# The Effect of Carbon Taxes on Agricultural Trade

Nicholas Rivers[1] and Brandon Schaufele[2]

[1]*Graduate School of Public and International Affairs and Institute of the Environment, University of Ottawa, 120 University, Ottawa, ON K1N 6N5, Canada (phone: 613-562-5800, ext. 4676; fax: 613-562-5241; e-mail: Nicholas.rivers@uottawa.ca).*
[2]*Department of Economics and Institute of the Environment, University of Ottawa, 120 University, Ottawa, ON K1N 6N5, Canada (corresponding author: phone: 613-286-1423; fax: 613-562-5873; e-mail: bschaufele@ivey.uwo.ca).*

*This study evaluates the implications of an existing carbon tax on international trade in the agricultural sector. Applying uniformly to all fossil fuels combusted within its borders, the province of British Columbia unilaterally introduced a carbon tax on July 1, 2008. In 2012, the province granted an exemption from the tax to certain agricultural sectors. Using commodity-specific trade flows and exploiting cross-provincial and intertemporal variation, we find little evidence that the carbon tax is associated with any meaningful effects on agricultural trade despite the sector being singled out as "at risk" by the provincial government. Our findings suggest that there is not compelling evidence to support exempting the agricultural sector from the tax. Discussion of potential policy remedies to address the tax's potential effects on firm profitability and international competitiveness is also included.*

*Dans la présente étude, nous examinons les répercussions qu'une taxe sur le carbone existante exerce sur le commerce international du secteur agricole. Le 1er juillet 2008, la Colombie-Britannique a assujetti unilatéralement tous les combustibles fossiles utilisés sur son territoire à une taxe sur le carbone. En 2012, la province a accordé une exonération de cette taxe à certaines activités agricoles. Un examen des flux commerciaux de certaines marchandises de base ainsi que des variations interprovinciales et inter-temporelles fournit peu d'éléments voulant que la taxe sur le carbone entraîne des répercussions importantes sur le commerce agricole malgré le fait que le gouvernement de cette province ait qualifié le secteur comme étant «à risque». Les résultats de notre étude permettent de penser qu'il n'existe aucune raison impérieuse d'appuyer l'exonération de cette taxe au secteur agricole. Nous avons également abordé la question des solutions politiques qui pourraient atténuer les répercussions potentielles de la taxe sur la rentabilité et la compétitivité internationale des entreprises.*

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## INTRODUCTION

British Columbia (BC) introduced a carbon tax on all fossil fuels purchased in the province on July 1, 2008. Carbon taxes are considered to be among the most efficient market-based instruments to reduce greenhouse gas emissions: They raise revenue which can be used for productive purposes such as reducing other tax distortions (Goulder et al 1997), provide strong incentives for technological innovation (Fischer and Newell 2008), and have small transaction costs (Stavins 1995). Further, BC's carbon tax combines a unique set of policy characteristics, placing it among the best designed environmental policies in the world: (i) the carbon tax is coupled with targeted rebates to low-income and remote households, alleviating concerns over the regressivity; (ii) revenue from the carbon tax is

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used to reduce rates of corporate and personal income taxation, a design that admits the possibility of a "double dividend" (i.e., a reduction in greenhouse gas emissions as well as an increase in economic output) (Goulder 1995); and (iii) the tax applies an identical rate per tonne carbon dioxide equivalent ($tCO_2e$) to all emitters, invoking the equimarginal principle and yielding greenhouse gas reductions at the lowest social cost. Yet, while the tax is well-designed, it was enacted unilaterally and applies exclusively to BC residents and firms—concerns linger over its consequences on particular sectors.

Unilateral implementation leads to apprehension over adverse competitiveness effects, especially in the presence of trade. Differential environmental regulations may cause firms operating in BC to move to other untaxed jurisdictions. This can reduce the effectiveness of the tax (and compromise efficiency) and undermine domestic support for the policy. Difficulties are greatest in sectors with relatively high greenhouse gas intensity, those which face international trade pressure, those which are "footloose," and those which receive little benefit from the revenue-recycling mechanisms that accompanied the tax. As such, in its 2012 budget speech, the BC Government looked to "examine the tax's impact—both positive and negative—on every economic sector" (BC Budget Speech 2012, p. 15). Of note, the government stated its intention to "pay particular attention to agriculture, recognizing its critical importance to our future" (BC Budget Speech 2012, p. 15).

Singling out the agricultural sector as "at risk" is likely the result of the prebudget consultation process. Industry representatives claimed that the tax was "devastating" agricultural producers and that "it is one of the hardest-hit industries when it comes to the carbon tax" (BC Budget Consultation 2012). They also claimed that, "There is no offset for [agricultural producers], so no matter what you give back in taxes, it doesn't matter" (BC Budget Consultation 2012). As a result of these deliberations, certain agricultural subsectors were granted exemptions from the BC carbon tax starting in 2012. The BC Government did not provide empirical evidence to justify the agricultural sector's exemptions, nor did it specify which criteria or evidence would support other sectors' exemptions from the tax based on competitiveness arguments.

This paper empirically evaluates the consequences of the BC carbon tax on trade in agricultural commodities. We exploit a commodity-specific panel data set reflecting trade in all provinces between 1990 and 2011 (prior to agricultural exemptions being implemented). After controlling for geography and time invariant factors in addition to other covariates (e.g., weather), we find little evidence that the implementation of the BC carbon tax is associated with a decline in exports from the agricultural sector; the tax does not appear to have any meaningful effects on the international competitiveness of BC's agricultural sector. Although most of our estimates are statistically insignificant, point estimates generally suggest an increase in aggregate international agricultural exports and a reduction in imports coincident with the tax. Introducing commodity-specific heterogeneity enables us to estimate several negative effects for particular commodities but none are statistically distinguishable from zero.

While our empirical findings are not precise, this paper makes two important contributions to the literature. To start, we are the first to econometrically analyze the implications of an actual carbon tax on the agricultural sector. To our knowledge, no other study has addressed this issue using real data (i.e., based on actual experience with carbon taxes rather than via simulation models). Second, this study is useful for an ongoing and timely policy discussion. Climate policies, including BC's Climate Action Plan, continue to be debated by national and subnational governments. Overall, our findings suggest that exemptions granted to the agricultural sector are not supported by the empirical evidence. While public pressure may induce governments to compensate sectors following the introduction of similar taxes, these provisions may be inefficient and unnecessary. Consequently, we discuss alternative rebating schemes which would alleviate competitiveness pressures at a lower efficiency cost than sector-specific exemptions.

The remainder of the paper is structured as follows. The second section describes the BC carbon tax, with a particular focus on the use of revenues raised as a result of the tax. The third section presents our empirical analysis. The fourth section reviews mechanisms that could be used to mitigate any potential negative impacts of a carbon tax on international trade and profitability of the agricultural sector in BC. The last section concludes.

## OVERVIEW OF THE BC CARBON TAX

The introduction of the BC carbon tax surprised the majority of province's residents (Harrison 2012). Announced by the province's Finance Minister in her February 2008 budget speech, the tax was implemented very quickly. By July 1, 2008, BC became the first jurisdiction in North America to tax fossil fuels based on carbon content at an equivalent level.[1] Only during the second half of 2007 did the government begin to hint that environmental pricing was possible. Even then, there was no public acknowledgement that carbon taxes were a prospective option until a speech late in October 2007. Early reactions to the carbon tax were positive and polls showed that a majority of voters supported the policy (Harrison 2012). Residents appear to have understood the impetus for the tax and accepted that it was a well-designed policy. The most notable demonstration of popular support was when the Liberal Party of BC, the political party that introduced the tax, was granted a third consecutive majority government in a post-carbon tax election.

