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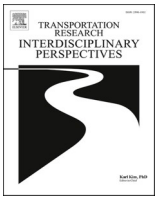

# Implications of carbon pricing on food affordability and agri-food sector in Canada: A scoping review

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ABSTRACT

This review delves into the effects of carbon pricing policies on food affordability and the performance of the agri-food sector, with a specific focus on Canada. Against the backdrop of the widespread adoption of carbon pricing as a crucial tool in reducing greenhouse gas (GHG) emissions, the discussion acknowledges potential economic repercussions, particularly for lower-income households. Findings reveal that the implementation of a mandated carbon tax across all provinces in Canada by 2019 led to reduced GHG emissions and an increase in food prices. In addition, this review positions Canada within the global context by examining actions taken by other countries and their impacts. Crucial research gaps are also identified, ultimately serving as a guide for future studies and policy formulation aimed at balancing the necessity of carbon tax implementation with considerations of food affordability.

## Introduction

Anthropogenic activities have triggered substantial climatic changes, posing severe risks to the environment, economies, and societies. These activities, including those within food systems, have led to approximately 1.0 °C of global warming. In this context, the agri-food sector has emerged as a substantial contributor to global greenhouse gas (GHG) emissions, accounting for approximately one-third of the total GHG emissions worldwide. Recent assessment show a sharp rise in this contribution by 16 %, from 14 $GtCO_2eq$ per year in 2018 to an estimated 31 % of global GHG emissions in 2021 (Crippa et al., 2021; Babiker et al., 2022). This escalation underscores the urgency of addressing global climate change, which has emerged as one of the most pressing global challenges. In response, concerted efforts are needed to reduce GHG emissions. According to the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2023) special report on climate change and land, global food systems emits between 10.8 and 19.1 Gt $CO_2$ equivalent ($CO_2e$) per year (Mbow et al., 2020). Hence, the IPCC has set a target to limit global warming to 1.5 °C, requiring GHG emissions to peak by 2025 and decline by 43 % by 2030, as outlined in the Paris Agreement.[1]

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[1] A global agreement addressing climate change mitigation, adaptation, and financing was adopted in 2015 and is commonly referred to as the Paris Agreement or the Paris Climate Accords. 196 parties engaged in negotiations on it during the 2015 United Nations Climate Change Conference. Iran is the only significant emitter of the pact, with 195 UNFCCC countries having ratified it as of February 2023.

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Countries that are already vulnerable to climate impacts are expected to experience the most severe consequences of these changes (Mendelsohn et al., 1994; Schlenker et al., 2006).

To address this environmental challenge, countries have implemented diverse policy tools such as carbon pricing, renewable energy standards, and efficiency policies (Busch et al., 2022). Among these tools, carbon pricing[2]—principally through mechanisms like carbon taxes and cap-and-trade—has garnered attention. Carbon taxation is a policy tool aimed at reducing greenhouse gas emissions by directly imposing a tax on the carbon content of fuels. It imposes tax either on the supply or demand side, incentivizing businesses and individuals to transition to cleaner energy sources or enhance energy efficiency. This tax can be applied at various levels—local, national, or international—and is typically calculated per ton of carbon dioxide (CO2) emitted. Sweden's carbon tax, introduced in 1991, has helped significantly reduce its $CO_2$ emissions. Before the tax, Sweden's emissions were notably higher, but from 1990 to 2018, emissions dropped by 27 %, largely thanks to a combination of the tax and investments in $CO_2$-free electricity, such as nuclear and hydropower. By focusing on sectors like heating and industrial production, Sweden's carbon tax effectively reduced fossil fuel reliance and encouraged a shift toward renewable energy, which also helped maintain steady economic growth during this period (Lans Bovenberg et al., 2002). Carbon taxes impact a wide array of sectors: they are applied to energy production, where fossil fuel-based power plants are encouraged to switch to renewable sources; to transportation, where taxes on gasoline and diesel aim to cut emissions from vehicles and airplanes; and to industry, particularly in energy-intensive manufacturing sectors, to promote reductions in emissions and spur innovation in cleaner technologies.

On the other hand, cap-and-trade systems, also known as emissions trading schemes (ETS), are designed to cap the total level of greenhouse gas emissions and allow the trading of emission allowances within that limit (García-Portela, 2023; Hepburn et al., 2020). This market-based approach enables entities to buy and sell allowances, offering flexibility in achieving emissions reductions. CAP-and-trade systems are implemented at regional, national, or international levels. For instance, the European Union Emissions Trading System (EU ETS), established in 2005, is one of the largest and most well-known systems, capping emissions from major industrial sectors and power generation. Allowances are distributed through auctions or based on historical emissions (Ellerman et al., 2010). These systems are applied to sectors with significant emissions and potential for cost-effective reductions, including power generation, where plants must reduce emissions or buy allowances; heavy industries such as cement, steel, and chemicals, which are major emitters; and, in some cases, aviation, as seen in the EU ETS, which requires airlines to manage their emissions or purchase allowances. While cap-and-trade has seen success in various regions including North America, Europe, and Australia, carbon taxes are similarly employed to incorporate the cost emissions into economic activities (Stavins, 2019; Xu et al., 2016). Ontario's cap-and-trade system for sulfur oxides ($SO_2$) and nitrogen oxides ($NO_x$) was introduced in 2001 to address emissions contributing to smog and acid rain. Since its implementation, the program has met its emission reduction targets, contributing to a notable improvement in air quality across the province. For example, smog days in Ontario decreased from 19 days in 2003 to just one by 2019. Additionally, provincial regulations, alongside the cap-and-trade mechanism, helped achieve lower emissions of both $SO_2$ and $NO_x$ below the original caps, indicating that many regulated facilities now maintain levels below targeted thresholds due to improved processes and technology (Wood, 2017).

