Jobs and Climate Policy: Evidence from British Columbia's *Revenue-Neutral* Carbon Tax*

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Forthcoming in

Journal of Environmental Economics and Management[1]

Abstract

This paper examines the employment impact of British Columbia's revenue-neutral carbon tax implemented in 2008. While all industries appear to benefit from the redistributed tax revenues, the most carbon-intensive and trade-sensitive industries see employment fall with the tax, while clean service industries see employment rise. By aggregating across industries I find the BC carbon tax generated, on average, a small but statistically significant 0.74 percent annual increases in employment over the 2007-2013 period. This paper provides initial evidence showing how a revenue-neutral carbon tax may not adversely affect employment.

Key Words: Environmental regulation; carbon tax; employment; unilateral climate policy

JEL Codes: E24, H23, J2, Q5

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*Previous versions of this paper were circulated under the title "On the Employment Effects of Climate Policy: The Evidence from Carbon Tax in British Columbia." I am very grateful to my advisors, Jared C. Carbone and M. Scott Taylor, for their great supervision and invaluable advice. The paper also benefited from extensive discussions with Pamela Campa, Arvind Magesan, Kenneth J. McKenzie, Nicolas Rivers, Brandon Schaufele, Stefan Staubli, and Trevor Tombe. I also thank the editor and two anonymous referees, and seminar participants at CREE Annual Conference 2014, EEPRN 2nd Annual Research Symposium 2014, MEA Annual Meeting 2015, University of Calgary for their very helpful comments. All remaining errors are my own.

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[1]Accepted on Match 21st, 2017.

1. Introduction

Despite half a century of experience in Europe and North America with environmental regulations, their likely impacts are still heavily debated.[2] For example, many believe that such regulations could lead to substantial layoffs due to major adjustments or the shutdown of firms, and that these costs outweigh any potential environmental benefits. However, others believe that such regulations could strengthen the economy by creating more green jobs.[3] While both job gains and losses are, in fact, reported, understanding the relationship between environmental regulations and jobs is difficult because every regulation is unique in its design and impact.[4] To better inform policymakers and the public about the effect of environmental regulations on jobs, this paper examines the employment effect of the revenue-neutral carbon tax in British Columbia (BC).

On July 1st, 2008, BC implemented a carbon tax on the purchase of all fossil fuels. This policy intervention has several unique and useful characteristics that make it an ideal natural experiment with which to study its employment effect. First, the tax was implemented relatively quickly, specifically only five months after its announcement. This ruled out the possibility that polluters would adjust their behavior in anticipation of the regulation. Second, the tax coverage was comprehensive as the tax was levied on all sources of carbon emissions from all industries. This comprehensive industrial coverage allows me to identify both job gains and losses across industries in response to the regulation. Third, the tax rate was set relatively high, which provided a strong signal to polluters to change their behavior when the policy was introduced. Last, it was designed to be revenue-neutral, i.e., all the tax revenue raised went to the reduction of personal and

[2]Examples of the environmental regulations in the earlier years are the Clean Air Act of 1956 in the United Kingdom (Brimblecombe, 2006) and the Clean Air Act in the United States (see http://www.epa.gov/clean-air-act-overview).

[3]A definition of a green job is loosely defined as a job that contributes substantially to preserving or restoring environmental quality (United Nations Environment Programme, 2008).

[4]For example, the Cross-State Air Pollution rule, implemented in 2011, had eliminated 500 jobs in Texas (see http://dailycaller.com/2011/09/12/epa-regulation-forces-closure-of-texas-energy-facilities-eliminates-500-jobs/). Hundreds of miners have been laid off due to EPA's new clean power policy (see http://thehill.com/policy/energy-environment/238902-coal-company-lays-off-hundreds-blames-obama). On the other hand, green jobs have been created in green goods and services in the United States. Between 2010 and 2011, the construction sector created 100,000 green jobs (see http://www.huffingtonpost.com/2013/03/20/green-job-growth-2010-2011_n_2915737.html).

corporate income taxes and provided lump-sum transfers to low-income households. Recycling tax revenues could raise the income of BC residents and is an important part of the policy because it could stimulate the labor market in BC. Many researchers have argued that lowering the personal income tax reduces distortion in the existing tax system and raises labor supply, which is referred to as the double dividend hypothesis.[5] However, one must also realize that the employment impact could come from the demand side, especially when the corporate income tax was also lowered. Therefore, this policy feature allows me to discuss the possibility of a demand side story of the double dividend hypothesis.

My empirical strategy is motivated by a simple labor market model. The model illustrates that there are three channels through which a revenue-neutral carbon tax affects employment. First, the tax reduces labor demand due to a decrease in output, which I call an output effect. In a long-run competitive equilibrium, the tax increases marginal costs, shifting the perfectly horizontal supply curve upward and raising price. As a result, output declines. Such decline would be large if demand is highly elastic and production is emission-intensive. Second, redistributing tax revenues could positively affect both labor demand and supply, which I call a redistribution effect. Recycling tax revenues to lower personal income tax and provide lump-sum transfers could stimulate labor demand through increases in product demand. Product demand could rise due to the spending of redistributed tax revenue by BC residents, thus raising outputs. In addition, lowering corporate income tax (CIT) could also stimulate labor demand because it reduces the burden of CIT from labor in the form of higher wages. At the same time, recycling the revenues to lower the labor tax could reduce the distortion in the labor market, thus increasing the labor supply. Lastly, labor demand could increase if energy is easily substitutable with labor, which I call a factor substitution effect. Depending on the size of these offsetting factors, the employment effects could differ across industries, and an overall employment effect is ambiguous.

I used industry-level data to decompose the employment effect into the output and redistribution effect. As the output effect depends on both demand elasticity and emission intensity, I

[5] This is often called the employment dividend when the non-environmental dividend is an increase in employment alone (Carraro et al., 1996).

explicitly allowed the output effect to be estimated separately based on these factors. Lacking demand elasticity data, I proxy for the elasticity with trade intensity. This is because some argue that industries targeting world markets face relatively elastic demand while industries targeting mainly domestic markets face relatively inelastic demand.[6] The redistribution effect is estimated using constructed tax revenue data for BC, i.e., interacting the tax rate with BC's aggregate annual greenhouse gas (GHG) emissions. Using this strategy, the employment effect is estimated by a difference-in-difference estimator allowing for differential treatment intensity across industries. This method compares changes in employment for industries in BC with changes in employment for industries in the rest of Canada before and after the unilateral implementation of the carbon tax. To clearly identify the employment effect, I exploit the panel structure of data by including various fixed effects to control for possible unobserved confounding factors, such as commodity price shocks, provincial geographic characteristics, and industry factor intensities.

I find that the output effect negatively affects employment for all industries but differently based on emission and trade intensity while the redistribution effect positively affects employment for all industries. The most carbon-intensive and trade-sensitive industries see employment fall with the tax while clean service industries see employment rise. For example, at \$10/t carbon dioxide equivalent (CO_2e), the basic chemical manufacturing sector, one of the most emission-intensive and trade-exposed industries, experiences the largest decline in employment at 37 percent. On the other hand, the health care service sector, one of the clean and domestic industries, experiences the largest increase in employment at 18 percent.[7] By aggregating the employment effects across industries, I find the BC carbon tax generated, on average, a small but statistically significant 0.74 percent annual increase in employment over the 2007-2013 period.

Although a large number of studies in the literature have examined the relationship between

[6]For example, Desmet and Parente (2010) and Edmond et al. (2015) theoretically and numerically show that increases in the market size and competition by engaging in international trades reduce the markups and market share. As a result, price elasticity of demand increases. Pagoulatos and Sorensen (1986) empirically show that more openness to trade increases price elasticity of demand by the increases in competition and substitutes.

[7]This does not imply that when the tax rate reaches \$30/t CO_2, the size of employment effects would simply be three times as much. It does, however, mean that if the tax rate is set initially at \$30/t CO_2, the employment effects would be three times as much.

jobs and environmental regulations, especially during the 80's and 90's using simulation methods, most studies have mainly focused on pollution control regulations, such as the Clean Air Act (CAA) of the United States.[8] Only a handful of studies, such as Berman and Bui (2001) and Greenstone (2002), econometrically investigated this relationship. What is missing from this literature are more studies examining the employment effect of a climate policy. Thus far, only Martin et al. (2014) have investigated the effect of the UK's carbon tax, the Climate Change Levy (CCL), on manufacturing activities. Their results found no statistically significant impact of such tax on employment. This paper differs from Martin et al. in several ways. First, although the CCL is considered a carbon tax, the CCL and BC carbon tax are designed differently, especially in sectoral coverage and exemptions.[9] Second, this paper investigated the net effect of the carbon tax by considering many different sectors while Martin et al. only focused on the manufacturing sector. For these reasons, this paper provides new evidence for the relationship between jobs and environmental regulations by investigating the employment effects of the BC carbon tax.

This paper also contributes to the literature on double dividend by providing empirical evidence to support the employment dividend hypothesis. While all empirical studies in this literature have used simulation methods, this is the first study examining this hypothesis econometrically.[10] Bovenberg and Goulder (2002) argue that an environmental tax reform, i.e., recycling the revenue from an environmental tax to reduce the rates of other distortionary taxes, can increase employment. This hypothesis holds on the basis of two conditions: industries facing the tax are not exceptionally labor-intensive and revenue is recycled to lower the labor tax. Although this paper does not provide a direct empirical test of the employment dividend hypothesis, the BC carbon tax appears to generate an employment dividend because these conditions are satisfied for the case of the BC carbon tax. In addition, I investigate the effect of the BC carbon tax on provincial wages, and find that the tax has a statistically significant negative effect. This finding suggests that the

[8]To name a few, see Hollenbeck (1979), Environmental Protection Agency (1981), Bezdek et al. (1989), Wendling and Bezdek (1989), and Hazilla and Kopp (1990).

[9]The CCL is a per unit tax only on industrial energy use. A 90 percent discount on the tax rate is applied if a firm voluntary commits to an emission reduction target by participating in the Climate Change Agreement. Therefore, although the CCL is a national-level carbon tax, the coverage was quite limited.

[10]See Majocchi (1996) and Bosquet (2000) for a survey of empirical evidence.

increase in aggregate employment partly comes from the rightward shift of labor supply, which provides further evidence of the employment dividend.

Methodologically, this paper is closely related to Berman and Bui (2001) and Greenstone (2002). Both papers examined the employment effect of air pollution regulations by using a difference-in-difference approach. Berman and Bui analyzed the employment impact of the local air pollution regulation on the manufacturing sector in Los Angeles (LA).[11] They found a small increase (2,600 to 5,400) in employment over the 1979-1991 period. Greenstone investigated the employment effect of the Clean Air Act Amendments (CAAA) on the manufacturing sector in U.S. counties during the 1972-1987 period. His results showed that the regulation decreased employment by roughly 590,000.

Although these papers came to opposing conclusions, their results are consistent with my findings. Berman and Bui (2001) argued that one of the potential reasons for their small positive employment effects is that manufacturing plants in LA are not trade-intensive because their market is mainly local. Based on my simple model, this suggests that the negative output effect on labor demand is likely to be small for the LA manufacturing plants. On the other hand, I argue that the negative output effect for Greenstone (2002) might be large as the manufacturing plants across the entire U.S. are more trade-intensive. The key element that led to the different results between these two papers appears to be the difference in the degree of trade intensity in the manufacturing plants. Therefore, although these studies both focus on the manufacturing sector, it makes sense that their employment effects differ. The negative employment effects for BC's manufacturing industries in this paper also stem from their high trade intensity. Understanding the characteristics of sectors facing the regulation could help predict the outcome of future policies.