The carbon tax is comprehensively applied to all greenhouse gas emissions generated from burning fossil fuels, with the effective tax rate for each fuel type based on its carbon content. The tax rate started at \$10 per $tCO_2e$ in July 2008 and increased by \$5 per tonne every year reaching \$30/$tCO_2e$ by July 2012 (BC Ministry of Finance 2011). At \$10/$tCO_2e$, the tax represents an increase of 2.69 ¢/liter of diesel and at \$30/$tCO_2e$ this increases to 7.67 ¢/liter. Increasing the level of the tax through time allows producers to gradually adjust their fuel usage and change their habits. This feature of the policy also facilitates investment planning by firms and individuals, since a fixed five-year schedule of tax rates was legislatively mandated. Initially, the BC carbon tax was implemented with no exemptions granted to any groups or industries.

Generating an estimated \$960 million in 2011–12 (BC Ministry of Finance 2012), the BC carbon tax was introduced as revenue neutral. Revenue neutrality entails returning all carbon tax revenues to residents via adjustments to personal and corporate taxes as well as via lump-sum transfers. The generated revenue lowered each of personal, corporate, and small business income tax rates. It also reduced school property taxes for land classified

[1] The city of Boulder, Colorado and the province of Quebec implemented carbon taxes in 2007, but at much lower levels than in BC.

as "farm," gave industries property tax credits, and provided transfers to lower-income families and northern and rural homeowners (BC Ministry of Finance 2012). The BC government, for example, lowered the rate of tax on the bottom two personal income tax brackets and introduced a series of lump-sum transfers to protect low-income and rural households. Low-income households receive quarterly rebates, which, for a family of four, equal approximately $300 per year. Beginning in 2011 northern and rural homeowners received a further benefit of up to $200.

Despite these tax shifts, there is a perception that the carbon tax is reducing the BC agricultural sector's competitiveness and profitability while dramatically increasing their energy costs. The carbon tax was introduced during an uncertain period for producers. A high Canadian dollar, volatile commodity prices, and lack of trade protection have been called a "perfect storm" for the farming community. The coincident timing of these challenges with the introduction of the carbon tax may have led farmers to target and blame the carbon tax for the difficulties in the sector (BC Budget Consultation 2012).

A major reason for the agricultural sector's dislike of the carbon tax is the perceived difficulties in adapting to the new tax by decreasing fuel use in the short run. Heating greenhouses and harvesting crops with machinery are essential to the proper functioning of farms. An increase in the price of fuels leads to an increase in energy costs that could lead to adverse results for the industry: decreasing profits, reduction of planted acres, a decline in net exports, or even farms leaving the BC market altogether.

As a result of these perceived challenges, in 2012 the government granted BC's high-tech greenhouse vegetable and horticulture growers a one-time, $7.6 million reprieve from the carbon tax, "allowing producers to focus on maintaining their competitive edge" (BC Ministry of Agriculture 2012). This was followed in the 2013 Budget by a permanent grant program for commercial greenhouse growers (vegetable, floriculture, wholesale production, and forest seedling nurseries) that is set at 80% of the carbon tax paid on natural gas and propane for heating and $CO_2$ production. Forthcoming legislation will also exempt farmers from carbon tax on the purchase of colored gasoline and diesel used for farm purposes starting in January 2014.

The objective of these exemptions is to enable BC growers to better compete with producers in the United States and Mexico. However, as exemptions can impose large efficiency costs (Bohringer and Rutherford 1997), they should only be considered when there is compelling evidence that a sector is being displaced by output from other regions. To our knowledge, this evidence was never produced when justifying the exemption to BC's agriculture sector. The objective of this study is to quantify impacts on international agricultural trade attributable to the carbon tax. In other words, we aim to estimate the extent to which the carbon tax affected the international competitiveness of BC's agricultural sector and to evaluate whether exemptions can be justified empirically.

## EMPIRICAL ANALYSIS

The empirical analysis is divided into several subsections. First, we examine whether BC's agricultural sector should be considered carbon intensive compared to other traded goods sectors operating within the province. Next, we present our econometric methodology, data, and estimate a series of models focusing on the effect of the carbon tax on agricultural exports and imports. Finally, we discuss our results in light of the agricultural sector's tax exemption.

**Is BC's Agricultural Sector Carbon Intensive?**

The introduction of unilateral environmental regulations increases domestic costs of producing pollution-intensive goods and may induce comparatively disadvantaged dirty good production to shift from a regulated jurisdiction to an unregulated jurisdiction. This core prediction comes from the canonical Heckscher–Ohlin model of comparative advantage (McGuire 1982; Copeland and Taylor 2004). In a small open economy, environmental regulation reduces output and net exports from the dirty sector in the regulating economy. However, even though unilateral environmental regulation reduces output and net exports in the dirty sector—as factors shift out of the dirty sector into the clean sector—output and net exports in the clean sector potentially increase. As such, it is useful to categorize sectors as "clean" or "dirty" according to carbon intensity in order to predict whether a given sector is likely to expand or contract in response to a carbon tax.

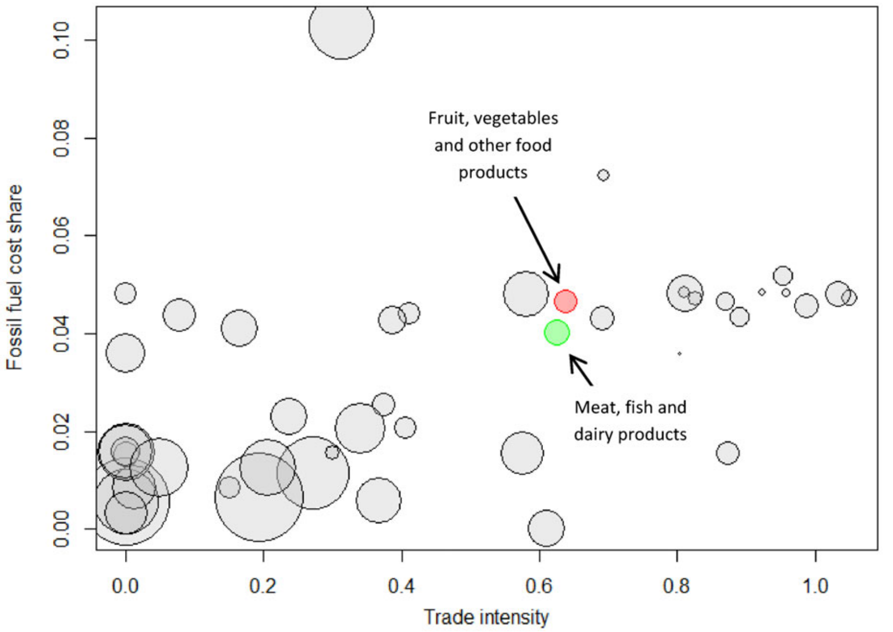
While classifying clean and dirty commodities is straightforward in theory, it is less so in practice. Multiple sectors produce a range of outputs; some goods are produced exclusively for domestic markets, while others are exported. The Heckscher–Ohlin theory is based on homogeneous goods, yet, in reality, consumers have preferences over the origin of goods, particular brands, or other heterogeneous characteristics—in general, tradable goods cannot be considered homogeneous (e.g., Carter et al 2006). As a first-order approximation however, it is possible to pinpoint sectors, based on the structure of BC's economy, that have the largest probability of being adversely affected following the introduction of a unilateral carbon tax.

Data on fossil fuel usage by sector and trade by commodity are available from Statistics Canada's System of National Accounts (see Supplementary Material). From these data, it is possible to obtain the cost share of direct fossil fuel inputs required to produce a unit of each commodity, as well as the trade intensity of each commodity.

Figure 1 plots the trade intensity (horizontal axis) for each commodity in Statistics Canada's S-Level database against the cost share of fossil fuel in its production (vertical axis) (national accounts data are available at different levels of aggregation, with the S-Level the only level of aggregation publicly available for provincial data). These two measures are directly relevant to the Heckscher–Ohlin model of comparative advantage. Commodities that are not highly traded are unlikely to experience large changes in imports or exports as a result of unilateral environmental policy. Similarly, sectors that do not consume substantial amounts of fossil fuels are unlikely to experience large cost increases due to the carbon tax, thus will not experience major changes in their ability to compete with foreign producers. Commodities that use a high proportion of fossil fuels in production and those that are highly traded are most susceptible to pressures from international competition.