Economic analysis underscores that carbon pricing is a vital long-term strategy for efficiently reducing GHG emissions. However, its implementation brings complexity, particularly in terms of its impact on food affordability. Numerous global programs were reviewed and summarized in Table 1 to get an understanding of how different carbon tax programs were implemented to control GHG emissions (Tietenberg, 2013). In North America, particularly in the United States and Canada, a hybrid approach integrating both carbon tax and cap-and-trade systems has been adopted, tailored to their unique economic landscape and climate priorities (Stavins, 2019).

In Canada, these policies affect key sectors significantly. One of the sectors is transportation, which fully depends on gasoline and diesel that are subject to carbon levies or cap-and-trade obligations. The mining, and oil and gas sectors, are targeted by output-based pricing systems and cap-and-trade programs. Waste management operations are also included in the carbon pricing system due to their methane emissions. In sum, non-renewable energy is greatly impacted, encouraging a shift towards lower-emission sources.

**Table 1**
Description of different carbon tax programs.

| Carbon Tax Programs | Description |
|---|---|
| Swedish Carbon Tax Program | Carbon tax was implemented in 1991.<br>Carbon is priced directly or indirectly.<br>In the direct method, the tax was imposed on each unit of $CO_2$ emitted.<br>In the indirect method, the tax was imposed on fossil fuels. |
| European Union (EU) Emission Trading System | • The EU, the largest trading system in the world, has pioneered a cap-and-trade system.<br>It was launched in 2005 and operates in 30 countries.<br>Emissions are targeted to be 21 % lower in 2020 than in 2005.<br>It currently includes half of the EU's $CO_2$ emissions and 40 % of total GHG emissions. |
| Regional Greenhouse Gas Initiative: | • Ten states in the northeastern United States launched the first carbon taxing program in 2009.<br>Participating states cap the $CO_2$ emission from power plants, allocate $CO_2$ emission allowances, and invest in programs that help in the reduction of GHG emissions. |
| British Columbia and Quebec Carbon Tax Program | • This program defines $CO_2$ emission as the total amount of $CO_2$, methane and nitrous oxide ($N_2O$) released in the atmosphere.<br>British Columbia has imposed a carbon tax on each metric ton of $CO_2$ emissions from the combustion of fuel.<br>It has affected 77 % of British Columbia's GHG emissions.<br>In Quebec, the carbon tax was introduced on the sale of gasoline in October 2007 to reduce greenhouse emissions.<br>It was eliminated in 2014 but then again replaced in January 2015 by the participation of QC fossil fuel distributors in the Western Climate Initiative Regional Carbon Market (Ganapati et al., 2020). |
| Australian Hybrid System | • This program started in 2012.<br>It was a two-stage transition *i.e.,* from a fixed price regime to an emission trading market.<br>The emitters faced a fixed price for each metric ton of carbon emitted.<br>Fixed price regime transformed to a fully flexible price regime with the price determined by the emission trading market. |

While carbon pricing schemes are crucial for transitioning to a low-carbon economy, it may also lead to increased costs for carbon-intensive goods, including food. This could exacerbate economic strain on

[2] Taxes on the carbon emissions necessary to generate products and services are known as carbon taxes.

vulnerable populations and low-income households (Dorband et al., 2019; Ganapati et al., 2020; Vogt-Schilb et al., 2019). To address concerns about carbon leakage,[3] some countries have introduced supplementary measures, such as border carbon adjustments and tariffs on imports based on their carbon content. These measures aim to ensure a level playing field for local industries subject to carbon pricing while encouraging global adoption of more sustainable practices (Böhringer et al., 2022; Jakob et al., 2022).

The debate over the effectiveness and equity of carbon pricing policies is ongoing, particularly regarding their impact on food prices and affordability. Concerns are rising about whether these policies might place a disproportionate economic burden on vulnerable groups and how equitably they are being implemented across sectors. This study aims to analyze the effects of carbon pricing on food prices, food affordability, and the Canadian agri-food sector, with a focus on understanding regional variations and identifying potential areas for policy improvement to mitigate unintended economic impacts on low-income households.

