too is likely minor as the effect of emissions pricing on food prices, as our analysis shows, is modest. In any case, these competitiveness effects are not covered in our paper, which focuses on the mechanical impact of emissions pricing on food prices, although worthy of further study.

Our analysis also does not take into account the general equilibrium effects of emissions pricing on the broader economy. We did not explore how these policies might impact wages, returns on capital, overall productivity, and other economic factors. Changes in production costs due to emissions pricing could affect labor markets and investment returns, for example, potentially influencing aggregate productivity and economic growth. These broader economic dynamics are complex and could alter the outcomes we present. Although to the extent that such policies tend to lower aggregate growth and productivity, which would lower the pace of wage growth over time, this would potentially dampen the effect of emissions pricing on good prices in Canada since lower wages would lower production costs. Of course, real wages and living standards would be lower as a result of these broader effects. Our analysis, however, does not provide a broader evaluation of the merits of emissions pricing.

Finally, we assume that the costs of emissions pricing are fully passed through to consumers in the form of higher food prices. However, the actual passthrough rates could be incomplete or even exceed the cost increases, which is ultimately an empirical question. Passthrough rates could be lower than one if producers absorb some of the costs increases, for example, which may be the case for particular items that face intensive import competition. Conversely, passthrough rates could be higher than one (i.e., "overshifting" cost increases to consumers) if producers mark up prices more than the increase in costs due to factors like market power (Weyl and Fabinger, 2013). These variations in passthrough rates could change how emissions pricing affects food prices.

5 Conclusion

In this paper, we examined the effect of emissions pricing on Canadian food prices. Using an input-output model of Canada's economy, we quantified both the direct and indirect cost increases across various food production sectors. Our findings indicate that emissions pricing at $80 per tonne could potentially increase domestically produced food prices by approximately 0.8 percent on average. This estimate includes emboddied emissions throughout Canada's food supply chain. But, importantly, it also reflects the large dampening effect of exempting most direct emissions in primary agricultural activities, non-priced imported inputs, and large emitter treatment under Canada's various emissions pricing systems. Such design details matter. For instance, we found that exempting direct emissions in primary agriculture reduces the average effect of pricing on consumer prices from 3.1 percent to 1.1 percent, with a maximum effect of 1.6 percent for fruits and vegetables. Additionally, the treatment of large emitters can further dampen the potential impact, bringing the increase in production costs down to a range between 0.6 and 1.1 percent for all food product manufacturing subsectors and to less than 0.8 percent on average. Combined with imported food, we estimate the average effect on food prices facing Canadian households may be roughly 0.5 percent. While these results provide valuable insights into the mechanical effects of emissions pricing, we abstract from the broader economic implications, potential competitiveness effects of emissions pricing, changes in consumer and business spending patterns, and so on. Our analysis nevertheless suggests that emissions pricing in Canada has only a modest effect on food prices.

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