The rest of the paper proceeds as follows. Section 2 describes the details of the construction and the implementation of the BC carbon tax. Section 3 uses a simple model to identify the channels through which a revenue-neutral carbon tax affects employment. Section 4 contains my empirical analysis where I explain data and methodology, and provides results and robustness checks. Then

[11] To be precise, their region of interest is South Coast Air Basin, which includes Los Angeles County, Orange County, Riverside County, and the non-desert portion of San Bernardino County.

I discuss how the carbon tax affects provincial wages and provide support for the employment dividend in Section 5. Section 6 concludes. Finally, more formal treatment of the model, additional estimates, and robustness checks are presented in Online Appendix.

2. Overview of the BC Carbon Tax

On February 2007, Premier Gordon Campbell announced BC's new climate policy agenda in his throne speech (Harrison, 2012). The Liberal government, led by Premier Campbell, had previously undergone deep cuts to the environmental budget and supported offshore oil and gas exploration. The announcement came as a surprise to many, including members of his own party (Harrison, 2012). In October 2007, the Ministry of Finance publicly acknowledged that a carbon tax is under consideration, and officially announced the implementation in their budget plan in February 2008. The tax was implemented relatively quickly, specifically only five months after its announcement. Although the announcement of the tax took the public by surprise, polls indicated that 72 percent felt that the introduction of a carbon tax is a positive step (Duff, 2008). Others, including businesses and industry associations, worried about the adverse effects on their operational costs and requested tax relief or exemptions (Ministry of Finance, 2013). Overall, the implementation of the carbon tax has been supported by BC residents as the Liberal party has won the majority of seats in the 2009 and 2013 post-carbon tax elections.

The carbon tax is levied on the purchases of the carbon content of all fossil fuels in BC, including gasoline, diesel, natural gas, coal, propane, and home heating fuel (Ministry of Finance, 2008), from businesses in all industries and residents. Often some forms of exemptions are granted to protect the domestic economy, such as energy-intensive and trade-exposed industries. The exemption usually makes the tax relatively narrow-based. However, the BC carbon tax is considered to be broad-based because exemptions were initially applied to none of the industries.[12]

[12] This has been changed as of March, 2012. To protect agricultural industries, a carbon tax relief was granted to commercial greenhouse growers. A temporary relief of $7.6 million was provided in 2012, and then the relief program was made into a permanent program in 2013. As of January 1, 2014, the farmers are exempted from the carbon tax on the purchase of colored gasoline and colored diesel fuel used for farm purposes. For further information, see

According to the Budget and Fiscal Plan (Ministry of Finance, 2014), the carbon tax raised $1.1 billion revenue for 2012-2013 and is estimated to raise about $1.2 billion revenue for 2013-2014.[13] As the BC carbon tax is designed to be revenue-neutral, all the tax revenue raised goes to the reduction of personal and corporate income taxes and provides lump-sum transfers to low-income households (Ministry of Finance, 2008).[14] The personal income tax for the two lowest brackets was reduced by 2 percent in 2008 and 5 percent in 2009. BC has two types of corporate income tax, high and low. The high rate is for the businesses whose income is above $500,000 and the low is for the businesses whose income is below $500,000. Both of the corporate income taxes were reduced. The high rate was lowered to 11 percent in 2008, further down to 10.5 percent in 2010, and finally to 10 percent in 2011. The low rate was lowered to 3.5 percent in 2008, further down to 3 percent in 2010, and finally to 2.5 percent in 2011. These made BC's corporate and personal income taxes the lowest in Canada (Elgie and McClay, 2013).[15] In addition, the BC government provides a lump-sum credit to protect low-income households. A lump-sum of $100 per adult plus $30 per child is provided to single individuals whose income is below $30,000 or families whose income is below $35,000. Such lump-sum transfers are increased by 5 percent in 2009 and increased further by 10 percent in 2011.

Although the government had designed this policy to be a revenue-neutral carbon tax, tax credits have been exceeding tax revenues since its implementation. For example, the excess was $260 million in 2012-2013. This discrepancy stems from failing to accurately estimate the expected revenue from the carbon tax. How the revenues would be recycled is determined before the actual amount of revenue collected is known, thus keeping the policy exactly revenue-neutral is a difficult task. The estimated revenues have been lower than anticipated since the implementation due to the much higher decline in consumption of fossil fuels. Although the policy has been revenue-

http:www.gov.bc.ca/agri/.

[13] Although the tax revenues from the carbon tax are increasing since the implementation, such revenues account only for less than 1 percent of BC's total GDP each year.

[14] The carbon tax revenue also lowered school property taxes for land classified as farm and gave industries property tax credits (Rivers and Schaufele, 2014).

[15] In fact, BC has tied with Alberta and New Brunswick for the lowest corporate tax rate, and has had the lowest personal income tax rate in Canada, but for only those earnings up to $119,000.

negative, given that the excesses account only for less than 1 percent of BC's total tax revenue, I treat it as revenue-neutral in this analysis to be consistent with the intention of the BC government.

In the tax's initial year of 2008, the rate was set at \$10/t CO_2e from burning fossil fuels and scheduled to increase by \$5/t CO_2e annually until 2012. This means that the carbon tax would increase 2.41 cents per liter for gasoline, rising gradually to 7.24 cents a liter by 2012 (Ministry of Finance, 2008). The gradual increase of the tax rate allows consumers to adjust their fuel usage slowly and minimize the financial burden from the tax.

Only several years have passed since the implementation of the BC carbon tax, but there has already been a significant reduction in the use of fossil fuels and GHG emissions. A recent report (Elgie and McClay, 2013) showed that the per capita use of fossil fuels in BC has declined by 17 percent during the first four years following its implementation, which is 19 percent more than in the rest of Canada. Similarly, the per capita GHG emissions have declined by 10 percent in BC from 2008 to 2011. Thus far, the BC carbon tax appears to be fulfilling its purpose.

3. A Model of Jobs and Carbon Tax

In this section, I use a simple model to identify the channels through which a revenue-neutral carbon tax affects employment. The different channels are illustrated using simple diagrams, but a formal mathematical representation of the model is presented in Online Appendix.

To illustrate that the employment effect could differ across industries, two industries are considered under a long-run competitive equilibrium, industry A and industry B. Industry A is an energy-intensive industry facing relatively elastic demand while industry B is a clean industry facing relatively inelastic demand.

The model illustrates that there are three channels through which a carbon tax affects employment. First, a carbon tax reduces output of all industries by increasing the marginal cost, which I call an output effect. The size of such reduction would differ across industries based on energy intensity and demand elasticity. As the size of the increase in the marginal cost is proportional to

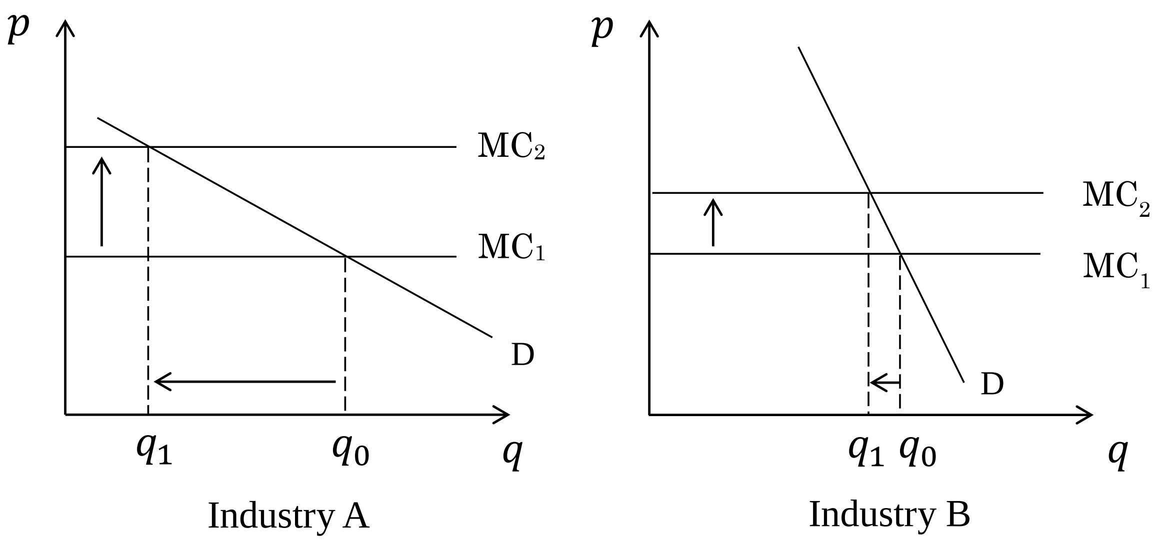

Figure 1: Negative Output Effects

Note: Figure 1 illustrates the reduction in output in response to a carbon tax, which I call an output effect. Industry A is an energy-intensive industry facing relatively elastic demand while industry B is a clean industry facing relatively inelastic demand. Due to these differences in factor intensity and demand elasticity, Industry A experiences a much larger decline in output than Industry B.

the share of energy use, the shift of the supply curve is much higher for industry A than industry B. This upward shift of the supply curve drives down output for both industries. Such reduction is much larger for Industry A than industry B due to its larger shift of the supply curve and flatter demand curve (Figure 1). The employment implication of this output reduction is what the public most worries about because labor demand declines as less employment is required to produce less output.

If this were the end of the story, a carbon tax would indeed be a job-killing climate policy as the public fears. However, there are two other channels that could positively affect employment. One is a redistribution effect. Redistributing the tax revenue from the carbon tax could increase both labor demand and supply. After such redistribution, consumers can spend the additional income on goods and services in both industries, which would increase demand for both industries.[16] Consequently, labor demand could increase as more labor is required to produce more to meet the increase in demand. In addition, lowering corporate income tax (CIT) could also stimulate labor

[16] The household income and consumption expenditure in British Columbia are strongly correlated. A naïve estimate of income elasticity for households in BC is about 1.1.

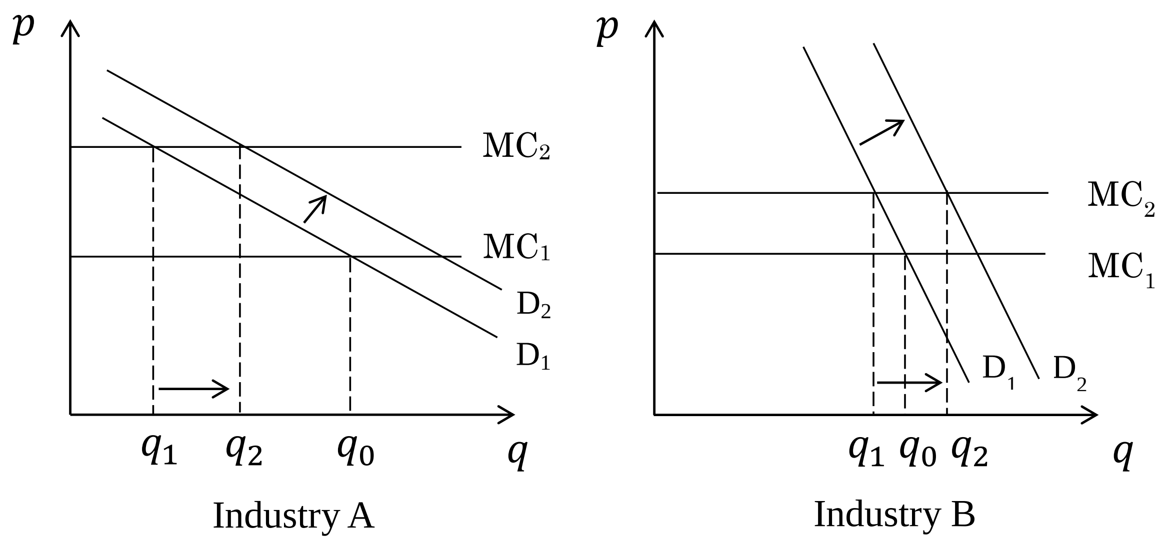

Figure 2: Positive Redistribution Effects

Note: Figure 2 illustrates the demand shift in response to the redistributed tax revenue. Such redistribution positively affects labor demand, and possibly offset the negative output effect shown in Figure 1. The increase in output for Industry A from the demand shift is not enough to outweigh the initial reduction, ($q_0 > q_2$), while it is enough to outweigh the initial reduction for Industry B, ($q_2 > q_0$).

demand because it reduces the burden of CIT from labor in the form of higher wages. In a small open economy, the incidence of CIT falls on labor when capital is mobile across regions (Kotlikoff and Summer, 1987). This is because capital would flee from a region with CIT, which lowers labor productivity and thus wages. Therefore, lowering CIT would shift labor demand curve outward. At the same time, the reduction of personal income tax by revenue-recycling could increase labor supply among BC residents because it reduces the distortion in the labor market, which is referred to as the employment divided hypothesis. The redistribution effect could thus increase employment through both an increase in labor demand and supply. The other is a factor substitution effect. If an industry can easily switch from energy to labor to lessen the tax burden, labor demand may increase. The larger the elasticity of the factor substitution is, the larger the positive effect on labor demand.

Depending on the size of these offsetting effects, the employment effect could differ across industries. In Figure 2, Industry A experiences a negative employment effect as the negative output effect outweighs the positive effects ($q_0 > q_2$). On the other hand, industry B experiences a positive

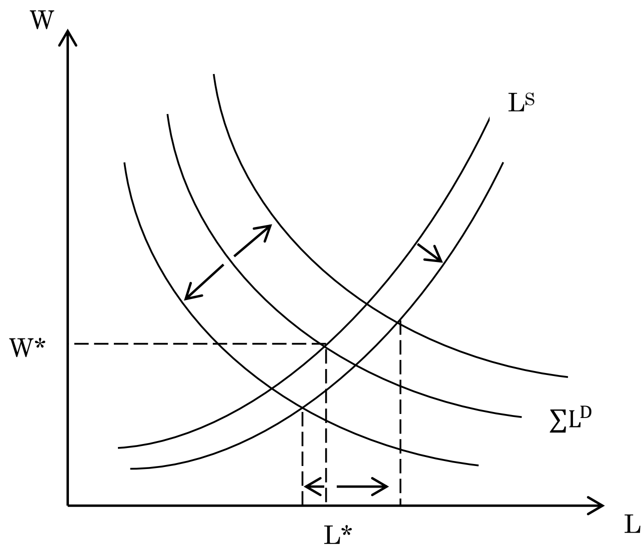

Figure 3: Aggregate Employment Effect

Note: Figure 3 illustrates the aggregate labor response to a carbon tax. Depending on the size of positive and negative labor demand responses across industries, aggregate labor demand could go either direction. Due to the reduction in personal income tax rates, labor supply is likely to be encouraged. Thus, aggregate employment effect in response to a carbon tax is ambiguous.

employment effect ($q_2 > q_0$).

Then adding these two employment effects together would determine the direction of the aggregate labor demand shift. However, it is ambiguous as the negative employment effect from industry A could easily be larger than the positive employment effect from industry B and vice versa. In addition, aggregate labor supply could shift to the right if the employment dividend hypothesis holds. Figure 3 illustrates the ambiguity of the aggregate employment effect of a revenue-neutral carbon tax. In sum, this simple model shows that it is difficult to determine how the carbon tax affects employment in BC a prior. Important factors that determine the sign of the employment effect are the output effect, redistribution effect, and factor substitution effect.

4. Empirical Analysis

I. Data Sources

To examine the employment effect of the BC carbon tax, annual data on employment, GHG emission intensity, and trade intensity are obtained from Statistics Canada.[17] The simple model illustrated that the output effect depends on energy intensity and demand elasticity. Lacking such data, I proxy for energy intensity with emission intensity based on the assumption that GHG emission intensity is proportional to energy intensity. I also proxy demand elasticity with trade intensity as the degree of trade-exposure is a good representation of demand elasticity.

Constructing the dataset requires manual merging as the industry classification used for employment and GHG emission intensity data is slightly different from the commodity classification used for trade intensity data. Table A.1 in Data Appendix documents the concordance between these two classifications. After merging data, 68 industries, 11 regions (9 provinces and 2 territories), and 13 years (2001-2013) are covered in the data.[18]

There are several potential concerns about data. First, Statistics Canada provides industrial GHG emission data only at national level and only from 1990 to 2008. On the contrary, employment data is available across industries for all provinces from 2001 to 2013. To make use of this limited data, an assumption is imposed — national GHG emission intensity level for each industry serves as a proxy for each industry in all provinces. While the emission intensity level might be different across provinces for each industry, the relative emission intensity level across industries within provinces is likely to be the same. For instance, a relatively dirty industry in Alberta, such as the oil and gas extraction, would also be a relatively dirty industry in other provinces. Therefore, GHG emission intensity data at the national level is sufficient.

[17] See Data Appendix for further details on the data construction.

[18] Québec introduced a carbon policy in 2007 as well; however, given that Québec's carbon tax rate is set at much lower rate, and its treatment of tax revenue differs from the BC carbon tax, I exclude it from the analysis. Two territories included in the data are Nunavut and Yukon. Industries are categorized based on the 2007 North American Industry Classification System (NAICS). They consist of 35 industries at 4-digit, 27 industries at 3-digit, and 6 industries at 2-digit NAICS.

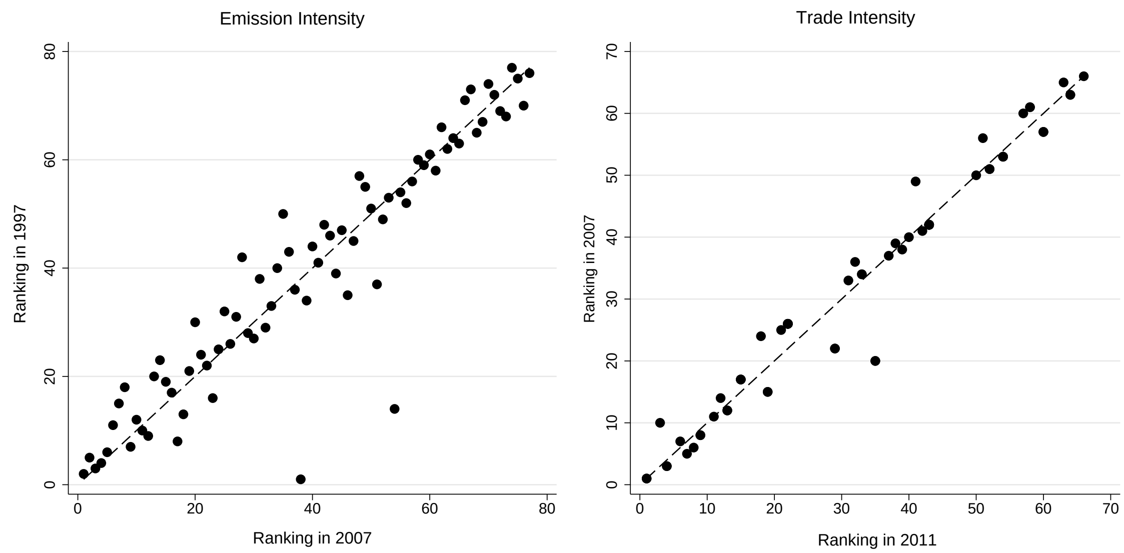

Figure 4: Emission Intensity & Trade Intensity Ranking

Note: Figure 4 plots the ranking of industry emission intensity (left) and trade intensity (right) in 1997 against the same ranking in 2007. Rank No.1 means the lowest intensity in the sample. If the relative intensities among industries are constant over time, the data would line up on the 45-degree line, shown as the dotted line. Except for a few outliers, emission intensity ranking in 1997 appears to be preserved in 2007. Similarly, trade intensity ranking in 2007 is maintained in 2011. These suggest that the relative intensities of emission and trade are fairly constant over time.
Source: Author's calculation.

To examine the employment effect of the carbon tax, only emission intensity variation across industries in the pre-carbon tax period is required. With data for more post-carbon tax years, one could examine an effect of the carbon tax on the level of GHG emissions. However, that is not the purpose of this study. GHG emission intensity is likely to decline in BC after the implementation of the carbon tax; yet, the relative emission intensity across industries is unlikely to change (i.e., a dirty industry will not suddenly become a clean industry solely due to the implementation of the carbon tax). Therefore, not having data for the post-carbon tax period is not problematic.

Second, trade intensity data is available by commodities, provinces, and years, but only covers the period from 2007 to 2011.[19] As trade intensity after 2008 is also likely to be affected by the carbon tax (i.e., trade intensity could be an outcome variable), only data from the pre-carbon tax period are used in the analysis. As for the GHG emission intensity, exploiting trade intensity

[19] The trade intensity data for 1997-2008 is available from Table 386-0002; however, this table does not provide information on a commodity classification ID, which makes the manual merging difficult. As Table 386-0002 and 386-0003 are not fully comparable, trade intensity data for prior to 2007 was not utilized in the analysis.

Table 1: Descriptive Statistics: 2001-2013

	Mean	Std. Dev.	Median
Overall (N = 4,181 , J = 68)			
Employment	24,787	61,548	5,880
Emission Intensity	0.55	1.21	0.108
Trade Intensity	0.577	0.277	0.58
British Columbia (N = 705, J = 57)			
Employment	25,027	45,375	6,416
Emission Intensity	0.554	1.07	0.119
Trade Intensity	0.6048	0.2947	0.727
Rest of Canada (N = 3,476, J = 68)			
Employment	24,738	64,339	5,646
Emission Intensity	0.549	1.242	0.108
Trade Intensity	0.5721	0.274	0.58

Note: N refers to the number of observations. J refers to the number of industries. There are 4,181 observations in total as not all provinces and territories have the same numbers of industries. And some years are missing from some of province × industry combinations, which makes the data unbalanced panel.

variation across industries and provinces at the pre-carbon tax period is sufficient for this analysis.

To justify the use of these data only from 2007, I ranked the industries in order of intensity over time and plotted them in Figure 4. If the relative intensities among industries are constant over time, the data would line up on the 45-degree line. Except for a few outliers, emission intensity ranking in 1997 appears to be preserved in 2007. Similarly, trade intensity ranking in 2007 is maintained in 2011. These suggest that the relative intensities of emission and trade are fairly constant over time.

There are several features of data worth mentioning from descriptive statistics, reported in Table 1 and Table 2. First, industry composition in terms of emission intensity is different between BC and the rest of Canada (ROC). Although emission intensity in the data is at the national level, there are differences in average emission intensity between these groups. Moreover, industries in BC seem more emission-intensive on average than ROC. Similarly, industries in BC are more trade-intensive than ROC. These patterns are shown in Table 1.

While these characteristics of BC industries may imply that the carbon tax might adversely

Table 2: Weighted Means of Emission and Trade Intensity

	Overall	Pre (2001-2007)	Post (2008-2013)
Emission Intensity			
BC	0.2000	0.2055	0.1937
ROC	0.2026	0.2047	0.2002
Trade Intensity			
BC	0.3422	0.3482	0.3351
ROC	0.3515	0.362	0.3393

Note: The weights are calculated using employment. Emission intensity is in tonnes per thousand dollars production. BC means British Columbia while ROC means rest of Canada.

affect employment in BC, that could be misleading because, for example, emission-intensive industries might be capital-intensive. In such case, the employment effect from the carbon tax might be small despite its high emission intensity. Therefore, to visualize how the carbon tax might affect employment, it is more informative to take into account the distribution of employment across industries in these intensities. That is, I calculated the employment-weighted means of emission and trade intensity, reported in Table 2. These suggest that in terms of employment, industries in BC are, in fact, dominated by less emission- or trade-intensive industries relative to ROC. Although industries in BC are more emission- and trade-intensive on average, having fewer workers in emission- or trade-intensive industries might lessen potential adverse employment effects of the carbon tax. These industry compositions in terms of emission and trade intensity are, indeed, important elements for determining the size of the employment effects of the carbon tax in the analysis.

II. Methodology

This section discusses the econometric design to estimate the employment effect of BC's revenue-neutral carbon tax. The simple model illustrated that the employment effects depend on three effects: the output effect, redistribution effect, and factor substitution effect. With available data, I attempt to separately estimate the output effect and redistribution effect as follows[20]:

$$\ln L_{ipt} = \beta_1(EI_i \times BC_p \times \tau_t) + \beta_2(Trade_{ip} \times BC_p \times \tau_t) + \beta_3(GHG_p \times BC_p \times \tau_t) + \delta_{it} + \eta_{ip} + \epsilon_{ipt} \tag{4.1}$$

where $\ln L_{ipt}$ is the natural log of employment for industry i in province p at time t.[21] Let EI_i be a GHG emission intensity level for industry i in 2007, $Trade_{ip}$ be trade intensity for industry i at province p in 2007, GHG_p be total GHG emissions in BC at 2007, BC_p be a dummy variable for BC, and τ_t be a carbon tax variable (i.e., 0 if t = pre-carbon tax period, 10 if $t = 2008$, 15 if $t = 2009$, ..., 30 if $t = 2012$, and 30 if $t = 2013$).[22] δ_{it} are industry-specific time fixed effects that control for industry-specific shocks at given year. Controlling for industry-specific shocks are particularly important as this will control for incidences such as the financial crisis, exogenous changes in prices of natural resources and commodities, and any shocks that are specific to industries but common across provinces. η_{ip} are industry-by-province fixed effects that control for time-invariant industry-by-province specific heterogeneity, as well as constant industrial and provincial characteristics such as industry factor intensities or province factor endowments.[23] Finally, ϵ_{ipt} is an error term that captures idiosyncratic changes in employment.

The first three interaction terms capture the employment effect of the BC carbon tax through different channels. The first interaction term measures the output effect through energy intensity. The second interaction term measures the output effect through demand elasticity. The third interaction term captures the redistribution effect. By interacting the carbon tax variable with BC's total GHG emission from 2007, a tax revenue variable is constructed to estimate the redistribution

[20] Factor substitution effect, discussed in the previous section, is excluded from this analysis for two reasons. First, data on elasticity of factor substitution is not readily available. Second, the time coverage in this paper is not long enough for industries to adjust employment by substituting their inputs.

[21] The natural log of employment is employed to remove the skewness in the distribution of employment. After the transformation, employment is approximately distributed normal.

[22] The use of $BC_p \times \tau_t$ to measure the stringency of the policy is inspired by Rivers and Schaufele (2014). They investigated an effect of the BC carbon tax on agricultural trade.

[23] $\mu_{ip} f(t)$, second-order polynomial industry-by-province specific time trends, are also included in (4.1) as a robustness check.

effect of the tax.[24]

In addition, using emission and trade intensity in the estimation is attractive because it allows me to discuss the employment effect of the carbon tax on emission-intensive and trade-exposed (EITE) industries. When environmental regulations are imposed, policymakers often worry that the financial burden from complying with the regulations falls harshly on EITE industries.[25] As the product price for EITE industries is determined at the world market, they are unable to mitigate the additional burden from the regulations by passing on the increased costs to consumers. As a result, the employment effect of the carbon tax for EITE industries might be largely negative.

The coefficients of interest are β_1, β_2, and β_3. In particular, the approximate percentage change in employment for industry i at time t in response to the carbon tax is calculated by $\alpha_{it} \equiv 100 \times (\hat{\beta}_1 EI_i + \hat{\beta}_2 Trade_{ip} + \hat{\beta}_3 GHG_p)\Delta\tau_t$.[26] The estimated coefficient $\hat{\beta}_1$ and $\hat{\beta}_2$ are estimated from across industry × province comparisons over time and $\hat{\beta}_3$ is estimated from across provincial comparisons over time. To properly estimate the employment effect, the underlying identification assumption requires that there be no factors other than the carbon tax creating differences in changes in employment between industries in BC and industries in other provinces. This assumption will be violated if the government of BC concurrently implements other policy induced by the carbon tax that affects all industries in BC differently while no other provinces implement a similar policy.

Another important identification assumption is the common trend. This assumption requires that the changes in employment for industries in BC (treatment group) and other provinces (control group) would follow the same time trend in the absence of the carbon tax. Although verifying this assumption is difficult, one can compare the mean employment growth rate in the pre-treatment

[24] In Online Appendix, I also estimate the redistribution effect ($\hat{\beta}_3$) of the carbon tax more directly using data on the actual amount of tax revenue rebated, reported in BC's budget plan. As the amount of rebate is potentially endogenous to labor supply decisions, using this variable in the estimation could be problematic. Therefore, the rebate variable is constructed as $GHG_p \times BC_p \times \tau_t$.

[25] For an example of U.S. Clean Air Act, see http://www.rff.org/Publications/Resources/Pages/The-Potential-Impact-on-Energy-Intensive-Trade-Exposed-176.aspx.

[26] As the estimation equation is in the semi-elasticity (log-linear) form, the exact percentage change in employment is calculated by $100 \times \left(e^{(\hat{\beta}_1 EI_i + \hat{\beta}_2 Trade_{ip} + \hat{\beta}_3 GHG_p)\Delta\tau_t} - 1\right)$.

Table 3: Mean Employment Growth in the Pre-treatment Period

	British Columbia	Rest of Canada	t-stats
Overall	0.11	0.08	0.34
2002	-0.31	0.11	-2.17*
2003	0.04	-0.09	0.74
2004	0.24	0.06	0.72
2005	0.23	0.03	1.06
2006	0.3	0.17	0.6
2007	0.18	0.21	-0.14

Note: Mean employment growth rates (%ΔlnL) from 2002 to 2007 are reported for both groups. A t-statistic from a t-test of a difference in mean employment growth rates between treatment and control group with unequal variance is reported in the last column. A null hypothesis is that the difference in group means is zero. This approach to test the common trend assumption is inspired by Martin et al. (2014). *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

period between BC and ROC. This allows me to check if there is a systematic difference in employment trends between these groups. This can be done by performing a t-test on the difference in mean employment growth rates during the pre-carbon tax period between BC and ROC (Table 3). The tests fail to reject the null hypothesis that the difference in group means is zero, suggesting that there is no significant difference in pre-treatment employment trends between the treatment and control group.

III. Results

The results are presented in the following subsections. The subsection A presents estimates of equation (4.1) and discusses heterogeneous employment effects across industries. In the subsection B, I construct a counterfactual based on the estimation in the first subsection to calculate the aggregate employment effect. Before I present the main results, I briefly explain and demonstrate the weakness of a conventional difference-in-difference estimator for estimating the effect of the BC carbon tax.

An alternative to equation (4.1), one can employ a conventional difference-in-difference esti-

Table 4: Conventional difference-in-difference estimations

lnL	(1)	(2)
D_{pt}	0.00945	0.00883
	(0.037)	(0.035)
N	4181	4181
R^2	0.734	0.802
Industry × time FE	Y	Y
Province FE	Y	
Industry × province FE		Y

Note: Dependent variable is log of employment. D_{pt} is a dummy variable for British Columbia after 2008, i.e., the post-carbon tax. Industry fixed effects are for 2-digit NAICSs. To account for serial correlations and within sub-industry correlations, standard errors are clustered by 3-digit NAICS industry × province, reported in parentheses. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

mator as follows:

$$\ln L_{ipt} = \beta D_{pt} + \delta_{it} + \eta_{ip} + \epsilon_{ipt} \tag{4.2}$$

where D_{pt} is a dummy variable for BC after 2008, i.e., the post-carbon tax, and the rests are defined as in equation (4.1). While this approach is intuitive and straightforward, it is difficult to isolate the effect for a causal interpretation. This is because the coefficient of interest β also captures other events happened in BC after 2008 that led to differences in employment between BC and ROC. Although some confounding factors will be captured by the fixed effects, any factors that are different across provinces and over time would bias the estimation. To mitigate this issue, I introduced more variations, motivated by my simple theory, in the treatment variable that are directly related to the carbon tax in equation (4.1).

Table 4 reports the results from estimating equation (4.2). Although the point estimates are not statistically different from zero, they suggest that the carbon tax increases employment, which is consistent with the finding discussed in the proceeding subsections.[27,28] Such consistent results, demonstrated by Table 4, suggest that equation (4.1) is reliable and adequate as it provides a more fruitful understanding of the employment effect of the BC carbon tax.

A. The Industry-Specific Employment Effect

The results of five specifications based on equation (4.1) are reported in Table 5. First two specifications include $EI_i \times BC_p \times \tau_t$ and $Trade_{ip} \times BC_p \times \tau_t$ separately before estimating the full specification. Third specification includes the full set of interaction terms and fixed effects based on equation (4.1). These estimates are estimated with clustered standard errors (clustered on industry × province).[29] For the robustness checks, industry-by-province time trends are included, reported in column (4) and (5) of Table 5.

$\hat{\beta}_1$ and $\hat{\beta}_2$ measure the heterogeneous employment effect of the carbon tax through the output effects across industries. The significant negative results suggest that the employment effects, indeed, differ across industries. The negative signs of $\hat{\beta}_1$ and $\hat{\beta}_2$ indicate that emission-intensive and trade-exposed (EITE) industries are most likely to experience a decline in employment due to the carbon tax. This is because their emission intensity and trade intensity are large enough that the combination of $\hat{\beta}_1 EI_i$ and $\hat{\beta}_2 Trade_{ip}$ exceeds $\hat{\beta}_3 GHG_p$, which makes α_{it} negative. Depending on the size of $\hat{\beta}_3$, clean and domestic industries see employment rise because of the opposite argument. This confirms the results from some earlier studies that emphasized the heterogeneous employment effects of environmental regulations across industries (Wendling and Bezdek, 1989; Hollenbeck, 1979; Hazilla and Kopp, 1990; Greenstone, 2002).