Energy-intensive and trade-exposed thresholds have been widely used in policy formation. For example, the Waxman–Markey cap and trade bill, a prominent piece of U.S. legislation, defined a sector as energy intensive and trade exposed if energy expenditures represented more than 5% of total costs, and if trade intensity was greater than 15%.[2] Figure 1 demonstrates that most commodities produced in BC have both low trade

[2] Trade intensity, as defined in the Waxman–Markey bill and adopted here, is (imports+exports)/(imports+domestic output). Trade intensity for the United States as a whole is much lower than for a Canadian province due to differences in size.




Notes: Area of circles is proportional to total domestic output of commodities in 2007. The colored circles correspond to agricultural products. The red circle represents "Fruit, vegetables, and other food products and feeds," while the green circle represents "Meat, fish, and dairy products."

Figure 1. Trade intensity and fossil fuel cost share for BC commodities, 2007

intensity and low fossil fuel intensity.[3] This reflects the fact that services, which dominate the BC's economy, are typically not highly traded and have low energy intensity. There is a natural break in the data at a trade intensity of 0.5, so we consider goods with trade intensity greater than 0.5 as "highly traded." Agricultural goods are highly traded. Compared to the other highly traded goods produced in BC however, agriculture does not stand out as particularly fossil fuel intensive. Both production of fruit, vegetables, and other food products and production of meat, fish, and dairy products have cost shares of approximately 0.04 for fossil fuels (i.e., 4% of total costs are for fossil fuels). This is larger than the fossil fuel cost share for services, but lower than or equal to the cost share of fossil fuels in many manufactured goods. Whether agriculture should be considered dirty or clean is not obvious. Likewise, the trade intensity of about 0.6 is greater than that of domestically oriented commodities (services), but less than that of internationally traded manufacturing commodities. While theory clearly suggests that exports from the dirty (clean) sector should decrease (increase) following a carbon tax, agriculture's classification is ambiguous and no clear theoretical predictions are available. Thus, we move to a more formal empirical approach to better understand the tax's impacts on trade.

[3] The high degree of data aggregation in the Statistics Canada S-Level data can obscure important outliers in the data.

**Estimating the Effect of the Carbon Tax on Agricultural Trade**

Jaffe et al (1995, p. 157) conducted a review of econometric studies and concluded that "there is relatively little evidence to support the hypothesis that environmental regulations have had a large impact on competitiveness." Several deficiencies plagued the early analysis however—endogeneity of pollution regulations and unobserved heterogeneity are most prominent. After correcting for these issues, environmental regulation has been shown to have a modest effect on trade, investment, and plant location decisions (Edgerington and Minier 2003; Levinson and Taylor 2008; Kellenberg 2009; Hanna 2010; Copeland 2012). Levinson and Taylor (2008), for example, estimate that a doubling in pollution abatement expenditures in response to more stringent U.S. environmental regulation between 1977 and 1986 led to an increase in net imports of pollution-intensive goods from Mexico of around 40%.

There are two reasons why a prospective negative relationship between exports and environmental regulation is important for policy makers. First, out-migration of polluting industries, from regulated to unregulated jurisdictions, works against the objectives of the policy—emissions in the unregulated jurisdiction are unaffected by the policy. Trade-related "leakage" is often perceived as unavoidable, but most estimates find that it is small to moderate relative to the effect of the policy (Felder and Rutherford 1993; Elliot et al 2010). Still, emissions leakage is a concern. Second, if unilateral environmental policy causes a shift of economic activity to other countries, there may be a decline in domestic welfare associated with losses in industry competitiveness. Adverse competitiveness effects occupy a central position in many policy discussions.

Competitiveness is an imprecisely defined term, loosely used to refer to profits, employment, and trade among other things. In an effort to examine the impact of the BC carbon tax on "agricultural competitiveness," we construct a data set covering international trade and output in agricultural commodities in all Canadian provinces and then estimate whether the introduction of the BC carbon tax is associated with a measurable change in trade patterns. To do so, we build on the framework introduced in Levinson and Taylor (2008). Specifically, we start from a partial equilibrium model of world trade in the presence of environmental regulations:

$$X_{ijt} = \beta_0 + \beta_1 s_{jt} + \beta_2 c_{ijt} + \beta_3 c_{ijt}^X + \beta_4 \tau_{ijt} + \beta_5 \tau_{ijt}^X + \varepsilon_{ijt}$$

where $X_{ijt}$ is exports or imports of good $i$ from region $j$,[4] $s_{jt}$ is region $j$'s share of world income,[5] $c_{ijt}$ is a unit cost function for production of good $i$ in region $j$ at time $t$, $\tau_{ijt}$ is

[4] In some of our estimates, we follow Levinson and Taylor (2008) by normalizing exports and imports by the size of the domestic industry. This is a convention in the international trade literature to accommodate the significant differences in industry size (Leamer and Levinsohn 1995). In particular, it ensures that any omitted variables that are correlated with industry size do not enter the error term and cause bias in estimation results. It has the additional benefit of making the dependent variable more likely to be stationary as it is a share rather than a level. We also estimate the equation where the dependent variable is not normalized.

[5] The intuition for the inclusion of the variable $s_{jt}$ is apparent from the derivation presented in Levinson and Taylor (2008): if the regulating country's share of world income is larger than its share of world production, then (assuming identical technologies and preferences) it will have positive net imports and vice versa.

the environmental policy in region $j$ for good $i$ at time $t$, and the superscript $X$ indicates a foreign variable.

We do not however observe home costs, foreign costs, or foreign environmental policies. As in Levinson and Taylor (2008), we accommodate these unobservables with a set of interacted time and region fixed effects controlling for factors that would otherwise confound our analysis. We specify and estimate the following model:

$$X_{ijt} = a\tau_{jt} + b_{ij} + d_{it} + f\left(t_{jt}, p_{jt}\right) + \varepsilon_{ijt}$$

The good-region fixed effect, $b_{ij}$, captures comparative advantage. Comparative advantage refers to slowly moving stocks such as land quality, climate, human, and physical capital. This time-invariant commodity-region parameter reflects average differences between home and foreign unit costs that govern comparative advantage. The commodity-time dummy, $d_{it}$, controls for commodity-specific changes over time that affect all Canadian provinces. For example, variation arising from national trade policy, exchange rate fluctuations, tariffs, and the mean ratio of foreign to domestic costs of production are captured by this parameter. Together, these fixed effects enable us to net out factors which drive common home-foreign jurisdiction cost differentials. Remaining variation comes from province-commodity-year shocks. The most prominent of these is prevailing weather. As such, we incorporate a polynomial of weather terms, $f\left(t_{jt}, p_{jt}\right)$, which includes actual and squared spring and summer temperature indices (given by $t_{jt}$) as well as actual and squared spring and summer precipitation indices (given by $p_{jt}$). Finally, the error terms, $\varepsilon_{ijt}$, are assumed to be uncorrelated with the primary variable of interest, the carbon tax, $\tau_{jt}$, and pick up changes in foreign environmental policies, classical measurement error in addition to time-variant changes in the ratio of home and foreign commodity-specific unit costs. Unbiased estimates for the carbon tax coefficient rely on lack of correlation between these omitted variables and the independent variables in the model, a plausible assumption in this case as the carbon tax was unilaterally implemented and not agriculture specific.

Our coefficient of interest is $a$. This parameter shows the impact of the tax on agricultural exports and imports. Unlike Levinson and Taylor (2008) (and many other contributors to the literature on international trade and the environment), we do not employ a proxy for environmental regulatory stringency. Instead we measure stringency directly with the carbon tax rate.[6] This exogenous measure of regulatory stringency simplifies our estimation significantly compared to other contributions as it is precise and plausibly unconfounded with the error term.[7] This is an important contribution to the literature as few studies have a comparably explicit measure of regulatory stringency. Finally, we conduct a sequence of robustness checks to test whether changes in the sample

[6] The typical measure of regulatory stringency in this literature is pollution abatement cost per unit of value added. Since industry structure can change in response to regulatory stringency, this proxy measure is endogenous, creating difficulties with estimation.