The structure of the paper is as follows: Section 2 describes the methodology and details the data charting process. Section 3 presents the study's findings. Section 4 discusses identified research gaps and provides policy recommendations. Finally, Section 5 concludes the paper, summarizing key insights and implications.

## Methodology

To enhance the robustness and trustworthiness of this scoping review, we have meticulously adhered to Arksey and O'Malley's five-step framework (Arksey and O'Malley, 2005). This process includes: identifying research questions, systematically locating relevant studies, performing rigorous study selection, thoroughly charting data, and synthesizing, summarizing, and reporting findings. While our primary focus is Canada, we have deliberately incorporated a broader Western context. By distinguishing discussions between Canadian-specific insights and the broader Western perspective, we aim to provide a nuanced understanding that respects both the particularities of Canada and the wider regional context.

One area we have refined based on feedback is the exploration of methodologies utilized across the reviewed studies. While our focus has been on results and their variation in the literature, this revised manuscript now includes a deeper examination of the diverse statistical methods employed, with particular emphasis on causal inference. Given that conclusions about carbon pricing's impact on inflation are strongly influenced by the analytical methods used, expanding this discussion helps clarify the interpretability of our findings. By addressing how various methodologies shape conclusions across studies, we aim to enhance the review's value for readers, offering insights into the complexities of establishing causal relationships in this domain.

This manuscript offers an insightful and timely review for both researchers and policymakers. Incorporating this expanded methodological analysis strengthens the review, providing a more comprehensive understanding of the challenges in assessing causality in this area of research.

### *Identifying relevant studies*

We conducted a comprehensive search for relevant peer-reviewed literature across four prominent academic databases: Scopus, Google Scholar, EconLit, and IEEE. To refine our search and focus on specific areas of interest, we utilized the Boolean search operators OR and AND. Despite the escalating interest in carbon pricing and carbon tax over the past decade, we intentionally avoided setting a specific date range for the search to ensure the inclusion of early literature in our findings. The key search terms can be found in Table 2. Additionally, beyond the primary search, we conducted post hoc searches using specific phrases, as detailed in Table 2, to uncover any additional relevant literature that might not have been captured by the key search terms. Our criteria for inclusion and exclusion, outlined in Table 2, were developed based on the methodology employed by O'Flaherty and Phillips (O'Flaherty and Phillips, 2015).

### *Study selection*

A comprehensive search using specific key terms across four identified databases yielded a total of 188 articles. Duplicate entries across databases were removed, followed by a thorough review of abstracts to assess their relevance to the predetermined research questions. Initially, articles focusing on other areas than food or the agri-foods sector were excluded from consideration. Subsequently, only the most relevant articles meeting the criteria of the scoping review were selected for further analysis. Details regarding the inclusion and exclusion criteria can be found in Table 3.

### *Data charting and collation*

The data captured for each major article included in this review comprises the study source, geographical focus, carbon pricing policy or policies covered, study focus, and main findings (Table 4). The last step of the Arksey and O'Malley (Arksey and O'Malley, 2005) approach is to collate, summarize, and report on the main findings.

## Findings

Given the broad scope of food affordability, establishing a universal definition remains complex. Generally, it refers to the financial accessibility of sufficient, nutritious food for individuals and households, ensuring they can purchase a healthy diet without financial hardship or compromising other essential needs. Studies often frame food affordability concerning household or individual income, as illustrated in Table 5. Additionally, factors like societal expenditures and perceived food value play significant roles in shaping this concept (Djimeu et al., 2022). These diverse definitions offer valuable perspectives. For instance, Hawkes et al. (Hawkes et al., 2020) describe it as the ability of vulnerable households to afford available food, while Maestre et al. (Maestre et al., 2017) focus on the combination of prices and disposable income that influence purchasing decisions. Turner et al. (Turner et al., 2020) explore food affordability within the food environment, where prices interact with purchasing power. Finally, Herforth and Ahmed (Herforth and Ahmed, 2015) define food affordability in terms of absolute, relative, and comparative cost.

In light of recent feedback, we have expanded our discussion on the methodologies applied in food affordability studies. While the manuscript primarily focuses on affordability outcomes and variations across literature, we now delve into the statistical techniques used, especially concerning causal inference. Conclusions about affordability impacts, such as those involving carbon policies on food costs, are highly dependent on the methodologies utilized, and without detailed methodological discussion, interpreting findings across studies is limited. This addition provides readers a more transparent view of the complexities in establishing causal relationships within food affordability research.

In Canada, food affordability is typically assessed through indicators like food price data, calculating the cost of a nutritionally adequate food basket across regions (Health Canada, xxxx). In Western contexts, food affordability issues are influenced by economic policies, welfare systems, and market forces, often examined through household

[3] The ratio of the rise in $CO_2$ emissions outside of the nations implementing domestic mitigation measures to the decline in emissions within these nations is known as carbon leakage." It can be more or less than 100% and is stated as a percentage.

**Table 2**
Literature search method.

| Key search terms |
|---|
| ('Carbon Tax' AND 'Food') |
| ('Carbon Pricing' AND 'Food') |
| ('Carbon Tax' AND 'Food Price') |
| ('Carbon Pricing' AND 'Food Price') |
| ('Carbon Tax' AND 'Food') AND ('West' OR 'Europe' OR 'Australasia' OR 'Canada' OR < specified country > ) |
| ('Carbon Tax' AND 'Food Price') AND ('West' OR 'Europe' OR 'Australasia' OR 'Canada' OR < specified country > ) |
| ('Carbon Tax' AND 'Food' AND 'Agri-Foods') |
| ('Carbon Pricing' AND 'Food' AND 'Agri-Foods') |
| ('Carbon Tax' AND 'Food Price' AND 'Agri-Foods') |
| ('Carbon Pricing' AND 'Food Price' AND 'Agri-Foods') |

**Table 3**
Inclusion and exclusion criteria.

| Criterion | Inclusion | exclusion |
|---|---|---|
| Time Range | Any | N/A |
| Language | English | Languages other than English where no translation is readily available or provided by the authors or publishers |
| Type of Article | Peer-reviewed and gray (news media, government documents) | Non-peer reviewed, other media (such as social media, media that has not undergone fact-checking by the author or editor) |
| Geographic Focus | Canada (and the West) | Countries other than Canada and the West (see definition above) |
| Study Focus | Effects of carbon pricing on food affordability and the agri-foods sector (with respect to food affordability) | Sectors that are not specific to food affordability and the agri-foods sector |
| Literature Focus | Articles where the focus is mainly on food affordability and agri-foods in the context of food affordability | Articles that address food affordability and agri-foods as tangential to or related to their main topic(s) |

expenditure surveys and comparing food prices to income levels (FAO, 2024; World Health Organization, xxxx).

*Carbon policies and its impacts*

The United Nations (UN) Sustainable Development Goals (SDGs) and the Paris Climate Agreement have set ambitious global targets, prioritizing climate change mitigation and public health improvement (Semba et al., 2020; Chand, 2020). Achieving these goals requires comprehensive transformation of food systems, encompassing all stages from farming and harvesting to transportation, processing, packaging, and distribution. Current food systems contribute significantly to greenhouse gas (GHG) emissions, which are accelerating climate change and increasing the urgency for sustainable interventions (Moran and Edgar, 2022).

Animal-based products, in particular, have a notably high environmental footprint compared to plant-based alternatives (Karwacka et al., 2020). In response, there is a global push toward sustainable development initiatives designed to reduce emissions and promote eco-friendly practices. Carbon taxation has emerged as a critical policy tool to address the environmental costs associated with CO2 emissions, providing long-term incentives for pollution reduction, fostering competitiveness for environmentally friendly products, and stimulating innovation in production processes (Karwacka et al., 2020; Kasterine and Vanzetti, 2010).

Carbon taxes influence not only crop prices and agricultural profitability but also broader economic dynamics, including trade patterns and consumer behavior, especially in meat and dairy markets. Countries such as Spain, Germany, and New Zealand have taken proactive measures by implementing taxes on meat and dairy to mitigate environmental impacts. For example, Spain increased VAT on meat to 10 % in 2012 while reducing it on fruits and vegetables to 4 % to promote healthier and lower-carbon dietary choices. In Germany, meat and dairy taxes are being considered, with support from major political groups, while the Dutch government is exploring a tax on meat based on environmental costs per kilogram (2–7 Euros/kg) (Moran and Edgar, 2022). However, critics argue that such taxes could potentially hinder economic growth by raising production costs, especially in sectors dependent on emissions-intensive practices like pesticide-heavy agriculture (Bosquet, 2000; Falconer and Hodge, 2001; Buchholz and Musshoff, 2021).

Studies on carbon pricing and inflation indicate modest impacts on consumer prices. Moessner (Moessner, 2022) analyzed inflation across 35 OECD economies, finding that a $10 increase in carbon taxes per ton of CO2 raised food CPI inflation by 0.1 percentage points. The Bank of Spain reported that while rising carbon prices do not significantly affect overall inflation volatility initially, emissions trading systems (ETS) can increase volatility after one year, impacting energy and core inflation due to price fluctuations. In contrast, carbon taxes show minimal impact on inflation volatility.

In Canada, a government study projected that nationwide carbon pricing could reduce carbon pollution by 80 to 90 million tonnes by 2022, equivalent to removing 23–26 million cars from the road or shutting down 20–23 coal-fired power plants for a year. The study suggests this approach would have a limited impact on GDP growth while promoting innovation and investment in clean technologies (Canada, xxxx). Similarly, Konradt and Mauro (Konradt and Weder di Mauro, 2023) found that carbon pricing has minimal initial effects on inflation volatility; however, ETS schemes may contribute to volatility in energy and core inflation due to price fluctuations, whereas carbon taxes generally have negligible effects.

Carbon pricing in agriculture, particularly in efforts to meet the 1.5 °C target, has significant implications, including increased prices for emissions-intensive foods like red meat and dairy, and reduced consumption. These effects disproportionately impact low-income rural households, which face greater losses in protein and energy intake. Income inequality may also widen, as lower-income households spend a larger share on food. Revenue recycling targeted at vulnerable groups could help alleviate these impacts, protecting food affordability (Zhang et al., 2024).

A study investigating carbon taxes on food systems suggests that imposing such taxes primarily on high-income countries could reduce GHG emissions and lower global food prices if targeted at consumers. Conversely, producer-targeted taxes may worsen food insecurity and have mixed effects on emissions. This underscores important considerations for climate change mitigation, environmental justice, and economic theory, indicating that targeting consumer demand in wealthier nations may better balance emissions reduction with global food security goals (Elbedawi et al., 2022).

**Table 4**
Major articles on carbon tax (based on the following studies further literature survey was conducted).

| Source | Geographical Focus | Study focus | Main findings |
|---|---|---|---|
| Dumortier and Elobeid (Dumortier and Elobeid, 2021) | USA & Brazil | Food pricing | The carbon tax mostly impacts fertilizer, and thus, it will not be profitable to use marginal cropland. The increase in commodity prices directly affects livestock and, thus, meat production. In the U.S., retail prices for beef and pork increase by 0.2–0.4 % and 0.3–0.6 % at the end of the projection period, depending on the carbon tax scenario. |
| Wu and Thomassin (Wu and Thomassin, 2018) | Canada | Food pricing | Food prices increase by ~ 1 % for sectors taxed on carbon emissions and by ~ 0.25 % for sectors not taxed. Industries most affected are dairy, beef, veal, pork, poultry, processed meat, and prepared seafood. |
| Fraser and Newman (Fraser and Newman, xxxx) | Canada | Food pricing | The carbon tax is not the source of, or even the main source of, increased food prices; pollution is. |
| Johnson et al. (Johnson et al., 2015) | Canada (Nova Scotia) | Food affordability | Standard food basket affordability, comprising a basic nutritious diet, can be used as a proxy to estimate affordability and accessibility. |
| Dhar et al. (Dhar et al., 2009) | New Zealand | Food affordability | In New Zealand, low-income households spend a greater proportion of their household expenditure on food than those with higher incomes. If carbon prices rose steeply, the flow-on effects on food costs would therefore cause a disproportionate burden on those already most vulnerable. The effect of a systemic carbon price rise will also increase inflation in New Zealand, exacerbating fuel and food inequities through a "welfare effect". |
| Moretti et al. (Moretti et al., 2023) | France | Environmental effect on food affordability | Environmental disasters have been found to have large inflationary effects in emerging countries. Hurricane and flood destruction led to an increase in consumer prices in the Caribbean islands. Storms only temporarily increase food price inflation; floods also typically have a short-run impact on inflation, whereas earthquakes reduce inflation, excluding food, housing, and energy. Hot summers will increase food price inflation in the near term. |
| Moran and Edgar (Bahoo et al., 2018) | Europe Germany, Spain, and New Zealand | Food affordability | New Zealand will include animal farms in the ETS system for $CO_2$ emissions by 2025. Spain increased VAT tariffs on meat in 2012 to 10 % and reduced tariffs on vegetables and fruits to 4 %. Germany will probably tax meat and dairy (a VAT tax increase or a consumer tax per kg) after 2021. It is biologically impossible to produce food in conventional farming systems without some level of GHG emissions. |
| Slade (Slade, 2018) | Canada | Environmental effect | A carbon tax could lead to carbon leakage, with reductions in Canadian emissions offset by increases in other countries, emphasizing the need for a comprehensive global model for accurate estimation. |
| Nuno-Ledesma and Massow (Nuño-Ledesma and von Massow, 2023) | Canada | Food pricing | A producer tax leads to the greatest reduction in emissions at the lowest social cost, whereas a consumer tax has minimal impact on emissions and higher social costs. |

*The effects of carbon pricing on food prices, food affordability, and the agri-food sector in Canada*

The federal government of Canada implemented a carbon tax starting at $10 per tonne of $CO_2$eq emissions in 2018, with plans to incrementally increase it to $50 per tonne by 2022. This federal carbon tax applies to provinces without a provincial carbon reduction system. A substantial body of literature addresses carbon pricing and taxation globally, with a predominant focus on energy consumption and GHG emissions. However, there is comparatively limited research specifically exploring the effects of carbon taxes on food prices and the agri-food sector in Canada (Wu and Thomassin, 2018).

The existing literature acknowledges both short-term and long-term effects of carbon taxation. In the short term, carbon taxation reduces the use of energy sources that emit GHGs by increasing production costs and fossil fuel prices. In the long term, it may stimulate the development of new technologies aimed at reducing GHG emissions. For example,

**Table 5**
Summary of studies measuring food affordability based on income ((.

| Study | Setting | Household or individual income level | Affordability outcomes |
|---|---|---|---|
| Colchero ( Colchero et al., 2019) | Mexican household | Household Income | 0.013 % of their income in 1996 to buy 1000 kcal of food and beverages, and 0.50 % in 2016 |
| Raghunathan ( Raghunathan et al., 2021) | Indian household | Cash wage of unskilled labor | 45–64 % of the rural poor cannot afford a nutritious diet |
| WONG (Wong et al., 2011) | Australian household | Disposable income for employed and welfare payments of unemployed | The average Australian family spends 17 % on food, while families on welfare payments spend 28–34 % of their income on food |
| Williams ( Williams, 2010) | A reference family of five in Australia | Average weekly earnings and welfare | Relative affordable only |
| Rossimel ( Rossimel et al., 2016) | Four different household types in Australia | Average fortnightly income | Relative affordable only |
| Mackay ( Mackay et al., 2018) | New Zealand household | Medium disposable income, Income support, minimum wage | For the minimum wage, diets required 27 % to 34 % of household income; for income support, 41–52 % of household income |
| Cafer and Kaiser (Cafer and Kaiser, 2016) | Rural households in USA | Weekly income per household | Missouri households spend an average of 17.451 % of their income on food |
| Newell et al. ( Newell et al., 2014) | Households with minimum wage in Canada | Minimum wage net essential expenses | 100 % of minimum wage |
| Williams et al. ( Williams et al., 2012) | Three household types relying on income assistance in Canada | Monthly gross income, net of essential monthly expenses | 100 % of net income |
| Vozoris et al. ( Vozoris et al., 2002) | Three types of hypothetical households in Ontario | Ontario Works Benefits (Welfare income) | No cut-off value-relative affordability only |

adopted from Djimeu et al. Djimeu et al., 2022)

British Columbia introduced Canada's first carbon tax in 2008 to reduce GHG emissions by 33 % by 2020. Farmers in Alberta and British Columbia argue that the carbon tax will increase domestic food prices, shifting costs from producers to consumers. This would result in higher food prices and reduced accessibility, particularly for low-income families.

The implementation of carbon pricing in Canada has several potential effects on food production. These effects can be direct, through increased costs of inputs and processes, or indirect, through changes in market dynamics and consumer behavior. Carbon pricing, through higher fuel prices, has impacted the cost of running farm machinery and transportation. Additionally, the production of fertilizers and pesticides has led to higher costs under carbon pricing by increasing energy, raw material, operational, and supply chain expenses associated with their production. However, crop production may be less severely impacted due to lower energy and input requirements, whereas livestock farming, including beef and dairy, has a higher carbon footprint, making these products more expensive (Yang et al., 2024).

Over the past year, the cost of specific food items has risen substantially. As of June 2022, Canada had experienced a significant surge in inflation, reaching an unprecedented 8 % [87]. Notable increases include a 14.7 % uptick in the price of rice, a 30.2 % hike in lettuce prices, a 40.4 % increase in margarine costs, and a substantial 44.8 % rise in pasta prices (Statistics Canada. Consumer Price Index;, 2022). This inflation surge has been driven by several recent events: the COVID-19 pandemic disrupted global supply chains and labor markets, while the Russia-Ukraine war exacerbated supply shortages and increased energy prices, particularly affecting agricultural inputs and transportation. Additionally, carbon taxes have raised the cost of energy and raw materials used in food production, further contributing to the rise in food prices.

Several studies have examined the impacts of carbon taxes in Canada, offering insights into regional variations and sector-specific effects. Wu and Thomassin (Wu and Thomassin, 2018), using a multi-regional model combined with an Almost Ideal Demand System (AIDS) model, found that carbon taxes increase food prices and reduce consumption, particularly in Quebec and Alberta. Their findings indicate that exempting the agricultural sector from carbon taxes could mitigate these impacts, lessening the burden on food prices and consumption levels. Interestingly, the study observed minimal variation in the tax's impact across different income groups, suggesting a broadly distributed effect rather than one disproportionately affecting low-income households.

Slade (Slade, 2018) highlights the issue of carbon leakage, where emission reductions achieved in Canada might be offset by increases in other countries, thereby limiting the overall effectiveness of domestic carbon taxes. This finding underscores the need for a comprehensive, globally coordinated model to accurately estimate and address such cross-border emissions transfers. Furthermore, the study points out that measuring livestock emissions with precision remains challenging, suggesting that governments may need to adopt emission-reducing technologies and utilize marginal abatement cost curves to better manage emissions within the agricultural sector.

These studies collectively emphasize the importance of international cooperation and technological innovation in achieving effective emission reductions, particularly in sectors like agriculture, where carbon taxes may have unintended consequences if implemented without coordinated efforts and advanced measurement tools.

Nuno-Ledesma and Massow (Nuño-Ledesma and von Massow, 2023) examines the effects of pricing Canadian livestock emissions through consumer and producer taxes and subsidies. It finds that a producer tax leads to the greatest reduction in emissions at the lowest social cost, whereas a consumer tax has minimal impact on emissions and higher social costs. A producer subsidy, though less effective in reducing emissions, may be more politically feasible. The study also highlights challenges such as carbon leakage and the difficulty of accurately measuring livestock emissions, suggesting the need for further research and policy development. A recent report by the Bank of Canada estimated that the carbon tax increases inflation by 0.15 % and another report by the University of Calgary estimated this impact to be less than 1 % (Wherry, 2023). A CGE macroeconomic model by Berthe et al. (Berthe et al., 2023) found that while carbon pricing diminished the fossil fuel sector's economic contribution, household rebates helped sustain economic growth, with climate variables like precipitation having significant impacts on agriculture and other key sectors, supporting alignment with Canada's net-zero CO2 emissions goal by 2050.

On the other hand, a study conducted by Olale et al. (Olale et al., 2019) revealed that carbon taxes are associated with a decline in the net farm income to receipt ratios, with reductions ranging between 8 and 12 cents per dollar of farm receipts. Some studies, including Rivers (Rivers, 2012); examined the potential distributional burden of carbon pricing, such as the assessment of the burden of carbon taxes on income across the ten provinces, identifying the progress of carbon tax with or without revenue recycling, and the role of the output-based pricing system (OBPS) in lowering the tax burden (Winter et al., 2023).

*The effects of carbon pricing on food prices, food affordability, and the agri-food sector in the West?*

As of 2020, over 30 economies worldwide have implemented carbon taxes (Timilsina, 2022). These taxes have significant economic and environmental implications for agriculture, which stakeholders must carefully consider. Research by Dumortier and Elobeid (Xu et al., 2016) utilized a global agricultural simulation model to assess the impacts of a U.S. carbon tax on production, commodity prices, and trade. Similarly, Ali and Anufriev (Ali and Anufriev, 2020) explored the association between agriculture production, economic growth, and CO2 emissions, revealing both short- and long-term effects.

To assess the broader economic implications of carbon taxation in agriculture, comprehensive modeling studies have been instrumental. For example, the Centre for Agricultural and Rural Development (CARD) model has been utilized to project the impacts of carbon taxes on agricultural sectors in the United States and Brazil. These studies forecasted varying degrees of impact on production costs, consumer prices, and trade dynamics under different tax scenarios (Dumortier and Elobeid, 2021; Elobeid and Tokgoz, 2008). The study's findings indicate that under the highest carbon tax scenario, U.S. retail prices for beef and pork are projected to increase by 0.2–0.4 % and 0.3–0.6 % at the end of the projection period, depending on the specific carbon tax scenario. In contrast, chicken retail prices are expected to rise between 0.9 and 1.9 %. These results align with previous research, such as Dumortier et al. (Dumortier et al., 2012), highlighting the inelasticity of U.S. meat consumption, particularly beef (Dumortier and Elobeid, 2021). The impact of carbon taxes is not limited to the United States; similar effects have been observed in Europe (Table 4), where Backman et al. (Backman et al., 2017) reported that the implementation of carbon taxes could lead to a 7 % to 12 % decrease in agricultural production, with potential increases up to 9 %.

In Europe, the 2021–2027 Common Agricultural Policy introduced supply-side initiatives to promote environment-friendly agricultural practices. These policies encompass both 'soft' measures, such as education and information campaigns, and 'hard' measures, including carbon taxes (Messer et al., 2017; Carattini et al., 2018). Studies have suggested that implementing carbon taxes in Europe could lead to reductions in agricultural production and corresponding price increases, underscoring the challenges and adjustments needed in transitioning towards sustainable agricultural practices (Backman et al., 2017). A study by Dumortier and Elobeid (Dumortier and Elobeid, 2021) revealed that A carbon tax of $144 per metric ton raises production costs for corn and soybeans by up to 32.6 % and 22.4 %, respectively, leading to higher commodity prices but reduced net returns for corn, soybeans, and wheat (11.4 %, 8.7 %, and 11.0 %). This results in decreased U.S. exports of corn, sorghum, and wheat (24.9 %, 20.5 %, and 8.7 %), while exports of barley, soybeans, and sunflower increase (1.2–8.8 %).

Konradt et al. (Konradt, 2024) studied the effect of carbon pricing on food inflation. The study found that an increase in carbon prices from 40 Euro per ton of CO2 to around 150 Euro could raise annual euro area inflation by between 0.2 and 0.4 percentage points. The effect of a carbon tax could be mitigated by adopting sustainable and environmentally friendly practices, which would help reduce the overall impact of carbon policies and climate change. Additionally, implementing better incentives and providing household compensation could further decrease the risk to food security (Habib et al., 2024). Another study undertaken in the European Union indicates that a moderate carbon price increases crop areas and outputs while reducing animal production, leading to a 25–35 % reduction in GHG emissions for 200 EUR/tCO2eq (Isbasoiu et al., 2021).

Carbon taxes can have significant macroeconomic effects (Hamilton, 2008; Edelstein and Kilian, 2009). They affect households and firms by reducing their disposable income and raising food prices. The increased costs associated with carbon taxes are distributed across the entire supply chain, from production to consumption, resulting in higher consumer prices due to the carbon costs embedded in food production (Moran and Edgar, 2022).

## Research gap and future recommendations

While existing research has provided valuable insights into the impact of carbon taxes on food prices, several significant gaps and uncertainties remain. Addressing these gaps is crucial for a comprehensive understanding of how carbon taxation affects food affordability and accessibility in Canada. This complex and evolving issue requires further investigation to grasp the nuances and potential consequences of carbon taxation. Recent inflationary trends further complicate the situation, intersecting with food pricing dynamics. To fully assess the impact of both inflation and carbon taxes on the Canadian food market, a more detailed analysis is necessary. This should encompass both short-term and long-term effects, potential mitigation strategies, and implications for various stakeholders, including farmers and consumers. Addressing these areas will be vital for informing policy decisions aimed at ensuring food security and affordability in Canada.

Current literature on the effects of carbon pricing on food affordability, particularly within the Canadian context, is limited. A notable challenge is the absence of a standardized definition of food affordability. This gap complicates policymakers' efforts to develop and implement effective strategies to combat food insecurity. Moreover, a clear definition is essential for public awareness, as food affordability directly influences dietary choices and overall health. Unclear definitions can lead to confusion regarding what constitutes an affordable and nutritious diet.

In comparison, Western countries have made more progress in understanding how carbon pricing impacts food prices. Research in these regions offers valuable insights but may not fully apply to Canada due to its unique geographical and climatic conditions. Consequently, Canadian studies should explore how carbon pricing affects food affordability across different regions and food categories, such as animal products, plant-based items, staples, and luxury foods. The pricing of food is influenced by numerous factors, including climate change, environmental disasters, political interference, and conflicts. These "unknown unknowns" add complexity to understanding the relationship between carbon pricing and food costs. Addressing these uncertainties is crucial for developing a comprehensive understanding of how carbon pricing influences food affordability. Filling these research gaps is essential for crafting policies that balance carbon reduction goals with the need to maintain food security and affordability. Future research should focus on these areas to provide the evidence necessary for effective and equitable climate and food policies.

This scoping review has highlighted the need for further research and laid the groundwork for a systematic review of food affordability and the agri-food sector, particularly in the context of Canada. Although this review has addressed major questions, it has limitations due to its focus on food affordability and carbon pricing in Canada, with comparative insights from Western countries. Expanding research to fill these gaps will be crucial for developing a nuanced understanding of the impact of carbon taxes on food affordability.

## Conclusions

Climate change remains one of today's most pressing global challenges, leading countries to adopt various policies aimed at reducing greenhouse gas (GHG) emissions. Among these, carbon pricing—particularly through carbon taxes—has played a key role, though its potential impacts on food prices and affordability continue to be debated. As governments expand their focus to include broader carbon compounds, ensuring that food remains affordable, especially for diverse income groups, has become a crucial policy priority. Food affordability is shaped by a range of factors, including income levels, societal expenditures, and differing definitions that emphasize elements

such as prices and purchasing power. In Canada, food affordability is closely tied to food security principles and the aim of equitable access across all income levels.

The effects of carbon taxation extend beyond national borders, influencing both domestic food prices and international food production exports. Studies indicate that countries like the United States and parts of Europe have observed slight increases in food prices attributed to carbon taxes. In Canada, carbon taxation is widely recognized as an effective GHG mitigation tool, but concerns remain about its potential effects on food prices, especially in provinces with significant agricultural production, such as Alberta and British Columbia. Research suggests that, while the impact of carbon pricing on food prices is generally modest, it can decrease farm income by raising input costs, which could affect the competitiveness of the agricultural sector.

One concern with carbon taxes is their potential regressive effect—where lower-income households bear a relatively higher economic burden. To address this, governments are considering redistributive measures, such as returning carbon tax revenues to those most affected, to alleviate economic strain and build public support for climate policies. Furthermore, incorporating technological advancements in agriculture, both before and after implementing carbon taxes, could improve policy outcomes, making climate action more efficient and equitable.

As the global community seeks solutions to the dual challenges of climate change and food affordability, a balanced approach that accounts for both environmental and economic goals is essential. Future research and policy refinement should focus on optimizing carbon pricing mechanisms to effectively reduce emissions while safeguarding food security and affordability for all income levels.

## CRediT authorship contribution statement

**Sylvain Charlebois:** Writing – review & editing, Writing – original draft, Resources, Investigation, Formal analysis, Data curation, Conceptualization. **Swati Saxena:** Writing – review & editing, Writing – original draft, Resources, Investigation, Formal analysis, Data curation, Conceptualization. **Gumataw Abebe:** Methodology. **Tony Walker:** Methodology. **Janet Music:** Methodology, Conceptualization. **Vlado Keselj:** Methodology. **Karim Tuffaha:** Methodology. **Keshava Pallavi Gone:** Writing – original draft, Validation, Investigation, Formal analysis. **Janele Vezeau:** Methodology. **Bibhuti Sarker:** Writing – review & editing. **Stacey Taylor:** Writing – original draft, Resources, Methodology, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

Data will be made available on request.

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