All specifications show statistically significant results. Referring back to the simple model in the previous section, the sign of the coefficients are consistent with the model predictions — there are negative employment effects through the output effect, and positive effects through the

[27] Lack of statistical significance in Table 4 could also be due to lack of variations in D_{pt} to precisely estimate the employment effect.

[28] Not only do the point estimates show the same sign, but also the magnitudes are also similar. Based on industry specific employment effects reported in Table 9, the average employment effect is 0.44% at \$10/t carbon tax. Then the average employment effect at the average tax rate is 0.96% (0.438 × 2.2).

[29] I also estimated with different cluster levels, such as province and industry. The results did not alter.

Table 5: Effects of the BC Carbon Tax on Employment

lnL	(1)	(2)	(3)	(4)	(5)
$EI_i \times BC_p \times \tau_t$ (β_1)	-0.0098**		-0.0098**	-0.013***	-0.014***
	(0.004)		(0.0038)	(0.0044)	(0.0045)
$Trade_{ip} \times BC_p \times \tau_t$ (β_2)		-0.020**	-0.020**	-0.063**	-0.083**
		(0.0096)	(0.010)	(0.025)	(0.034)
$GHG_p \times BC_p \times \tau_t$ (β_3)	0.0814*	0.187**	0.263**	0.647***	0.799**
	(0.044)	(0.092)	(0.102)	(0.235)	(0.322)
N	4,181	4,181	4,181	4,181	4,181
R^2	0.80	0.80	0.80	0.81	0.81
Industry × province trends				Y	Y
Industry × province trends sq					Y

Note: Dependent variable is log of employment. EI_i is a GHG emission intensity level for industry i in 2007; $Trade_{ip}$ is trade intensity for industry i at province p in 2007; GHG_p is total GHG emissions in BC at 2007; BC_p is a dummy variable for British Columbia; τ_t is a carbon tax variable (i.e., 0 if t = pre-carbon tax period, 10 if $t = 2008$, 15 if $t = 2009$, ..., 30 if $t = 2012$, and 30 if $t = 2013$). All specifications include industry by time fixed effects and industry by province fixed effects. Industry fixed effects are for 2-digit NAICSs. To account for serial correlations and within sub-industry correlations, standard errors are clustered by 3-digit NAICS industry × province, reported in parentheses. The main specification is shown in column (3) while results in column (4) and (5) are shown as robustness checks.
*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

redistribution effect.

These results suggest that increases in either emission or trade intensity (or even both) lead to a decline in employment in response to the carbon tax. For example, a 10 percent increase in these intensities from their mean (0.51 and 0.58, respectively) leads to a decline in employment by 0.5 and 1.2 percent with a \$10/t CO_2e carbon tax. These results imply that changes in trade intensity in response to the carbon tax would have larger effects on employment than changes in emission intensity. On the contrary, increases in the level of redistributed tax revenues positively affect employment ($\hat{\beta}_3$). Every billion dollar returned to residents of BC increases provincial employment by 26 percent (column 3). To put it differently, as average annual tax returns over the post-carbon tax period is roughly \$1 billion, a 10 percent increase from such average would lead to a 2.6 percent increase in employment. This suggests the possibility of the employment dividend from

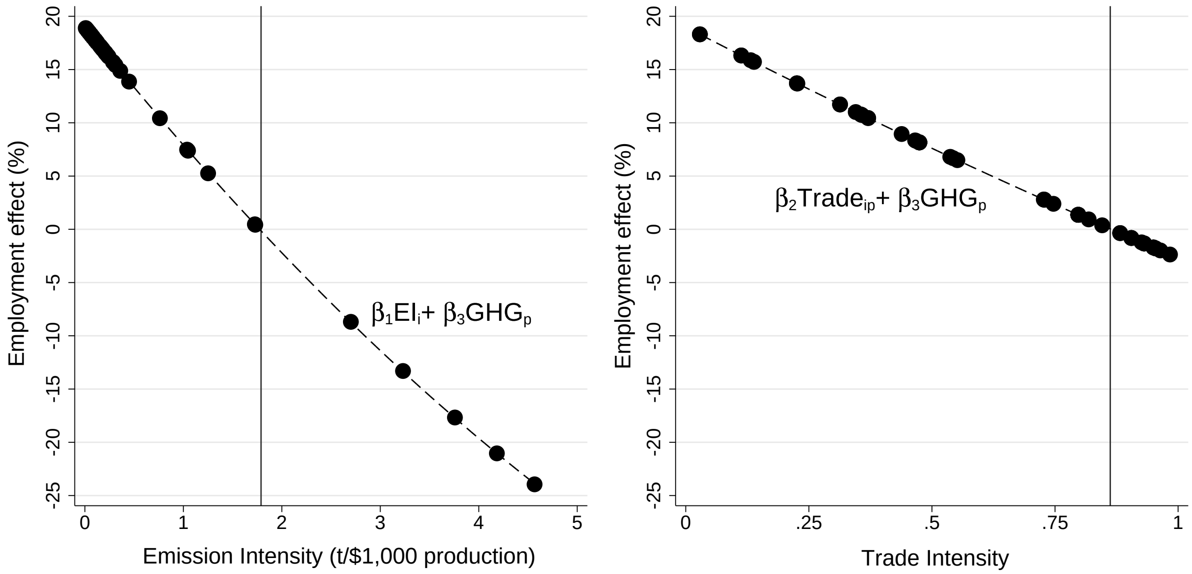

Figure 5: Industry Specific Employment Effects vs. Emission Intensity and Trade Intensity

Note: Figure 5 plots the industry specific employment effects against emission (left) and trade intensity (right). The vertical solid lines indicate the threshold of emission and trade intensity that make the employment effect positive or negative. For an industry whose emission intensity is larger than 1.77 tonnes per thousand dollars production, the employment effect would be negative if the industry trades at all. Similarly, for an industry whose trade intensity is larger than 0.87, the employment effect would be negative if the industry emits emission at all.
Source: Author's calculation.

the BC carbon tax, although I cannot determine whether this increase in employment is coming from the demand side or supply side. The size of redistribution effect varies across first three specifications. This is because when one of the heterogeneous output effect ($\hat{\beta}_1$ or $\hat{\beta}_2$) is excluded, the redistribution effect absorbs what is left out of the estimation. Thus, to clearly understand the possible channels, it is important to include them all together. Yet, column (1) and (2) emphasize that channels through emission intensity and demand elasticity are important.

To interpret these coefficients of interest together, the sign and size of employment effects (i.e., the value of α_{it}) are calculated for each industry based on the coefficients from column (3). The sign of α_{it} depends on the relationship between the output and redistribution effects. For an industry whose trade intensity is larger than 0.87, the employment effect would be negative if the industry emits emission at all (i.e., emission intensity > 0) because the negative output effect exceeds the positive redistribution effect. Similarly, for an industry whose emission intensity is larger than 1.77 tonnes per thousand dollars production, the employment effect would be negative if the industry trades at all. Figure 5 illustrates these thresholds and also that employment effects are a decreasing function of both emission intensity and trade intensity.

These results suggest that trade-intensive industries would always see employment fall because the emission intensity level is strictly positive for all industries in the sample. On the other hand, emission-intensive industries could see employment rise if they are not trade-intensive. For example, even though emission intensity for the forestry and logging sector is 0.76, which is above the mean and relatively emission intensive, its employment effect is positive (7.4 percent at $10/t CO_2e) as its trade intensity is only 0.14 in BC.[30] In addition, EITE industries would certainly see employment fall because their emission and trade intensity exceed the thresholds. The percentage changes in employment in response to the carbon tax at $10/t CO_2e for all the industries are reported in Table 9, and the corresponding scatter plot with 95 percent confidence intervals is presented in Figure 8.[31]

Based on the estimation for each industry, the results for many industries are statistically significant. For example, the basic chemical manufacturing sector, one of the EITE industries, experiences the largest decline in employment at 37 percent. On the other hand, the health care service sector, one of the clean and domestic industries, experiences the largest increase in employment at 18 percent.

B. The Aggregate Employment Effect

To discuss the aggregate employment effect of the BC carbon tax, the change in employment in response to the tax is first calculated for each industry. The aggregate employment effect is the sum of these changes in employment across industries. These calculations involve constructing

[30] Here I assume that a $1 increase in the tax at any given year would have the same employment effects in size. In Online Appendix, I also estimate the time path of the employment effects, which allows the size of employment effects to vary over time.

[31] To calculate a standard error of α_{it} for each industry, the equation (4.1) is transformed. For example, to calculate a standard error for the coal mining industry, I transform the equation (4.1) as $\ln L_{ipt} = \beta_1(EI_i - EI_{\text{coal}})(BC_p \times \tau_t) + \beta_2(Trade_{ip} - Trade_{\text{coal, BC}})(BC_p \times \tau_t) + \alpha_{\text{coal}}(BC_p \times \tau_t) + \text{Fixed effects} + \epsilon_{ipt}$ where $\alpha_{\text{coal}} = \beta_1 EI_{coal} + \beta_3 Trade_{coal,BC} + \beta_3 GHG_{BC}$. This transformation allows the standard error of α_{coal} to be calculated directly.

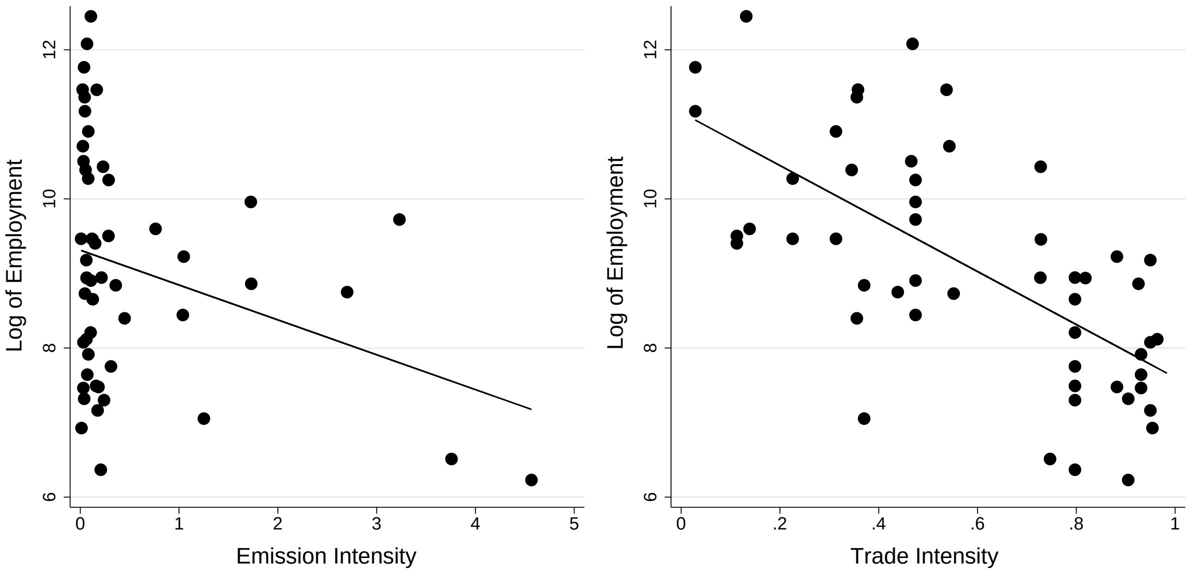

Figure 6: Correlations between Emission/Trade Intensity and Employment

Note: A scatter plots show the relationship between log of employment and emission/trade intensity. The solid lines are the fitted lines. The data shows a negative correlation between these intensities and employment.
Source: Author's calculation.

counterfactual employment — calculating the level of employment in the absence of the carbon tax.[32] Comparing the counterfactual employment with the observed employment in the sample yields the employment effect of the carbon tax.

To visualize the employment effects, Figure 9 plots the changes in employment for all industries at \$10/t CO_2e. The air transportation sector experiences the largest reduction in employment (roughly 2,000 job losses) whereas the retail trade sector experiences the largest increase in employment (roughly 17,000 job gains). These suggest that the positive employment effect of 15 percent for the retail trade sector leads to employment gains by 17,000. On the contrary, the negative employment effect of 21 percent for the air transportation sector leads to employment losses by 2,000. Even though the negative effect (21 percent) is larger in the absolute value than the positive effect (15 percent), the size of the employment increases is almost eight times as large

[32]The counterfactual log of employment is equal to the observed log of employment minus the estimated impact of the carbon tax, i.e., $\ln L_{ipt} - (\hat{\beta}_1 EI_i + \hat{\beta}_2 TI_{i,p} + \hat{\beta}_3 GHG_p)\overline{\Delta\tau_t}$ where $\overline{\Delta\tau_t}$ is the average tax increment. Then the counterfactual employment is calculated simply by taking exponent of the counterfactual log of employment. This approach is inspired by Nunn and Qian (2011).

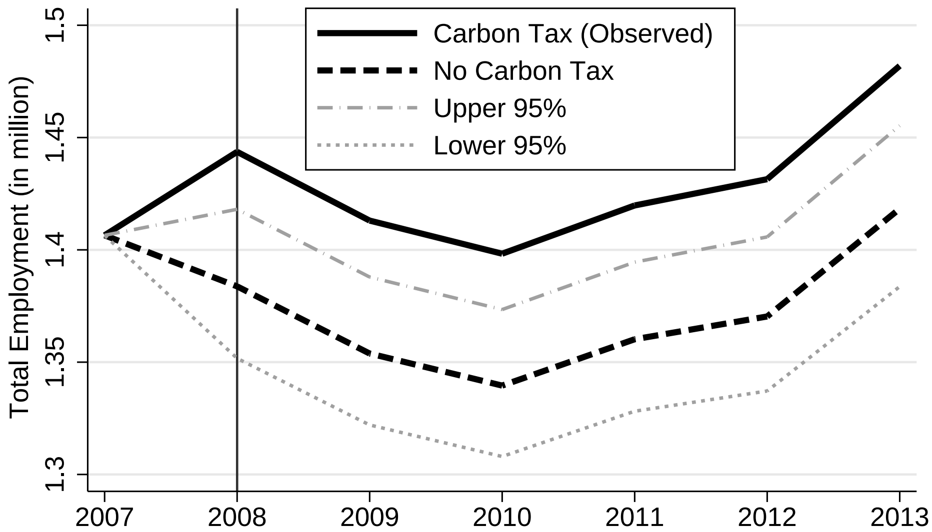

Figure 7: Changes in Aggregate Employment for British Columbia

Note: Figure 7 plots the annual trend in aggregate employment without the carbon tax, shown as the solid dotted line. Such conterfactual employment is compared with the observed aggregate employment, shown as the solid line. The vertical solid line indicates the implementation year for the carbon tax.
Source: Author's calculation.

as that of the employment decreases. This could reflect the fact that emission-intensive industries and trade-intensive industries are less labor-intensive. In fact, the data indeed shows a negative correlation between these intensities and employment (Figure 6). Therefore, the relatively large negative employment effects lead to small reductions in employment while the relatively small positive employment effects lead to large increases in employment. This explanation is consistent with Berman and Bui (2001) and Bovenberg and Goulder (2002), who find that the positive employment effect is possible if the regulatory burden falls disproportionally on capital-intensive industries with relatively little employment (i.e., less labor-intensive industries).

Finally, by summing the counterfactual employment across industries, the annual trend in aggregate employment without the carbon tax is plotted in Figure 7.[33] The observed aggregate employment has increased by 75,000 (5.3 percent) between 2007 and 2013 while the counterfactual

[33]Figure 7 also plots the lower and upper 95 percent confidence interval for the counterfactual aggregate employment trend. As these bounds are calculated using 95 percent confidence intervals for $\hat{\beta}_1$, $\hat{\beta}_2$, and $\hat{\beta}_3$, the reader should note that these bounds are not technically confidence interval for the counterfactual aggregate employment in BC. Yet, it provides a reasonable bound for the counterfactual aggregate employment trends.

aggregate employment has increased by 12,000 (0.85 percent) during the same period. Therefore, the BC carbon tax generated an average of 0.74 percent (roughly 10,000 jobs) annual increases in employment over these six years, a 4.5 percent increase overall.[34] Therefore, the overall employment effect of the BC carbon tax is positive. This means that increases in employment in cleaner industries who face relatively inelastic demand exceeded declines in employment in dirty industries who face relatively elastic demand.

IV. Robustness Checks

This paper has attempted to estimate the causal effect of BC's revenue-neutral carbon tax on employment. Even with a perfect econometric design, non-experimental research might be vulnerable to unobserved variations that could confound the causal interpretation. To ensure the reliability of the estimates, I probed the robustness of the estimates in many different ways, but found little evidence that undermines the results reported in the previous section.[35]

Firstly, I re-estimated equation (4.1) by including Québec (QC) in the sample to investigate how sensitive the results are to the different samples.[36] The results are reported in Table 6. All the specifications include industry × time fixed effects and industry × province fixed effects. The results reported in column (1) are taken from column (3) in Table 5, and serve as a benchmark. The rest of the results, reported in column (2) through (4), should be compared to the benchmark.

In this analysis, I first include QC in the sample as an additional province in the control group, reported in column (2). Then QC is included in the treatment group along with BC, reported in column (3). QC implemented its carbon tax in 2007 at the rate of \$3.50/t CO_2e, but it was not revenue-neutral. Finally, column (4) reports separate estimates of the BC and QC carbon taxes.

[34] The upper and lower bounds suggest that the average annual increase in employment ranges from 4,000 to 16,000 (0.3 percent to 1.1 percent, respectively).

[35] In Online Appendix, I also performed a placebo test, treating one of non-BC provinces as a pseudo treatment group. Of twenty-one coefficients (three coefficients for seven provinces), four are statistically significant at 1 percent, two are significant at 5 percent, and one is significant at 10 percent. However, in contrast to BC, no province had a pattern of sign and significance in line with the model except Ontario.

[36] Ideally, I would like to also include Alberta as one of the carbon tax provinces for another robustness check. However, Alberta's carbon tax is only for firms that emit more than 100,000 tonnes. With industry-level data, I cannot appropriately estimate the employment effect.

Table 6: Estimating the Employment Effects of the Carbon Tax with Different Samples

lnL	(1)	(2)	(3)	(4)
$EI_i \times \mathrm{CT}_p \times \tau_t$	-0.0098**	-0.0097**	-0.0118***	
	(0.0038)	(0.00375)	(0.0038)	
$\mathrm{Trade}_{ip} \times \mathrm{CT}_p \times \tau_t$	-0.0201***	-.0186*	-0.0223**	
	(0.00998)	(0.0095)	(0.0096)	
$EI_i \times BC_p \times \tau_t$				-0.01***
				(0.0037)
$\mathrm{Trade}_{ip} \times BC_p \times \tau_t$				-0.0193**
				(0.0095)
$GHG_p \times BC_p \times \tau_t$	0.263**	0.256***	0.3***	0.251***
	(0.102)	(0.0976)	(0.095)	(0.0967)
$EI_i \times QC_p \times \tau_t$				-0.0743***
				(0.022)
$\mathrm{Trade}_{ip} \times QC_p \times \tau_t$				-0.0124
				(0.0338)
N	4,181	5,284	5,284	5,284
R^2	0.803	0.797	0.797	0.799
Carbon Tax	BC	BC	BC & QC	BC & QC
Sample	Exclude QC	All	All	All

Note: Dependent variable is log of employment. $\mathrm{CT}_p = 1$ if $p \in$ Carbon tax province. QC_p is a dummy variable for Québec. All specifications include industry × time FEs and 2-digit NAICS industry × province FEs. To account for serial correlations and within sub-industry correlations, standard errors are clustered by 3-digit NAICS industry × province, reported in parentheses. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

These results suggest that the inclusion of QC in the sample does not affect the analysis of the employment effect of the BC carbon tax. Even with QC in the sample, the sign and significance of the parameters of interest are maintained. One interesting result occurred when the BC and QC carbon taxes are evaluated separately: the QC carbon tax does not appear to affect employment (at least through the negative output effect caused by the demand response to the price increase). A potential reason is that the QC carbon tax rate is much smaller than the BC carbon tax. This could imply that setting the tax rate is important for designing the future policy.

One concern about estimating the employment effect using equation (4.1) is that the third interaction term (β_3) is estimated only by provincial variations over time. There might be omitted

Table 7: Estimating the Employment Effects of the Carbon Tax with Additional Controls

lnL	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$EI_i \times BC_p \times \tau_t$ (β_1)	-0.00981**	-0.00978**	-0.00978**	-0.0098**	-0.00982**	-0.0098**	-0.00979**
	(0.00382)	(0.00382)	(0.00382)	(0.00382)	(0.00382)	(0.00382)	(0.00382)
$Trade_{ip} \times BC_p \times \tau_t$ (β_2)	-0.0201**	-0.0199**	-0.0199**	-0.0199**	-0.02**	-0.02**	-0.0199**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$GHG_p \times BC_p \times \tau_t$ (β_3)	0.265**	0.260**	0.264**	0.270***	0.279***	0.268***	0.264**
	(0.103)	(0.103)	(0.103)	(0.103)	(0.103)	(0.103)	(0.102)
Controls							
ln(inflow of migration)	Y	Y	Y	Y	Y	Y	
ln(outflow of migration)	Y	Y	Y	Y	Y	Y	
ln(population)		Y		Y		Y	Y
ln(working-age population)			Y	Y		Y	Y
Share of working-age population					Y	Y	Y
N	4,181	4,181	4,181	4,181	4,181	4,181	4,181
R^2	0.803	0.803	0.803	0.803	0.803	0.803	0.803

Note: Dependent variable is log of employment. All specifications include industry × time FEs and 2-digit NAICS industry × province FEs. To account for serial correlations and within sub-industry correlations, standard errors are clustered by 3-digit NAICS industry × province, reported in parentheses. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

variables that could contribute to the differences in employment trends between BC and the rest of Canada (ROC). For example, employment in BC seems to be increasing in response to the carbon tax; however, this could simply be because population (or working-age population) in BC is growing faster than ROC. Another concern is that there might be differences in job creation and job reallocations across provinces. If workers are moving across provinces in response to the carbon tax, this would either overstate or understate the estimation. To deal with these two concerns, I included province- and time-varying factors in equation (4.1) as controls. The results are reported in Table 7. These results suggest that even after taking account for potential omitted variables, β_3 is credibly estimated as the point estimates stayed positive and highly significant.

5. Wage Effect and the Employment Dividend

The positive aggregate employment effect could arise from a rightward shift of either labor demand or labor supply. If the positive employment effect is solely due to the rightward shift of the aggregate labor demand curve, the equilibrium wage should rise. On the other hand, if it is solely due to the rightward shift of the aggregate labor supply curve, the wage should fall. Of course, it could also be due to the shift of both curves. In this case, the direction of the wage effect is ambiguous.

To test the wage effect of the BC carbon tax, I collected data on average hourly and weekly wages and fit them to the following estimation equation:

$$\ln \text{Wage}_{ipt} = \beta(BC_p \times \tau_t) + \delta_{it} + \eta_{ip} + \epsilon_{ipt} \tag{5.1}$$

where $\ln \text{Wage}_{ipt}$ is the natural log of either hourly or weekly wage for industry i in province p at time t and all other variables are defined as in the previous section.[37] β is the parameter of interest and captures the wage effect of the BC carbon tax.

Estimates of equation (5.1) are reported in Table 8. These results suggest that the imposition

[37] See Data Appendix for further details on the data source.

Table 8: Effects of the Carbon Tax on Wages

ln(Wage)	(1) Weekly	(2) Hourly
$BC_p \times \tau_t$	-0.0016***	-0.0018***
	(0.00025)	(0.00024)
N	4,459	4,459
R^2	0.985	0.983

Note: Dependent variable is log of wage. Both specifications include industry × time FEs and 2-digit NAICS industry × province FEs. To account for serial correlations and within sub-industry correlations, standard errors are clustered by 3-digit NAICS industry × province, reported in parentheses. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

of the BC carbon tax has a statistically significant negative effect on provincial wages. It reduces average hourly and weekly wages by 1.8 and 1.6 percent at the rate of \$10/t CO_2e, respectively.

Although the results might be biased due to the omitted variables that cannot be controlled by fixed effects, the significant negative wage effect suggests that BC's revenue-neutral carbon tax appears to generate the employment dividend. With the positive aggregate employment effect, wages would only decline due to the increase in labor supply. If the carbon tax also shifts the aggregate labor demand curve, wages would fall when the increase in labor supply is sufficiently large. When labor demand rises, wages fall only if the increase in labor supply is larger than labor demand. On the contrary, wages fall without a shift of labor supply when labor demand falls. However, without the shift of labor supply, the aggregate employment would fall, which is inconsistent with the aggregate positive employment effect estimated in this paper. Therefore, the labor supply would have to rise sufficiently as well to ensure the positive aggregate employment effect. In sum, the combination of the positive aggregate employment effect and negative wage effect suggest that the BC carbon tax positively affects labor supply. Although this is not a direct empirical test of the employment dividend, this provides sensible evidence for the employment dividend hypothesis.

6. Conclusion

This paper provides new evidence that a revenue-neutral carbon tax can positively affect provincial employment. The existing literature provides mixed findings on how an environmental regulation affects employment in a regulated region, and particularly lacks evidence on the employment impact of a climate policy.

This paper found that in response to the BC carbon tax, employment declines in emission-intensive and trade-exposed industries while employment rises in clean service industries. The employment impacts differ across industries due to the difference in the output effect and redistribution effect of the tax. Employment falls in industries whose negative output effect outweighs their positive redistribution effect. The negative output effect tends to be large in emission- and/or trade-intensive industries, resulting in the negative employment effect.

By aggregating the employment effects across industries, the overall employment effect of the BC carbon tax appears to be positive. The positive employment effects outweigh the negative employment effects because labor-intensive industries experience job gains. The results from the preferred specification suggests that the BC carbon tax generated, on average, a small but statistically significant 0.74 percent (roughly 10,000 jobs) annual increases in employment over the 2007-2013 period, a 4.5 percent increase overall.

I also investigated the effect of the BC carbon tax on provincial wages, and found that the tax had a statistically significant negative effect. This suggests that the increase in aggregate employment partly comes from the rightward shift of labor supply, which provides support for the employment dividend hypothesis.

Although these estimates are not outcomes of randomized experiments, they provide fairly robust evidence that a revenue-neutral carbon tax does not adversely affect employment in a regulated region. The latest report (Elgie and McClay, 2013) claimed that the implementation of the carbon tax did not have any apparent adverse impact on BC's economy. This paper adds another perspective to the evaluation of the BC carbon tax because the report only focused on the impact to

BC's GDP. To my knowledge, this paper is the first to provide the ex-post empirical evaluation of a revenue-neutral carbon tax. As the structure of a carbon tax can take many different forms in terms of the rate, the coverage of tax-base, and the treatment of the tax revenue, empirical investigations of a carbon tax in other regions would bring fruitful contributions to the literature.

Table 9: Industry specific employment effects at $10/t CO_2e

NAICS	Industry	α (%)
113	Forestry and logging	7.39
2122	Metal ore mining	-4.33
211	Oil and gas extraction	-2.3
213	Support activities for mining and oil and gas extraction	6.63*
2211	Electric power generation, transmission and distribution	-24.56*
3111	Animal food manufacturing	-0.68
3113	Sugar and confectionery product manufacturing	-1
3114	Fruit and vegetable preserving and specialty food manufacturing	-1.68
3115	Dairy product manufacturing	-0.22
3116	Meat product manufacturing	0.12
3117	Seafood product preparation and packaging	0.32
311A	Miscellaneous food manufacturing	-0.75
31A0	Textile and textile product mills	-3.38
31B0	Clothing and leather and allied product manufacturing	-2.01
321	Wood product manufacturing	0.49
3221	Pulp, paper and paperboard mills	-10.08***
3222	Converted paper product manufacturing	-2.14
323	Printing and related support activities	6.01**
324	Petroleum and coal product manufacturing	-29.15***
3251	Basic chemical manufacturing	-36.61***
3254	Pharmaceutical and medicine manufacturing	-1.2
325A	Miscellaneous chemical product manufacturing	-1.85
3261	Plastic product manufacturing	-0.43
327	Non-metallic mineral product manufacturing	-16.4**
331	Primary metal manufacturing	-16.64***
332	Fabricated metal product manufacturing	1.53
333	Machinery manufacturing	-2.29
3341	Computer and peripheral equipment manufacturing	-1.91
334A	Electronic product manufacturing	-1.95
335	Electrical equipment, appliance and component manufacturing	-2.58
3362	Motor vehicle body and trailer manufacturing	-2.01
3364	Aerospace product and parts manufacturing	-1.63
3366	Ship and boat building	-2.12
337	Furniture and related product manufacturing	2.15
339	Miscellaneous manufacturing	0.29
41	Wholesale trade	5.07*
4A	Retail trade	14.66**
481	Air transportation	-21.2**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

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NAICS	Industry	α (%)
482	Rail transportation	-2.3
484	Truck transportation	-8.68*
48B0	Transit, ground, scenic and sightseeing passenger transportation	5.16*
493	Warehousing and storage	7.03**
51	Information and cultural industries	6.4**
5A01	Depository credit intermediation and monetary authorities	10.43**
5241	Insurance carriers	11.63***
5A06	Other finance, insurance and real estate	10.83**
5311	Lessors of real estate	13.12**
5A05	Rental and leasing services	14.62**
541	Professional, scientific and technical services	10.46***
561	Administrative and support services	10.3**
562	Waste management and remediation services	6.01*
6113	Universities	12.82**
611A	Educational services (except universities)	12.39**
622	Hospitals	17.76**
62A0	Health care services (except hospitals) and social assistance	17.87**
71	Arts, entertainment and recreation	8**
72	Accommodation and food services	7.57**

*** Significant at the 1 percent level
** Significant at the 5 percent level
* Significant at the 10 percent level

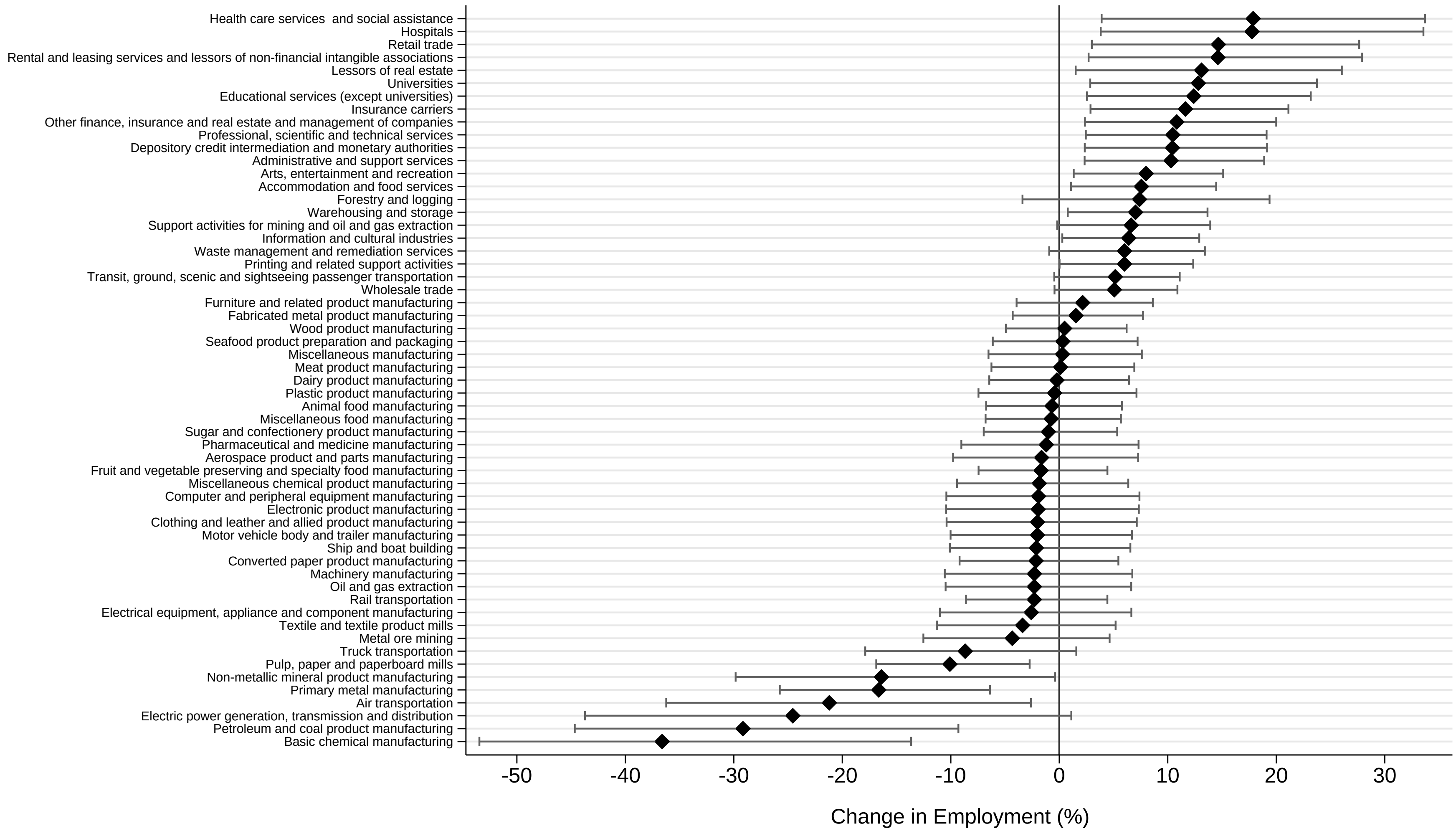

Figure 8: Industry Specific Employment Effects with 95% C.I.

Note: Figure 8 plots the industry specific employment effects, shown in Table 9, with their corresponding 95 percent confidence interval.
Source: Author's calculation

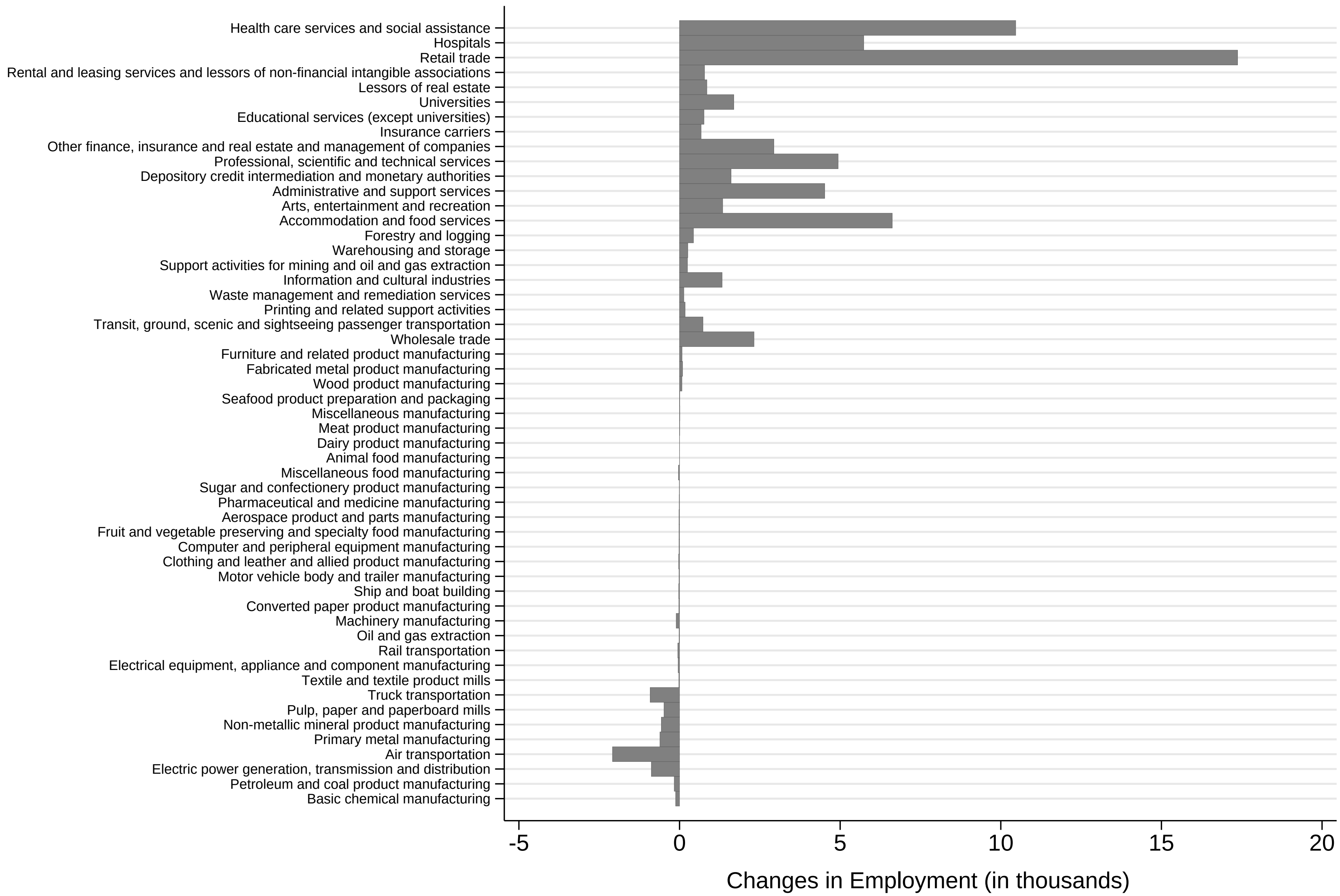

Figure 9: Changes in Employment at \$10/t CO_2e

Source: Author's calculation

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A. Data Appendix

This appendix describes additional details of the data sources and construction used to create the dataset for the analysis. It also provides a list of industries in the sample as well as the concordance between two classifications.

I. Data

To identify the employment effect of the BC carbon tax, I collected data on employment (Table 281-0024), GHG emission intensity (Table 153-0034 and 379-0029), and trade intensity (Table 386-0003) from tables in Statistics Canada. While the time coverage for each table is different, I use employment data from 2001 to 2013 while I use GHG emission intensity data and trade intensity data only from 2007.

Employment is measured as a number of all employees in an industry. GHG emission intensity is calculated as GHG emission (Table 153-0034) divided by industrial GDP (Table 379-0029) and measured in tonnes per thousand dollars of production. Trade intensity is defined as $(\text{Import} + \text{Export})/(\text{Total demand} + \text{Import})$. Import and export both include international and inter-provincial trade. Total demand is defined as the sum of consumption out of own production and inventory withdrawals plus exports. This construction of trade intensity is to have a similar meaning to openness to trade, which is often calculated as $(\text{Import} + \text{Export})/\text{GDP}$.

Although all these variables are obtained from Statistics Canada, they are categorized based on the different classifications. Employment and emission intensity data are categorized based on the North American Industry Classification System (NAICS) while trade intensity data is categorized based on the North American Products Classification System (NAPCS). As Statistics Canada provides the detail description for each category of the classifications, manual merging is possible to construct the dataset for this analysis. The concordance between these classifications is listed in the next section.

I also collected data on wage to identify the wage effect of the BC carbon tax. Average hourly and weekly wage data are obtained from Table 282-0072 in Statistics Canada. They are measured in current dollar and categorized based on NAICS.

II. Concordance

This appendix provides a list of industries in the sample as well as a concordance between datasets.

Table A.1: Concordance between commodities in trade data and NAICS

Commodity (Table 386-0002)	**NAICS Industry**
Forestry products and services	Forestry and logging (113)
Mineral fuels	Coal mining (2121)
Metal ores and concentrates	Metal ore mining (2122)
Non-metallic minerals	Non-metallic mineral mining and quarrying (2123)
Mineral support services	Oil and gas extraction (2111)
	Support activities for mining and oil and gas extraction (2131)
Utilities	Electric power generation, transmission and distribution (2211)
	Natural gas distribution, water and other systems (221A[1])
Food and non-alcoholic beverages	Animal food manufacturing (3111)
	Sugar and confectionery product manufacturing (3113)
	Fruit and vegetable preserving and specialty food manufacturing (3114)
	Dairy product manufacturing (3115)
	Meat product manufacturing (3116)
	Seafood product preparation and packaging (3117)
	Miscellaneous food manufacturing (311A[2])
Textile products, clothing, and products of leather	Textile and textile product mills (31A0[3])
	Clothing and leather and allied product manufacturing (31B0[4])
Wood products	Wood product manufacturing (321)
Wood pulp, paper and paper products and paper stock	Pulp, paper and paperboard mills (3221)
	Converted paper product manufacturing (3222)
Printed products and services	Printing and related support activities (323)
Refined petroleum products (except petrochemicals)	Petroleum and coal product manufacturing (324)
Chemical products	Basic chemical manufacturing (3251)
	Resin, synthetic rubber, and artificial synthetic fibers manufacturing (3252)

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[1] 221A includes 2212 and 2213.
[2] 311A includes 3112, 3118, and 3119.
[3] 31A0 includes 313 and 314.
[4] 31B0 includes 315 and 316.

Commodity (Table 386-0002)	NAICS Industry
	Pharmaceutical and medicine manufacturing (3254)
	Miscellaneous chemical product manufacturing (325A[5])
	Pesticide, fertilizer and other agricultural chemical manufacturing (3253)
	Rubber product manufacturing (3262)
Plastic and rubber products	Plastic product manufacturing (3261)
Non-metallic mineral products	Non-metallic mineral product manufacturing (327)
Primary metallic products	Primary metal manufacturing (331)
Fabricated metallic products	Fabricated metal product manufacturing (332)
Industrial machinery	Machinery manufacturing (333)
Computer and electronic products	Computer and peripheral equipment manufacturing (3341)
	Electronic product manufacturing (334A[6])
Electrical equipment, appliances and components	Electrical equipment, appliance and component manufacturing (335)
Transportation equipment	Motor vehicle manufacturing (3361)
	Motor vehicle body and trailer manufacturing (3362)
	Motor vehicle parts manufacturing (3363)
	Aerospace product and parts manufacturing (3364)
	Railroad rolling stock manufacturing (3365)
	Ship and boat building (3366)
Furniture and related products	Furniture and related product manufacturing (337)
Other manufactured products and custom work	Miscellaneous manufacturing (339)
Wholesale margins and commissions	Wholesale trade(41)
Retail margins, sales of used goods and commissions	Retail trade (4A[7])
Transportation and related services	Air transportation (481)
	Rail transportation (482)
	Truck transportation (484)
	Water transportation (483)
	Transit, ground, scenic and sightseeing passenger transportation (48B0[8])
	Postal service and couriers and messengers (49A0[9])
	Warehousing and storage (493)
Information and cultural services	Information and cultural industries (51)

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[5] 325A includes 3255, 3256, and 3259.
[6] 334A includes 3342-3346.
[7] 4A includes 44 and 45
[8] 48B0 includes 485, 487 and 488.
[9] 49A0 includes 491 and 492.

Commodity (Table 386-0002)	NAICS Industry
Depository credit intermediation	Depository credit intermediation and monetary authorities (5221)
Other finance and insurance	Insurance carriers (5241)
	Other finance, insurance and real estate and management of companies (5A06[10])
Real estate, rental and leasing and rights[11]	Lessors of real estate (5311)
	Rental and leasing services (5A05[12])
Professional services (except software and research and development)	Professional, scientific and technical services (541)
Administrative and support, head office, waste management	Administrative and support services (561)
	Waste management and remediation services (562)
Education services	Universities (6113)
	Educational services (except universities) (611A[13])
Health and social assistance services	Hospitals (622)
	Health care services (except hospitals) and social assistance (62A0[14])
Arts, entertainment and recreation services	Arts, entertainment and recreation (71)
Accommodation and food services	Accommodation and food services (72)

[10] 5A06 includes 5222, 5223, 523, 5242, 526, 5312, 5313, and 551.
[11] Real estate, rental and leasing and rights to non-financial intangible assets to be exact.
[12] 5A05 includes 532 and 533.
[13] 611A includes 6114, 6115, 6116, and 6117
[14] 62A0 includes 621, 623, and 624.