[7] One concern in the previous literature linking pollution regulation at the sector level to international trade is that policy makers may select regulations based on their expectations of the response of the sector to the regulation, such that the regulation is endogenous. In our case, BC applied the carbon tax uniformly to all sectors, such that this type of endogeneity is less likely to be a concern.

or estimating equation induce changes in the economic or statistical significance of our coefficients.

Bias may still arise if there are omitted variables that are correlated with agricultural trade and the carbon tax. One potential confounder is the emissions offset system implemented at the same time as the carbon tax. This offset system supported the provincial government's aim to become carbon neutral—all publicly funded agencies had to achieve mandated carbon neutrality through emissions reductions or offsets. Agricultural projects are eligible sources for offset projects and a small number of credits originate in the agricultural sector (we count fewer than 10 agricultural offset projects in the retired offset credit registry).[8] To the extent that these are subsidies for the agricultural sector implemented concurrently with the tax, omitting them in the regression could lead us to underestimate the effect of the tax—that is, the offset program will lead to an attenuation of our coefficient of interest. We believe that any bias attributable to the program will be very small due to the exceedingly small number of agricultural offset projects that were funded. Still, supposing that offsets are an important source of bias, our coefficient on the carbon tax can be thought of as the joint effect of the tax and offset programs.

**Data**

Our data set is assembled from three sources, each requiring manual processing. The empirical strategy is based on comparing international agricultural trade on a commodity level between BC and other provinces. Commodity classifications are coarse however. There may be an imperfect match between the commodities traded in each province. For example, one commodity in our sample is edible fruits and nuts, which clearly is heterogeneous. If one province produces a distinct subset of this aggregate commodity compared to another, it may yield less useful information about a counterfactual. We collect annual data on farm receipts by agricultural commodity and by province for 1970–2011 from Statistics Canada (Table 002-0001) and annual data on provincial imports and exports by agricultural commodity from 1990–2011 from Industry Canada (see Supplementary Material). The commodity classifications used by Statistics Canada and Industry Canada are slightly different, so manual merging was needed. Table A1 in the Appendix documents the commodity concordance table that we assembled to conduct the analysis.[9] In addition to data on production, imports, and exports, data on weather are sourced from Environment Canada's Climate Trends and Variations Bulletins, which reports regional precipitation and temperature anomalies on a seasonal basis. Although the regions used by Environment Canada closely approximate provincial boundaries, the match is not exact. The concordance between Environment Canada regions and provinces used in the analysis is reported in Table A2.[10] All data and code are available for download from the authors' websites.

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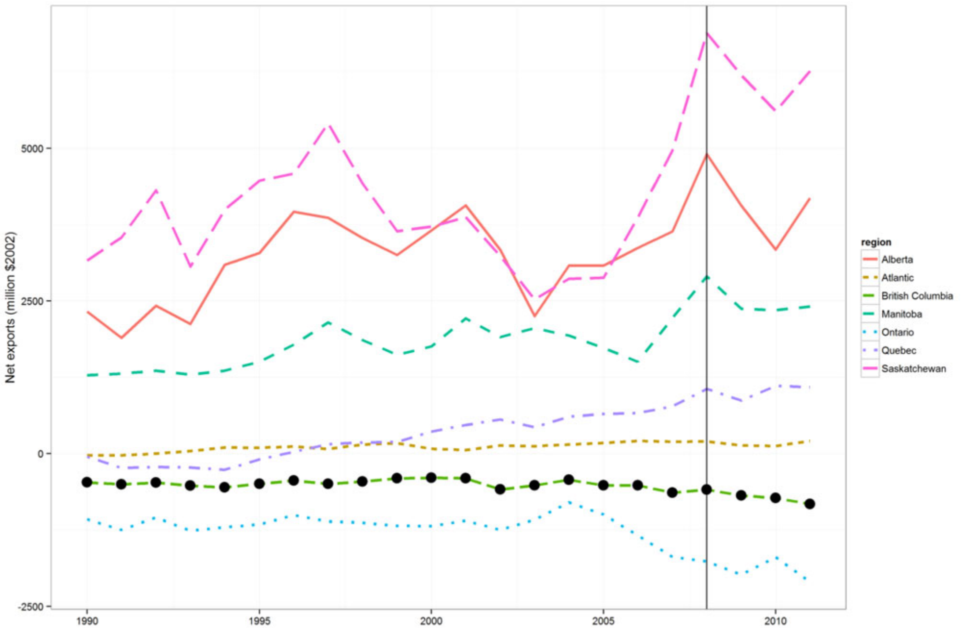
[8] The registry is available at: http://www.pacificcarbontrust.com/our-projects/offset-registry/.

[9] Supply-managed commodities (poultry, dairy, etc.) are not included in the analysis, since producers in these sectors face different incentives compared to other sectors. Specifically, we (a) do not expect that these products will be exported and (b) that trade restrictions (quota levels vis-à-vis tariffs, etc.) may be considered endogenous to domestic environmental policy.

[10] The regions adopted by Environment Canada are reported in seasonal bulletins: http://www.ec.gc.ca/adsc-cmda/default.asp?lang=En&n=4CC724DA-1#a4.




Note: Deflation of nominal values to real values is conducted using the Consumer Price Index (Statistics Canada 2013).

Figure 2. Net exports from agriculture by province, 1990–2011

**Results**

Results are presented in three steps. We begin by providing some graphical evidence and summary statistics. Next, aggregate econometric results are presented using both the standard normalization and an unnormalized first-differenced dependent variable. Finally, commodity-specific heterogeneity is examined. As the analysis progresses, it becomes increasingly clear that any policy implications and empirical conclusions on the link between BC's carbon tax and agricultural trade are highly sensitive to the underlying model specification. However, throughout the analysis, it is also clear that there is no empirical evidence linking the carbon tax to a decrease in the international competitiveness of the agricultural sector.

Figure 2 shows the evolution of net exports of aggregate agricultural trade for each Canadian province. Significant volatility is apparent even at this level of aggregation. Net exports from Alberta and Saskatchewan fell dramatically in 2003, corresponding to the discovery of bovine spongiform encephalopathy (BSE) in an Albertan cow. Exports from these provinces then increased rapidly in the period around 2008. There are also large fluctuations in agricultural trade concurrent with the 2009 recession. BC is a net importer of agricultural commodities, and net imports are gradually increasing during the period covered by our data. (Ontario is the only other province for which aggregate agricultural net exports are negative.) We illustrate the introduction of the carbon tax in BC with the

Table 1. Annual average growth rate in gross agricultural exports

| | 2001–07 | 2009–11 | Difference |
|---|---|---|---|
| **Panel A** | | | |
| British Columbia | −3.93 | −4.07 | −0.14 |
| Other provinces | 0.82 | 1.76 | 0.94 |
| Difference | −4.75 | −5.83 | −1.08 |
| **Panel B** | | | |
| | 2000–08 | 2008–11 | Difference |
| British Columbia | −0.49 | −4.86 | −4.37 |
| Other provinces | 5.39 | −2.93 | −8.32 |
| Difference | −5.88 | −1.93 | 3.95 |

Note: Values are in percentage terms and refer to the real dollar value of agricultural exports.

vertical black line. At this level of aggregation, there is little visually discernable change in net exports.

Table 1 provides numerical context for Figure 2. It summarizes growth rates, both prior to and following the introduction of the carbon tax, in the real value of aggregate gross agricultural exports in BC compared to other provinces (note that the table focuses on gross exports, while Figure 2 shows net exports). Panel A focuses on 2001–07 (prior to the 2008 introduction of the tax) compared with 2009–11 (posttax). The first row demonstrates that exports of agricultural commodities from BC declined by 3.93% in real terms per year during the early part of the decade compared with a decline of 4.07% from 2009 to 2011. The second row repeats the calculations for the rest of Canada: exports grew by 0.82% annually in other provinces in 2001–07 and by 1.76% in 2009–11. Table 1's right-hand column then shows the difference in the growth rates in exports before and after the tax in BC and the rest of Canada. The bottom cell presents the difference-in-differences calculation which suggests a decline of 1.08% in gross exports attributable to the tax. This insinuates that the tax had a negative effect on exports, perhaps warranting the exemption granted by the government.

Before drawing conclusions however, caution is required when interpreting these results. The tax was introduced on July 1, 2008 and a slight shift in the window of analysis generates completely different results. Panel B of Table 1 changes the periods both before and after the tax slightly. Now, the before period is from 2000 to 2008 while the after period is 2008–11. This one-year change yields results that suggest a large positive impact of the tax—the difference-in-differences calculation shows that BC's gross agricultural exports increased by 3.95% relative to the rest of Canada. Clearly, these high level comparisons are insufficient to precisely determine the impact of the carbon tax on trade. Moreover, Table 1 highlights two challenges that arise when using simple averages to evaluate environmental policy. First, there is notable intertemporal volatility in trade over time. Results are sensitive to the selection of the period of analysis. Second, there is likely substantial commodity-specific heterogeneity across commodities even within provinces—for example, Alberta's aggregate agricultural sector was more affected by BSE in 2003 as cattle comprised a larger share of exports compared with

Table 2. Regression results with logged exports and imports normalized by domestic output as dependent variables

| | Gross exports | Gross imports |
|---|---|---|
| Carbon tax | 0.061** | 0.002 |
| | (0.024) | (0.026) |
| Good-region fixed effects | Y | Y |
| Commodity-year fixed effects | Y | Y |
| Weather controls | Y | Y |
| $R^2$ | 0.88 | 0.85 |
| Obs. | 2,332 | 2,332 |

Notes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; robust standard errors in parentheses.

other provinces. It is possible to control for the border closure affecting beef and cattle, and other commodity-specific heterogeneity, via commodity-province and province-year fixed effects. As a consequence, we apply more formal econometric methods as described above in an attempt to better identify the impact of the tax.

Our first regression results are reported in Table 2 and correspond to the analysis in Table 1. Following Leamer and Levinsohn (1995) and Levinson and Taylor (2008), we evaluate the influence of the carbon tax on gross exports and gross imports. This initial specification adopts the convention of normalizing the dependent variable by domestic output, which accommodates the wide distribution in sector size found in trade data. Both columns include year-commodity and commodity-province fixed effects as well as a full set of weather controls. The year-commodity variables accommodate much of the volatility in commodity prices as well as other commodity-specific events that occur in time. Similar to Panel B in Table 1, these results suggest that the carbon tax had a statistically and economically significant positive effect on agricultural exports from BC. A small and statistically insignificant coefficient on agricultural imports is also found.[11] If our analysis ended with Table 2, we would conclude that BC's carbon tax led to an increase in agricultural exports and that, even without the exemption, the sector was a net winner following the province's climate policy. As commodity-specific heterogeneity is introduced, it becomes apparent that this conclusion is misleading. In reality, it is challenging to identify any meaningful effect of the carbon tax on agricultural trade in BC.

Table 3 repeats the analysis of Table 2 but uses nonnormalized versions of the dependent variables. Although it is common to normalize these values by domestic output in empirical trade work, it may confound interpretation of the results since a change in normalized imports or exports can be due to a change in either the numerator or the denominator of the normalized variable. As such, we transform our dependent variable using natural logs. This helps to account for differences in size of industry sectors. Finally, instead of estimating the model in levels, we estimate the model in first differences.

[11] We conduct regressions for gross exports and imports rather than for net exports because in a later section of the paper we use natural logarithms of the dependent variable, which cannot be used for net exports, since these can fall on either side of zero.

Table 3. First-differenced estimates of logged gross exports and imports

| | Gross exports | | Gross imports | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Carbon tax | 0.014<br>(0.022) | 0.008<br>(0.023) | –0.026<br>(0.037) | –0.018<br>(0.039) |
| Commodity-year fixed effects | N | Y | N | Y |
| Weather controls | N | Y | N | Y |
| $R^2$ | 0.00 | 0.27 | 0.00 | 0.21 |
| Obs. | 1,871 | 1,871 | 1,850 | 1,850 |

Notes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; robust standard errors in parentheses.

This facilitates potential nonstationarity in the export and import dependent variables.[12] Columns (1) and (3) do not include controls, simply regressing first differences in log exports and imports on first differences in the carbon tax. After making these changes, the results in column (1) for gross exports are similar to those in Table 2, except that we do not obtain statistical significance. Point estimates, however, suggest that the carbon tax is associated with an increase in gross exports from the agriculture sector. Column (3) shows a decrease in imports, signifying an improvement in international competitiveness associated with the introduction of the tax. Columns (2) and (4) repeat the same regression, this time adding the complement of time-varying fixed effects. The coefficients on both gross exports and gross imports move nearer to zero. Both remain statistically indistinguishable from zero as well. In Table 2, gross imports were similarly statistically insignificant; however, in this alternative specification, gross export becomes statistically indistinguishable from zero. Further, in both situations, normalization causes the magnitude of the coefficients to increase. Table 3 implies that a \$20/t$CO_2$e carbon tax increases gross exports by 16% (column (2)) and decreases gross imports by 36% (column (4)); there is significant uncertainty around these estimates.

The empirics to this point have assumed that the impact of the carbon tax on all agricultural commodities is identical. This is unrealistic because of both diverse technologies and the degree of competition. Some agricultural subsectors are likely to be more exposed to the carbon tax than others. The next set of regressions is presented in two symmetric tables: Table 4 reports regression results for a series of models using gross exports as the dependent variable, while Table 5 reports results for the same model specifications using gross imports as the dependent variable. In total, six models are estimated for each dependent variable (12 models in total). Each regression interacts the carbon tax with commodity indicators, capturing commodity-specific heterogeneity. Column (1) includes commodity-year fixed effects. Column (2) maintains commodity-year dummy variables and adds a linear time trend for each commodity-province pair. A quadratic time trend is added for each commodity-province pair to the previous specification in column (3), while column (4) incorporates a cubic time trend for each commodity-province pair. Increasing the flexibility of trends helps to address the volatility in the import and export series over

[12] This is not a problem for the regressions in Table 2, since the dependent variable is a share and is stationary.

Table 4. First-differenced results with commodity-specific heterogeneity and the natural log of the real value of gross exports as dependent variable

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Carbon tax*cattle | 0.003 | −0.027 | −0.051 | −0.050 | −0.058 | −0.079 |
| | (0.076) | (0.104) | (0.122) | (0.124) | (0.123) | (0.128) |
| Carbon tax*swine | 0.078 | 0.122 | 0.147 | 0.143 | 0.118 | 0.133 |
| | (0.076) | (0.104) | (0.122) | (0.124) | (0.123) | (0.127) |
| Carbon tax*sheep | −0.053 | 0.031 | 0.091 | 0.208 | 0.092 | 0.143 |
| | (0.080) | (0.137) | (0.155) | (0.163) | (0.166) | (0.399) |
| Carbon tax*honey | 0.053 | 0.049 | 0.082 | 0.082 | 0.033 | 0.054 |
| | (0.077) | (0.106) | (0.124) | (0.127) | (0.125) | (0.130) |
| Carbon tax*floriculture | −0.016 | −0.026 | −0.016 | −0.018 | −0.022 | −0.021 |
| | (0.076) | (0.104) | (0.122) | (0.124) | (0.123) | (0.127) |
| Carbon tax*vegetables | −0.007 | 0.007 | 0.016 | 0.015 | 0.023 | 0.015 |
| | (0.075) | (0.104) | (0.122) | (0.124) | (0.123) | (0.127) |
| Carbon tax*fruit&nuts | 0.007 | 0.040 | 0.042 | 0.051 | 0.039 | 0.049 |
| | (0.076) | (0.104) | (0.122) | (0.124) | (0.123) | (0.127) |
| Carbon tax*wheat | 0.038 | 0.084 | 0.087 | 0.081 | 0.092 | 0.069 |
| | (0.080) | (0.112) | (0.129) | (0.131) | (0.129) | (0.134) |
| Carbon tax*barley | −0.004 | 0.047 | 0.072 | 0.068 | 0.057 | 0.058 |
| | (0.082) | (0.116) | (0.133) | (0.135) | (0.134) | (0.139) |
| Carbon tax*oats | 0.020 | 0.070 | 0.064 | 0.064 | 0.055 | 0.060 |
| | (0.082) | (0.116) | (0.133) | (0.135) | (0.134) | (0.139) |
| Carbon tax*soya | −0.076 | −0.051 | −0.051 | −0.061 | −0.011 | −0.084 |
| | (0.080) | (0.109) | (0.130) | (0.136) | (0.126) | (0.139) |
| Carbon tax*canola | 0.045 | 0.157 | 0.209 | 0.202 | 0.204 | 0.203 |
| | (0.082) | (0.116) | (0.133) | (0.135) | (0.134) | (0.139) |
| $R^2$ | 0.28 | 0.35 | 0.39 | 0.41 | 0.41 | 0.53 |
| Obs. | 1,871 | 1,871 | 1,871 | 1,871 | 1,043 | 605 |

Notes: All models include commodity-year fixed effects as well as weather controls. Description of specifications is contained in the main text.
$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; robust standard errors in parentheses.

time. It also ensures that we don't attribute unobserved events to the carbon tax. Finally, columns (5) and (6) are identical to column (2), but restrict the sample to post-2000 and post-2005, respectively. Shortening the sample ensures that the results are robust to any potential structural shifts in BC's agricultural sector that occurred within the last decade. Two corresponding figures—Figures 3 and 4—illustrate the point estimates and confidence intervals for our preferred specifications—column (2) from each table.

Table 4 shows that we fail to find any statistically significant effect of the carbon tax on exports. Point estimates are a mix of positive and negative values but all have wide confidence intervals. Figure 3 provides the best illustration of these results. The vertical line in this figure represents no change in gross exports attributable to the carbon tax. Dots reflect the point estimates from column (2), while the bars show the 95% confidence intervals. In each case, the confidence interval is wide and includes zero. For the majority of our specifications, point estimates are positive, indicating a positive effect

Table 5. First-differenced results with commodity-specific heterogeneity and the natural log of the real value of gross imports as dependent variable

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Carbon tax*cattle | 0.007 | 0.015 | 0.039 | 0.049 | 0.041 | 0.082 |
| | (0.118) | (0.163) | (0.193) | (0.194) | (0.199) | (0.199) |
| Carbon tax*swine | −0.014 | −0.051 | −0.074 | −0.071 | −0.063 | −0.062 |
| | (0.120) | (0.167) | (0.197) | (0.197) | (0.203) | (0.203) |
| Carbon tax*sheep | 0.030 | −0.058 | −0.043 | −0.049 | −0.037 | −0.050 |
| | (0.126) | (0.189) | (0.219) | (0.217) | (0.228) | (0.221) |
| Carbon tax*honey | −0.001 | −0.012 | −0.015 | −0.004 | 0.014 | −0.004 |
| | (0.119) | (0.166) | (0.196) | (0.196) | (0.201) | (0.202) |
| Carbon tax*floriculture | 0.002 | −0.007 | −0.003 | 0.000 | −0.009 | 0.008 |
| | (0.118) | (0.163) | (0.193) | (0.193) | (0.198) | (0.199) |
| Carbon tax*vegetables | 0.013 | 0.017 | 0.002 | 0.002 | −0.007 | 0.012 |
| | (0.117) | (0.162) | (0.192) | (0.192) | (0.197) | (0.198) |
| Carbon tax*fruit&nuts | −0.002 | −0.011 | −0.019 | −0.019 | −0.019 | −0.021 |
| | (0.118) | (0.163) | (0.193) | (0.193) | (0.199) | (0.199) |
| Carbon tax*wheat | 0.010 | −0.149 | −0.156 | −0.178 | −0.248 | −0.159 |
| | (0.123) | (0.173) | (0.202) | (0.202) | (0.208) | (0.208) |
| Carbon tax*barley | 0.075 | 0.205 | 0.041 | 0.043 | −0.065 | 0.019 |
| | (0.127) | (0.180) | (0.209) | (0.209) | (0.214) | (0.215) |
| Carbon tax*oats | −0.224 | −0.340 | −0.418* | −0.432* | −0.359 | −0.482* |
| | (0.127) | (0.183) | (0.210) | (0.210) | (0.216) | (0.215) |
| Carbon tax*soya | −0.020 | −0.025 | −0.078 | −0.036 | −0.022 | −0.024 |
| | (0.126) | (0.168) | (0.203) | (0.209) | (0.203) | (0.217) |
| Carbon tax*canola | 0.030 | 0.002 | −0.003 | −0.015 | −0.023 | −0.017 |
| | (0.127) | (0.179) | (0.209) | (0.208) | (0.214) | (0.215) |
| $R^2$ | 0.26 | 0.33 | 0.36 | 0.42 | 0.37 | 0.44 |
| Obs. | 1,662 | 1,662 | 1,662 | 1,662 | 954 | 550 |

Notes: All models include commodity-year fixed effects as well as weather controls. Description of specifications is contained in the main text.
$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; robust standard errors in parentheses.

of the carbon tax on agricultural exports. For two commodities, we do find a consistently negative, although statistically insignificant, relationship between the carbon tax and gross exports: soy and floriculture. Thus, there is some very weak evidence that the carbon tax is associated with reduced exports of these commodities.

Table 5 and Figure 4 reproduce results for gross imports. With the exception of one commodity, oats, we similarly fail to find a statistically significant association between the carbon tax and imports. In the case of oats, parameter estimates hint that there may be a negative relationship between imports and the carbon tax, signifying an improvement in competitiveness. BC is not a major oat producer, so these results are of minimal economic importance. As depicted in Figure 4, most of the coefficients for imports are negative or effectively zero, indicating a limited relationship between agricultural imports in BC and the introduction of the carbon tax. The signs for two commodities are consistently positive, but not statistically significant, indicating that imports increased contemporaneously with

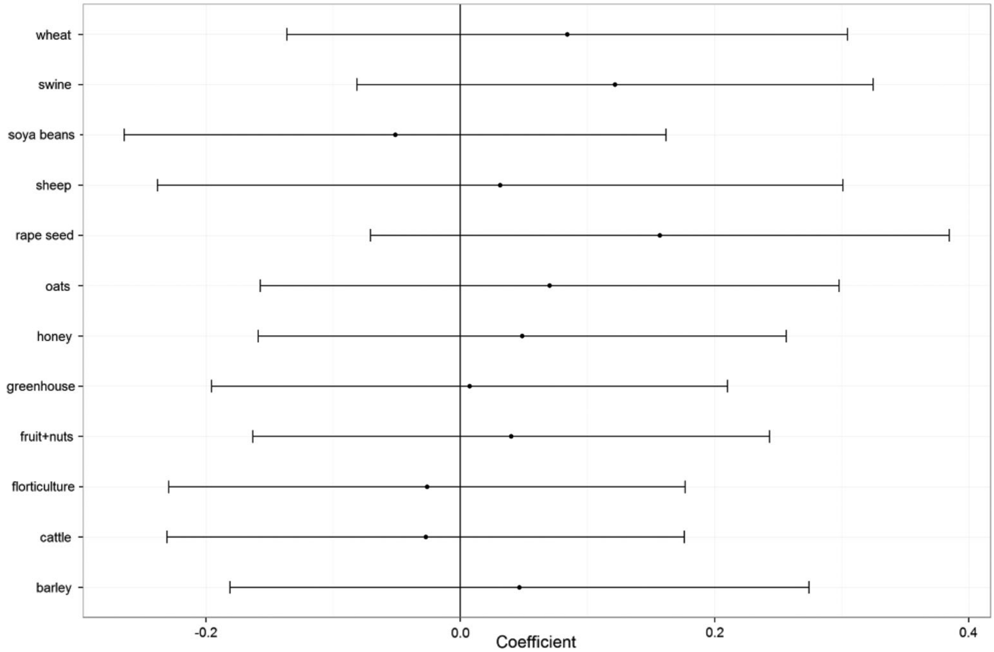



Figure 3. Commodity-specific effect of the carbon tax on gross exports, point estimates, and 95% confidence intervals

the tax: vegetables and cattle. Once again, this provides weak evidence that the carbon tax is potentially associated with reduced competitiveness for BC producers of these commodities. Of note, soy and floriculture saw decreases in imports with magnitudes of roughly half their decreases in exports displayed in Table 4.

Overall, the data do not conclusively reveal any changes in the pattern of agricultural trade that can be linked to the carbon tax. Most of the point estimates suggest that agricultural exports increased contemporaneously with the carbon tax and that agricultural imports to BC decreased with the carbon tax. Both of these trends could be interpreted as an improvement in competitiveness. However, it should be stressed that confidence intervals around the point estimates are large. Weak evidence may support the claims that several specific subsectors were adversely affected. Still we emphasize prudence when interpreting these results as we demonstrate that conclusions are sensitive to econometric specification.

## Discussion

Finding a consistent and credible link between the BC's carbon tax and agricultural trade patterns remains elusive. In nearly all cases, coefficients from our regressions are not statistically significant. Even the few cases where statistical significance is found, results suggest that agricultural exports increased or imports decreased in conjunction with the introduction of the tax. This conclusion runs contrary to the conventional wisdom in the sector: the *ex ante* expectation is that increases in environmental regulations lead to

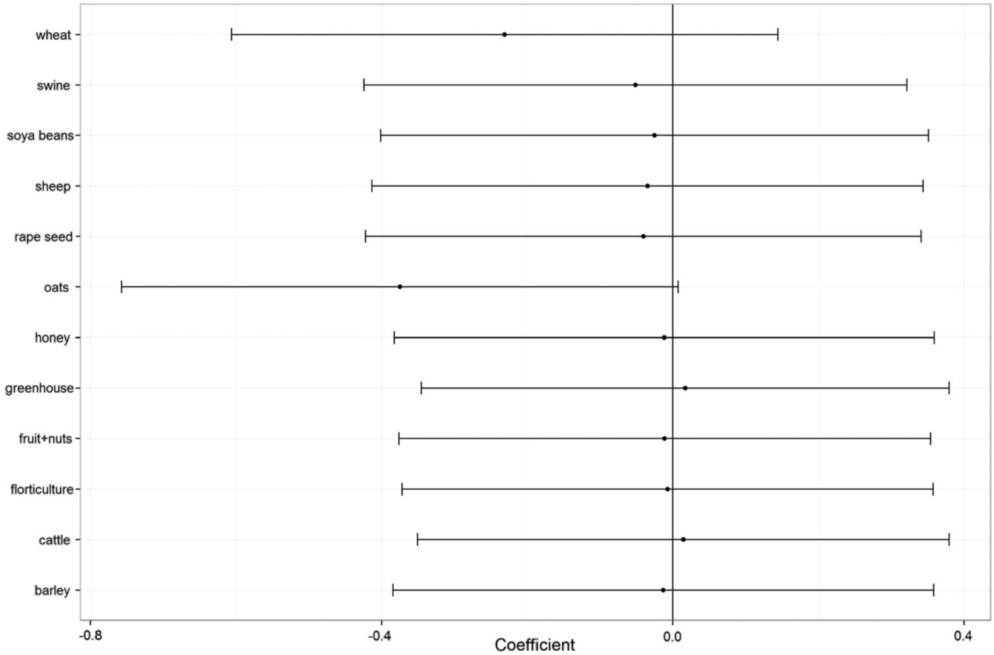



Figure 4. Commodity-specific effect of the carbon tax on gross imports, point estimates, and 95% confidence intervals

a reduction in international competitiveness and a decline in international exports. In fact, these arguments motivated the exemptions granted to the greenhouse sector and the pending legislation targeted at the broader agricultural sector. We propose, but do not empirically test, three potential hypotheses to explain our findings.

First, despite claims to the contrary, it may be that the carbon tax had at best a second-order effect on the agricultural sector. Unambiguous classification of agriculture as carbon intensive and trade exposed was not possible given the available data. Factor endowments such as land quality, climate, and human capital may swamp any impact of the tax. A simple counting exercise demonstrates this. First, using the data from Figure 1 the average fuel cost share for agriculture is 4%. Next, assume that a 7.67¢/liter tax on diesel fuel comprises a 10% increase in the cost of fuel. With these values, under restrictive assumptions of no trade and Leontief technology, it is possible to calculate a ball-park figure for the cost increase due to a \$30/t$CO_2$e carbon tax. In this scenario, the carbon tax generates a maximum increase in costs equal to 0.4%. Based on this magnitude, it seems reasonable to state that the carbon tax only had a second-order effect on the agricultural sector and the declarations made during BC's budget consultation process may have incorrectly attributed other factors affecting agriculture to the carbon tax.

Second, as discussed in the context of the Heckscher–Ohlin model, carbon taxes are likely to reduce net exports from carbon-intensive (dirty) sectors, but potentially increase net exports from other (clean) sectors. If agricultural production is not carbon intensive, then increases in exports following the introduction of the tax are consistent with theory.

Figure 1 suggests that on average the agricultural sector is less carbon intensive than many other highly traded sectors such that it may experience an increase in comparative advantage following introduction of the carbon tax.

Finally, there exists a possibility that the introduction of the carbon tax helped to stimulate process innovations or intra-industry substitutions on BC farms, which offset any first-order effects of the carbon tax. The potential for this was first raised by Porter and van der Linde (1995). Since then, there have been many empirical tests of the so-called "Porter Hypothesis," some which document situations where more stringent environmental regulations created an advantage for regulated firms compared to unregulated firms in other jurisdictions (Ambec et al 2011). To the extent that the carbon tax had a first-order effect on agriculture, the Porter Hypothesis may partially explain its ability to adapt.

## POLICIES TO ADDRESS COMPETITIVE CONCERNS OF CARBON TAXES ON AGRICULTURE

This paper examined the effect of the carbon tax on the international competitiveness of the agricultural sector. The analysis finds little evidence that net exports from BC agricultural firms declined following implementation of the carbon tax. It does not however preclude the possibility that certain agricultural subsectors experienced declines in exports following the introduction of the tax (or that other economic sectors experienced declines in international competitiveness related to the tax). Further, it is possible that even if international exports were relatively unaffected by the tax, profits of agricultural firms declined. For economic efficiency or distributional reasons, the BC government may be interested in mitigating any negative impacts on agriculture associated with the tax. Recognizing that legitimate concerns may exist, it is important to consider the suite of available strategies available to address these worries. The literature raises several possibilities, which could each be targeted at commodities considered most negatively affected by a carbon tax: (1) sector exemptions, (2) lump-sum rebates, and (3) output-based rebates.[13] We discuss each in turn.

Prior to considering these mechanisms, it is worth noting that, in general, policies to support a particular sector of the economy are costly and frequently come at the expense of other sectors. As a result, clear standards should be set to guide the government when supporting particular sectors. The previously discussed U.S. Waxman–Markey Bill implemented this type of condition very clearly. For example, in the case we examine here, sector support to maintain international competitiveness could be contingent on a clear demonstration of a loss in net exports (which we were unable to find with the available data). Without clear conditions such as these, it is difficult to distinguish legitimate assistance from rent seeking.

### Exemptions

When implemented elsewhere (notably in Europe), carbon taxes have often been accompanied with exemptions for certain sectors to shield them from the full impact of the carbon tax. Such exemptions have taken various forms, including complete exemptions such as Norway's exemption on coal use in the cement industry (Ekins and Speck 1999),

[13] Border tax adjustments are also the subject of a substantial literature, but are not explored here. These results indicate that border tax adjustments are unnecessary however.

conditional exemptions such as the UK's Climate Change Agreements and Levy (Martin et al 2011), and reduced tax rates which exist for most manufacturers subject to European carbon taxes (Ekins and Speck 1999). While such exemptions are politically popular, most economists consider them to be economically inefficient because they entail forgoing cost-effective opportunities to reduce carbon emissions. To achieve the same level of emission reductions, more costly activities need to be pursued. Bohringer and Rutherford (1997), as an example, estimate that sector exemptions are an extremely costly way to preserve employment in the exempted sector and Hoel (1996) shows that sector exemptions are inferior to other support mechanisms that governments can use.

Conventional economic wisdom suggests that the number of policy instruments should be equal to the number of policy goals. In the context of BC's carbon tax, there appear to be at least three goals facing policy makers—(1) improving environmental performance, (2) maintaining international competitiveness, and (3) maintaining employment or firm profitability when the carbon tax is implemented. Trying to address all three of these goals with a single policy (carbon tax with exemptions) is suboptimal and compromises efficiency across all goals. Instead, individual policies should be used to address each policy goal.

**Lump-Sum Rebates**

Sectoral rebates are an alternative form of compensation for affected sectors. Rebates can be unconditional (lump sum) or conditional. Lump-sum rebates are transfers from government to a firm's shareholders and should not create economic incentives or disincentives (of course, raising funds to provide the rebates can distort economic activity). In the current context, they would be used to support firms' profits during a transitory period when carbon taxation was applied, in a manner similar to the $100 Climate Action Dividend which was provided to households when BC's carbon tax was first implemented. Goulder et al (2010) estimate that to preserve firm profits following implementation of a carbon tax, a lump-sum transfer equivalent to about 15% of total carbon tax payments is adequate for energy-intensive firms in the United States. A 100% lump-sum rebate substantially overcompensates industries. Several market-based climate policies do provide substantial lump-sum rebates for participating sectors. For example, the European Union's Emission Trading System uses a lump-sum allocation of emission permits to industrial facilities, similar to the allocation system in the U.S. sulfur dioxide trading program. Importantly, a lump-sum rebate is not tied directly to a firm's current carbon emissions or fossil fuel use (or any other current-year variable)—this is what distinguishes it from an exemption. Instead, lump-sum rebates could be distributed on a per-firm basis (similar to the climate action dividend, which distributed revenue on a per-person basis) or based on historic emissions. In this way, the rebate functions purely as a transfer mechanism and does not influence firm decisions.

**Output-Based Rebates**

An alternative to lump-sum rebates are conditional rebates, in which rebates depend on a firm's performance. Fischer and Fox (2009) explore output-based rebates, where payments are calculated based on a measure of physical or economic output. A sector may receive a rebate which is some percentage of total carbon tax payments and distribution to firms within the sector is according to shares of physical output (e.g., tonnes of corn produced). This structure provides the firm with two incentives: first, because of the carbon tax, each firm faces an incentive to reduce emissions; and, second, because firms receive a subsidy contingent on their share of sector output, each firm faces an incentive to increase output. This structure helps to mitigate some of the negative impacts of the tax on "competitiveness." Simulations suggest that this type of rebating can be effective (Fischer and Fox 2007).

## CONCLUSIONS

Although the design of the carbon tax adopted in BC in 2008 appears to conform very closely to best practice, concerns remain over implementation. The carbon tax is unilateral and may provide incentives for carbon-intensive firms to shift production to other jurisdictions to avoid paying the tax. Partly in response to this concern, in its 2012 budget, the BC government offered a temporary (one-year) exemption to the greenhouse sector, which reported problems with international competitiveness as a result of the tax. In its 2013 budget, it made the exemption permanent (for 80% of total carbon costs) and expanded it to include all gasoline and diesel purchases from the agricultural sector.

Our aim in this paper is to evaluate the impact of the BC carbon tax on the international trade of the agricultural sector. We demonstrated that among highly traded sectors in BC, the agricultural sector has a fossil fuel intensity that is approximately average. Thus a simple theoretical model does not give an unambiguous prediction for whether the carbon tax would expand or contract net exports from the sector. Next, we estimated the effect of the carbon tax on agricultural exports using a panel data set, covering imports and exports of a number of agricultural commodities in each province in Canada over the 22-year period from 1990 to 2011. We control for time-varying factors that are similar for all provinces (world commodity prices, national tariffs, costs, and environmental policies in other countries), time-invariant factors that are specific to each province (comparative advantage) as well as weather. Our results do not conclusively reveal a connection between the carbon tax and agricultural trade. As a result, the exemptions from the carbon tax for the greenhouse sector, which were justified primarily based on concerns over international competitiveness, appear unnecessary and are not justified by available data.

To our knowledge, this analysis is the first to estimate the *ex post* effect of the BC carbon tax on a sector's performance. It is also the first to examine the consequences of an actual carbon tax on the agricultural sector. We believe that it is a useful initial study in a field that deserves more attention. In particular, this research was based on aggregate data. Using firm-level microdata, it would likely be possible to generate more precise estimates of the impact of the tax on firm performance, and to test other hypotheses relating to the causal impact of the tax. This is a fruitful avenue for future research.

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## APPENDIX

Table A1. Concordance for agricultural commodities

| Statistics Canada commodity (Table 002-0001) | Industry Canada commodity (HS Code) |
|---|---|
| Wheat | HS 1001 – WHEAT |
| Durum wheat | HS 1001 – WHEAT |
| Wheat, excluding durum, marketing board payments | HS 1001 – WHEAT |
| Durum wheat, marketing board payments | HS 1001 – WHEAT |
| Oats | HS 1004 – OATS |
| Oats, Canada Wheat Board payments | HS 1004 – OATS |
| Barley | HS 1003 – BARLEY |
| Barley, Canada Wheat Board payments | HS 1003 – BARLEY |
| Rye | HS 1002 – RYE |
| Flaxseed | HS 120400 – LINSEED |
| Canola, rapeseed | HS 1205 – RAPE OR COLZA SEEDS (WHETHER OR NOT BROKEN) |
| Soybeans | HS 1201 – SOYA BEANS, WHETHER OR NOT BROKEN |
| Corn | HS 1005 – CORN |

*(continued)*

Table A1. Continued

| Statistics Canada commodity (Table 002-0001) | Industry Canada commodity (HS Code) |
|---|---|
| Greenhouse vegetables | HS 07 – Edible Vegetables and Certain Roots and Tubers |
| Potatoes | HS 07 – Edible Vegetables and Certain Roots and Tubers |
| Vegetables | HS 07 – Edible Vegetables and Certain Roots and Tubers |
| Total tree fruits | HS 08 – Edible Fruits and Nuts |
| Apples | HS 08 – Edible Fruits and Nuts |
| Other tree fruits | HS 08 – Edible Fruits and Nuts |
| Total small fruits | HS 08 – Edible Fruits and Nuts |
| Blueberries | HS 08 – Edible Fruits and Nuts |
| Strawberries | HS 08 – Edible Fruits and Nuts |
| Grapes | HS 08 – Edible Fruits and Nuts |
| Other berries and grapes | HS 08 – Edible Fruits and Nuts |
| Floriculture | HS 06 – Live Trees and Other Plants (Incl. Cut Flowers and Ornamental Foliage) |
| Nursery | HS 06 – Live Trees and Other Plants (Incl. Cut Flowers and Ornamental Foliage) |
| Sod | HS 06 – Live Trees and Other Plants (Incl. Cut Flowers and Ornamental Foliage) |
| Cattle | HS 0102 & 0201 & 0202 – CATTLE |
| Calves | HS 0102 & 0201 & 0202 – CATTLE |
| Hogs | HS 0103 & 0203 – SWINE |
| Sheep | HS 0104 & HS0204 SHEEP AND GOATS |
| Lambs | HS 0104 & HS0204 SHEEP AND GOATS |
| Honey | HS 0409 – HONEY, NATURAL |

Table A2. Climate data and province concordance

| Province | Climate region |
|---|---|
| Newfoundland and Labrador | Atlantic Canada |
| Prince Edward Island | Atlantic Canada |
| Nova Scotia | Atlantic Canada |
| New Brunswick | Atlantic Canada |
| Quebec | Great Lakes/St. Lawrence |
| Ontario | Great Lakes/St. Lawrence |
| Manitoba | Prairies |
| Saskatchewan | Prairies |
| Alberta | Prairies |
| British Columbia | South BC Mountains |

## SUPPORTING INFORMATION

Additional Supporting Information may be found in the online appendix of this article: