Online Appendix: On the Labor Market Consequences of Environmental Taxes

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1 Appendix A: The Employment Effect of Carbon Taxes

This appendix demonstrates that BC's carbon tax causes the employment level and the total labor hours to decline. It shows that it is important to select an appropriate reference period and province as the pre-policy period and the control province. For example, it provides evidence that the employment trends in BC and the rest of Canada are parallel a few years before the tax policy is introduced but diverge in a more distant period. Furthermore, it shows that MB experiences a sharp increase in the employment during the post-policy period of the BC's carbon tax policy. The inclusion of these early periods as part of the pre-policy period and Manitoba (MB) as one of the control provinces could yield qualitatively and quantitatively different conclusions.

1.1 Data Descriptions

This appendix utilizes the public-use files of the Canadian Labor Force Survey (LFS) between January 2001 and June 2015. The Canadian LFS is a monthly household survey, which includes approximately 100,000 individuals. The main purpose of the Canadian LFS is to generate data for official labor force statistics and is similar in nature to the United States Current Population Survey.

In Yamazaki (2017), the employment effect of BC's carbon tax policy is examined using annual aggregate employment data at the industry level. To make this study comparable to his, I first aggregate a monthly employment level by province and industry and then estimate the impact of the policy on the employment level and the total labor hours. This analysis may lose useful demographic information at the individual level. To fully utilize the LFS survey, I conduct an analysis using data at the individual level to estimate the effects of the policy in the main content of the paper. As such, the information on individual demographic characteristics, such as age, gender, educational level, marital status, etc., are to be fully utilized and the analysis allows us to estimate the effects of the policy on an unemployment rate, a labor force participation rate, and the heterogeneity in these effects, all of which cannot be achieved using the aggregate employment data.

1.2 Identification Method

This section discusses the identification methods and describes the data. Following the identification strategy of Yamazaki (2017), I estimate the employment effect of BC's carbon tax using a difference-in-differences (DID) method to isolate a country-wide employment shock in the absence of the reform. Using the DID approach, the causal effect of the carbon tax can be estimated

by a regression model as follows:

$$\ln L_{ijt} = \alpha + \beta_1(BC_j \times Post_t) + \delta_{it} + \eta_{ij} + \varepsilon_{ijt}, \tag{1}$$

which is analogous to the equation (4.2) in Yamazaki (2017). $\ln L_{ijt}$ is the natural logarithm of the employment level (and the total labor hours) in industry i in province j at time t. BC_j equals one if the observation is from BC, and zero otherwise. Therefore, BC serves as the treatment group and the rest of Canada is the control group. $Post_t$ equals one if the industry employment level is observed on or after July 2008, and zero otherwise. Therefore, the term $BC_j \times Post_t$ takes the value of one if employment is observed in BC during the post-policy period, and zero otherwise. In addition, I estimate the model by replacing $BC_j \times Post_t$ with $BC_j \times Tax_t$, where Tax_t equals 0, 0.1, 0.15, 0.2, 0.25, and 0.3 if the observation is during January 2001-June 2008, July 2008-June 2009, July 2009-June 2010, July 2010- June 2011, July 2011- June 2012, and July 2012-June 2015, respectively. These allow us to estimate the employment effect for each Canadian dollar of carbon tax.

According to Yamazaki (2017), δ_{it} and η_{ij} are industry-specific time fixed effects that control for industry-specific shocks at a given year and industry-by-province fixed effects that control for time-invariant industry-by-province specific heterogeneity and constant industrial and provincial characteristics, respectively. ε_{ijt} captures idiosyncratic shocks in employment. Following Yamazaki (2017), I estimate the standard error clustered at the industry-by-province level, providing us with 180 clusters.

Two comments deserve mention. First, the frequency of observation is different from Yamazaki (2017): while this paper analyzes the monthly employment level, he uses an annual data. Hence, the LFS data provides us with more variations in the employment level and the total labor hours. Second, the definition of the carbon tax Tax_t in this paper fits well with the policy. Since the carbon tax was introduced in mid-2008 and the tax increased in the middle of each year during 2009-2013, the data at the monthly level allows us to define the treatment variable Tax_t appropriately. Hence, the treatment variable of this paper may not be perfectly comparable to that in Yamazaki (2017).[1]

In this analysis, the coefficient estimate β_1 is the DID estimate of our primary interest because it captures the variation in the employment level in response to BC's carbon tax policy. To interpret the coefficient estimate of $\hat{\beta}_1$ as the causal employment effect, several assumptions are required.[2] For example, there exists no policy or shock other than the carbon tax policy that affects BC's industry employment level but not the industry employment level in the rest of Canada. Second, the employment levels in BC and the rest of Canada display a similar time trend in the absence of the carbon tax. I will discuss the credibility of the common trend assumption in Section 1.3.1.

[1] See the definition of τ_t in Section 4.2. in Yamazaki (2017).

[2] These assumptions are also highlighted in Section 4.2 of Yamazaki (2017).

1.3 The Adverse Employment Effect of the Carbon Tax

This section is divided into two subsections: subsections 1.3.1 and 1.3.2 investigate the effect of the carbon tax policy on the employment level and the total labor hours, respectively.

1.3.1 The Effect on the Employment Level

Table 1 presents the employment results from the estimation of equation (1) using the aggregated data. All the specifications include industry-by-period and industry-by-time fixed effects. Here, the estimated effects are derived from comparisons between BC and the rest of Canada.

Following Yamazaki (2017), the estimation window is restricted to January 2001-December 2013. The columns correspond to models with various control provinces. Yamazaki (2017) argues that Quebec (QC) should be excluded from the sample because a carbon policy was introduced in QC in 2007. Indeed, Alberta (AB) also introduced a carbon tax policy in July 2007.[3] To serve as a sensitive analysis, QC is excluded in columns (2) and (5) and AB is excluded in columns (3) and (6).

The results suggest that BC's carbon tax policy increases the employment level. The estimates indicate that the employment level rises by 7.5-8.1 percent and that a dollar increase in the carbon tax causes the employment level to rise by 0.25-0.3 percent. These estimates are all materially and statistically significant at one percent level and robust to control groups. This exercise, consistent with the findings in Yamazaki (2017), confirms that the revenue-neutral carbon tax policy causes the employment level to increase.

This estimation strategy is subject to whether BC and the rest of Canada follow a parallel trend in employment. The positive employment effect could be interpreted as the causal effect of the carbon tax only if the common trend assumption is satisfied. While there exists no direct statistical test on this assumption, it is common in the empirical literature to verify the credibility of this assumption by estimating an alternative model as follows:

$$\ln L_{ijt} = \alpha + \sum_t \beta_t (BC_j \times d_t) + \delta_{it} + \eta_{ij} + \varepsilon_{ijt}, \tag{2}$$

where d_t equals one if the employment level is observed between July in year t and June in year $t+1$ for all years between 2001 and 2012 except 2007, and zero otherwise. The d_t for July 2007-June 2008 is excluded because it serves as a reference year.

If the employment levels in BC and the rest of Canada happen to follow a similar trend prior to the implementation of the policy, it is likely that their employment trends are parallel subsequent to the tax policy. Hence, the positive employment effect is unlikely to be causal in nature, if the

[3] Alberta introduced the specified gas emitters regulation that required companies emitting more than 100,000 tonnes of greenhouse gas annually to pay $15/tonne.

Table 1: The Employment Effect of the Carbon Tax

Difference-in-Differences Analysis						
Estimation Window: January 2001-December 2013						
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$BC \times Post$	0.081***	0.075***	0.085***			
	(0.015)	(0.016)	(0.017)			
$BC \times Tax$				0.279***	0.253***	0.294***
				(0.063)	(0.066)	(0.070)
Adjusted R^2	0.981	0.979	0.982	0.981	0.979	0.982
Sample	All	QC Excluded	AB Excluded	All	QC Excluded	AB Excluded

Notes: Data come from the Canadian LFS January 2001-December 2013. Dependent variables are ln(industry employment level). Control variables include dummies for industry×time and industry×province. BC is the treatment group. The rest of Canada is the control group. The post-policy period is defined as the time from July 2008 onwards. The numbers of observations are 28,080 in columns (1) and (4) and 25,272 in columns (2) and (3) and (5) and (6). Robust standard errors in parentheses are clustered at the level of industry and province, providing us with 180 clusters in columns (1) and (4) and 170 clusters in columns (2) and (3) and (4) and (5). Significance levels: ***=1%, **=5%, *=10%.

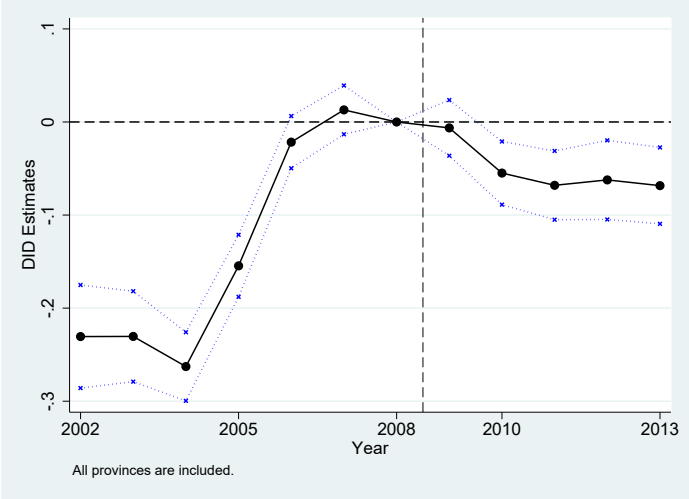
following two features are not seen from the $\hat{\beta}_t$ in the estimation of equation (2). First, one should expect that the difference in the employment level between BC and the rest of Canada prior to the reference year is close to the difference in the reference year. That is, the employment trends between the treatment and the control group are close prior to the treatment period. All the $\hat{\beta}_t$ prior to the reference year should be statistically no different from zero. Second, if the carbon tax policy does increase BC's employment level, all the $\hat{\beta}_t$ should be positive immediately following the reference year. But if the policy happens to take time for the employment effect to emerge, $\hat{\beta}_t$ is expected to grow steadily and, at the very least, $\hat{\beta}_t$ is nonnegative.

Figure 1 displays the main DID estimate $\hat{\beta}_t$ of each year. Being a reference year, the estimate corresponding to July 2007-June 2008 is normalized to zero. The first dot represents the estimate $\hat{\beta}_t$ of the period July 2001-June 2002, which captures the average differences in the employment level between BC and the rest of Canada relative to the differences in the reference year.

Apparently, the result suggests that the policy decreases BC's employment level. Following the reference period, all the estimates $\hat{\beta}_t$ are negative, meaning that the average employment level in BC is less than that in the rest of Canada, relative to the reference period. If the employment effect is indeed negative, why do the results in Table 1 suggest a positive employment effect of the policy?

The employment trends between BC and the rest of Canada are parallel during July 2005-June 2007 but not during July 2001-June 2005. The estimates during July 2005-June 2007 are all close to zero, reflecting the common employment trend between BC and the rest of Canada during

Figure 1: The Employment Effect in BC Relative to the Rest of Canada



Notes: Dependent variables are ln(industry employment level). Data are from the Canadian LFS July 2001-June 2013. The reference period is July 2007-June 2008. Each dot represents the main DID estimate from equation (2) in the corresponding year. For example, the first dot represents the main DID estimate of the period July 2001-June 2002. The vertical line represents the first month of the carbon tax policy (July 2008). BC is the treatment province. The dashed line represents the 95 percent confidence interval.

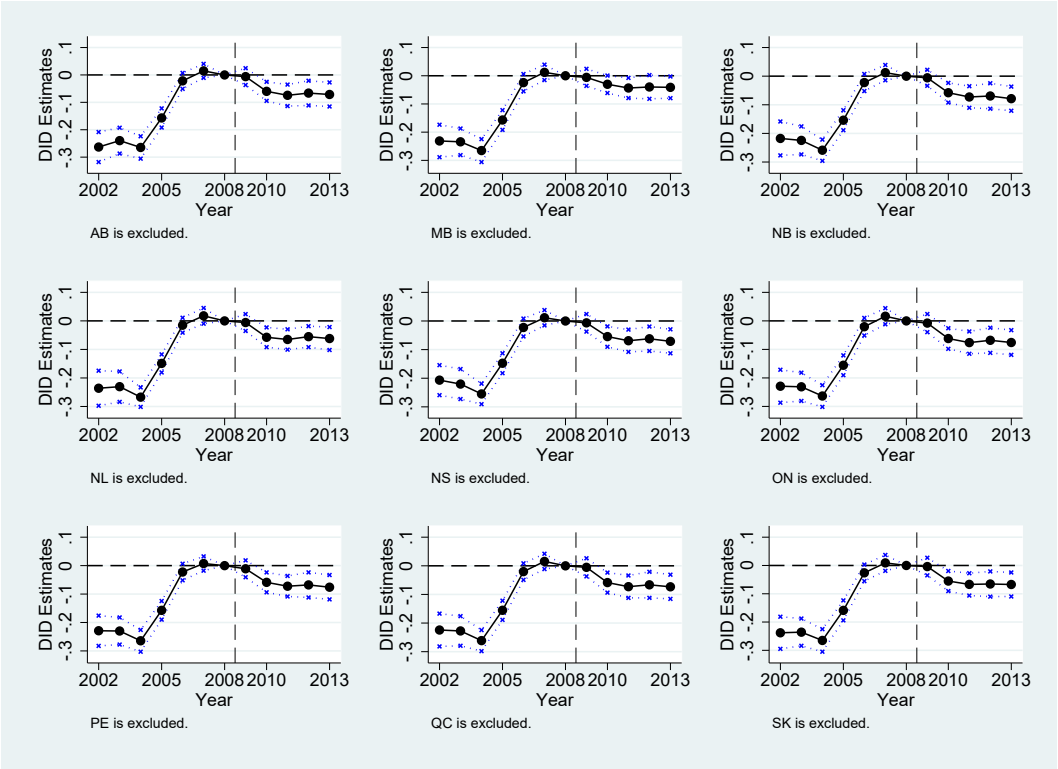
the three years prior to the policy. Nevertheless, the estimates are all materially and statistically negative during July 2001-June 2005. These estimates reveal that the employment trends in the treatment and the control provinces are unparallel: relative to the reference year, BC's average industry employment level during July 2001-June 2005 is substantially smaller than that in the rest of Canada. Therefore, if one considers this period as part of the pre-policy period, no causal employment effect could be easily obtained.

Since the relative employment level in BC is substantially small during July 2001-June 2005, it drives down the average of the relative pre-policy employment level significantly. This creates the illusion on the rise in BC's relative employment level after the implementation of the policy. In fact, the positive estimate does not capture the employment effect of the carbon tax policy; instead, it only reflects the rise in BC's employment level relative to the rest of Canada during July 2001-June 2005, which is likely unrelated to BC's revenue-neutral carbon tax policy. This explains why the estimates in Table 1 are positive when the observations during July 2001-June 2005 are included in the pre-policy period.

One may be concerned that such a low employment level in BC in the early period is driven by control provinces. I repeat the analysis by excluding each province from the control group one-by-one and report the results in Figure 2. In each figure, the features of the estimates are all alike: the estimates are substantially small during July 2001-June 2005 and are around zero during

July 2005-June 2007, and they are negative subsequent to the policy implementation. Hence, this exercise not only provides strong support that the employment effect of BC's carbon tax policy is, at the very least, not positive but also suggests that to obtain the causal employment effect of this policy, the observations during a more distant period (i.e., July 2001-June 2005) should be excluded. Inspired by this analysis, I restrict the pre-policy period to July 2005-June 2008 throughout the main content of the paper.

Figure 2: The Relative Employment Effect in BC relative to the Rest of Canada



Notes: The dependent variable is ln(industry employment level). Data are from the Canadian LFS July 2001-June 2013. The reference period is July 2007-June 2008. Each dot represents the main DID estimate from equation (2) in the corresponding year. For example, the first dot represents the main DID estimate of the period July 2001-June 2002. The vertical line represents the first month of the carbon tax policy (July 2008). BC is the treatment province. The dashed line represents the 95 percent confidence interval.

The DID method requires a double differencing in the dependent variable across time (i.e., pre- and post-policy period) and province (i.e., BC and control provinces). Hence, choosing the set of control provinces is no less important than picking an appropriate time-frame for the pre-policy period. The common trend assumption requires that the employment trend in BC and the average employment trend in the control provinces are parallel. There exists no statistical test on this assumption; nevertheless, one could verify whether the employment trend of each control

province is indeed parallel to the trend of the other control provinces.

I investigate whether the employment trends are parallel among control provinces. I estimate the annual employment effect from equation (2). I treat one of the control provinces as a pseudo treatment province and the rest as the control province. I repeat this analysis with a different control province as a pseudo treatment province. In this analysis, I exclude BC from the sample because the employment trend in BC is not of interest.

Two points deserve mention. First, over time, many policies are introduced in the control provinces. Ideally, there is no shock or policy that affects the employment level in the control provinces. Unfortunately, it is not always the case, especially when the horizon of the estimation window and the set of the control province expand over two periods of time and over two control provinces. Therefore, there may exist one or more provinces whose employment trends deviate from the trend of the rest of the control provinces. If the derivation is sufficiently large, I exclude those provinces from the main analysis.

Second, there should exist no other control province that experiences a sharp change in the employment level immediately following BC's revenue-neutral carbon tax policy. Otherwise, it may be reasonable to assume that the estimated effect on BC's employment level is driven from factors that are likely unrelated to BC's carbon tax policy.

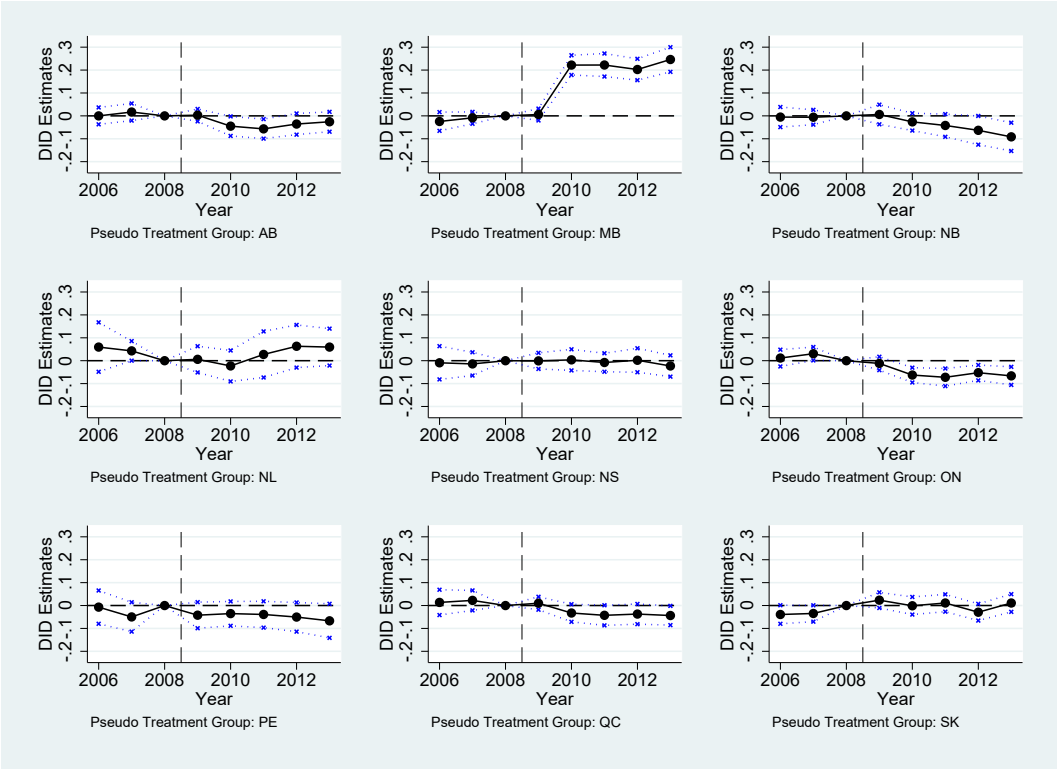
Figure 3 illustrates the estimates $\hat{\beta}_t$ from the estimation of equation (2). In each figure, one of the province is treated as the pseudo treatment province. A number of points emerge from the figure. First, the employment trend in MB is obviously different from other control provinces. MB experiences a sharp increase in its employment level during July 2009-June 2010. The comparison between BC's employment trend with that of MB would conclude that the carbon tax policy decreases BC's employment level even though there may be no effect of BC's carbon tax policy. Hence, MB is excluded from the sample throughout this paper.

Second, it seems that no province, including MB, experiences a sharp change in employment trend right after the implementation of BC's carbon tax policy. It suggests that there are common employment trends between BC and the rest of Canada prior to the carbon tax policy and among the control provinces (including MB) across the implementation date of the policy. Moreover, the employment trends among the control provinces (except MB) are parallel throughout the entire period of examination.

Third, Ontario (ON) may experience a slight decline in its employment level in latter periods. This may be driven from the huge increase in the minimum wage. ON's minimum wage increases by over 18 percent within the first two years of BC's carbon tax policy and continues to increase after that. Since the decline is small, I leave ON in the control group. One should note that removing ON from the control group likely drives the employment effect downwards. The results are qualitatively similar in the rest of the analysis if I exclude ON from the sample.

I re-estimate equation (1) with the pre-policy period during July 2005-June 2008. This pre-

Figure 3: The Relative Employment Effect in the Pseudo Treatment Province



Notes: The dependent variable is ln(industry employment level). Data are from the Canadian LFS July 2005-June 2013. The reference period is July 2007-June 2008. Each dot represents the main DID estimate from equation (2) in the corresponding year. For example, the first dot represents the main DID estimate of the period July 2005-June 2006. The vertical line represents the first month of the carbon tax policy (July 2008). The dashed line represents the 95 percent confidence interval.

Table 2: The Adverse Effect of the Carbon Tax on the Employment Level

Difference-in-Differences Analysis

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$BC \times Post$	-0.028*	-0.030**	-0.030*			
	(0.014)	(0.015)	(0.015)			
$BC \times Tax$				-0.122**	-0.134**	-0.127**
				(0.059)	(0.061)	(0.064)
Adjusted R^2	0.987	0.986	0.987	0.987	0.986	0.987
Sample	MB	MB & QC	MB & AB	MB	MB & QC	MB & AB
	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded

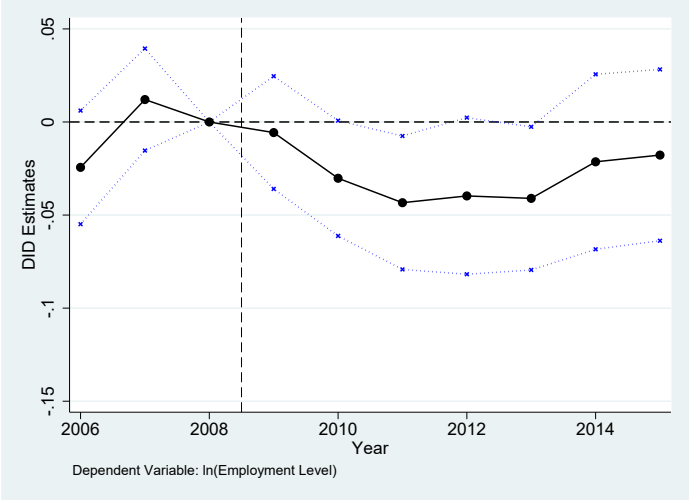
Notes: Data come from the Canadian LFS July 2005-June 2013. Dependent variables are ln(industry employment level). Control variables include dummies for industry×time and industry×province. BC is the treatment group. The post-policy period is defined as the time from July 2008 onwards. The numbers of observations are 15,552 in columns (1) and (4) and 13,824 in columns (2) and (3) and (5) and (6). Robust standard errors in parentheses are clustered at the level of industry and province, providing us with 162 clusters in columns (1) and (4) and 144 clusters in columns (2) and (3) and (4) and (5). Significance levels: ***=1%, **=5%, *=10%.

policy period is ideal because the parallel employment trends between BC and the control group during July 2005-June 2008 suggests that the common trend assumption is likely to be satisfied. All the specifications include industry-by-period and industry-by-time fixed effects. Here, the estimated effects are derived from the comparisons between BC and the control provinces.

Table 2 presents the results. The columns correspond to models with various control provinces. To serve as a sensitivity analysis, QC is excluded in columns (2) and (5) and AB is excluded in columns (3) and (6). The results suggest that the carbon tax decreases employment level. The estimates indicate that BC's employment level drops by 2.8 percent and that a dollar increase in the carbon tax reduces the employment level by 0.12 percent. All the estimates are statistically significant and robust to control groups.

Lastly, I explore the dynamics of the effect of the policy on the employment level. To do so, I estimate equation (2) with a prolonged post-policy period to obtain a longer series of the effect of the carbon tax on employment. Figure 4 illustrates the main DID estimate of each year. Consistent with the findings above, the figure indicates that BC's employment level decreases following the carbon tax policy. The estimates indicate that the carbon tax slightly decreases the employment level in the first year of the policy and largely cuts the employment level by approximately four percent in the second year of the policy. Such a significant employment effect persists and BC's employment level remains low for the following three consecutive years. The negative employment effect starts to diminish (slightly) in the fifth year of the policy. This analysis not only provides support on the negative employment effect of the revenue-neutral carbon tax policy from its extensive margin but also indicates that such an adverse effect of the carbon tax

Figure 4: The Dynamic Effect on the Employment Level



Notes: The dependent variable is ln(industry employment level). Data are from the Canadian LFS July 2005-June 2015. The reference period is July 2007-June 2008. Each dot represents the main DID estimate from equation (2) in the corresponding year. For example, the first dot represents the main DID estimate of the period July 2005-June 2006. The vertical line represents the first month of the carbon tax policy (July 2008). BC is the treatment province. The dashed line represents the 95 percent confidence interval.

could be persistent.

1.3.2 The Effect on the Total Labor Hours

This subsection explores the impact of the carbon tax policy on the total labor hours. This analysis is informative for two reasons. First, while the previous section confirms the negative impact on employment from its extensive margin, the analysis on total labor hours provides an opportunity to measure the effect of the carbon tax policy on employment and provides insights on the employment effect from its intensive margin. Second, it serves as an internal validity check on the results above. If BC's total labor hours happen to increase subsequent to the carbon tax policy, it may be reasonable to assume that the negative effect on the employment level (i.e., the employment effect from its extensive) arises from other unobserved factors such as labor market policies that are unrelated to the carbon tax policy.

Table 3 presents the carbon tax policy effect from the estimation of equation (1). The total labor hours are measured by aggregating the actual weekly working hours on the main job at the level of time, province, and industry. The columns correspond to models with various control provinces. QC is excluded in columns (2) and (5) and AB is excluded in columns (3) and (6). All the specifications include industry-by-period and industry-by-time fixed effects.

Two points emerge from the table. First, the results suggest that the carbon tax policy decreases

Table 3: The Adverse Effect of the Carbon Tax on the Total Labor Hours

Difference-in-Differences Analysis

$BC \times Post$	-0.032**	-0.033**	-0.036**			
	(0.015)	(0.015)	(0.016)			
$BC \times Tax$				-0.149**	-0.159***	-0.160**
				(0.059)	(0.060)	(0.063)
Adjusted R^2	0.978	0.977	0.978	0.978	0.977	0.978
Sample	MB	MB & QC	MB & AB	MB	MB & QC	MB & AB
	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded

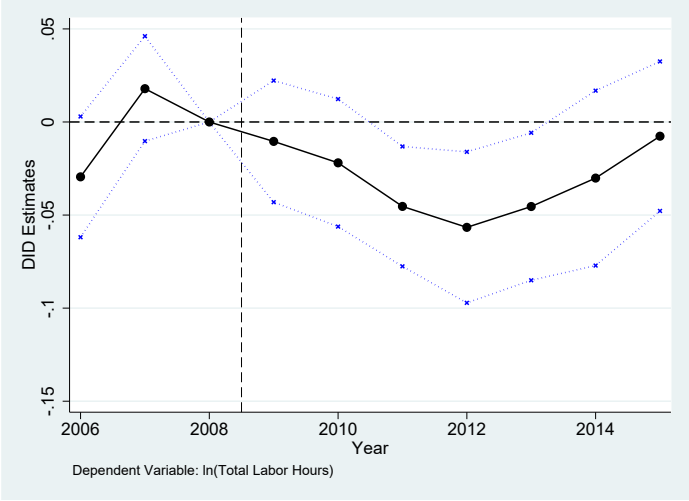
Notes: Dependent variables are ln(industry total weekly labor hours). The weekly labor hour is defined as the actual weekly working hours on the main job. BC is the treatment group. The rest of Canada is the control group. Data come from the Canadian LFS July 2005-June 2013, respectively. The post-policy period is defined as the time from July 2008 onwards. The numbers of observations are 15,552 in columns (1) and (4) and 13,824 in columns (2) and (3) and (5) and (6). Robust standard errors in parentheses are clustered at the level of industry and province, providing us with 180 clusters in columns (1) and (4) and 170 clusters in columns (2) and (3) and (4) and (5). Significance levels: ***=1%, **=5%, *=10%.

the total weekly labor hours. The estimates indicate that, on average, the total weekly labor hours drop by 3.2 percent and that a dollar increase in the carbon tax reduces the weekly working hours by 0.15 percent in BC. All the estimates are statistically significant and robust to control groups.

Second, the results infer that the carbon tax reduces employment mainly from the extensive margin. Notice that $\ln$(Total Labor Hours) $=$ $\ln$(Employment Level)$+$ $\ln$(Average Working Hours), where the employment level and the average working hours are the employment from its extensive and intensive margin, respectively. While subsection 1.3.1 provides evidence that the carbon tax reduces the employment level by 2.8 percent, this subsection indicates that the total labor hours fall by 3.2 percent. This implies that the carbon tax policy may reduce the employment from its intensive margin by about 0.4 percent, close to zero. In the main content of this paper, the effect on the average working hours is found statistically no different from zero regardless of educational level, consistent with the result here.

Lastly, I explore the dynamics of the effect of the policy on the total labor hours. To do so, I estimate equation (2) to obtain the effects of the policy on the total labor hours. Figure 5 illustrates the main DID estimate of each year. Consistent with the adverse employment effect, the figure indicates that BC's total labor hours drop following the policy. The estimates indicate that the policy gradually decreases the total labor hours in the first four years of the policy. In the fifth year of the policy, the total labor hours in BC is about five percent less than it would otherwise be in the absence of the policy. Regarding BC's economic recovery in the latter period, the estimates rebound between the fourth and the seventh year of the policy and BC's employment level returns to its pre-policy level in seven years. This analysis suggests that the adverse effect on employment

Figure 5: The Dynamic Effect on Total Labor Hours



Notes: The dependent variables are ln(industry total weekly labor hours). Data are from the Canadian LFS July 2005-June 2015. The reference period is July 2007-June 2008. Each dot represents the main DID estimate from equation (2) in the corresponding year. For example, the first dot represents the main DID estimate of the period July 2005-June 2006. The vertical line represents the first month of the carbon tax policy (July 2008). BC is the treatment province. The dashed line represents the 95 percent confidence interval.

is persistent, possibly lasting seven years.

1.4 Conclusion

This appendix reveals that the positive employment effect in the literature may not capture the causal employment effect of BC's carbon tax policy. Instead, it may reflect the rise in the relative employment level in BC in a more distant period from the implementation date of the policy. This section also shows that the carbon tax policy reduces the employment level and the total labor hours by about 2.8 and 3.2 percent, respectively.

2 Appendix B: Summary Statistics in the Pre-Policy Period

This appendix provides summary statistics for Table 3 in Section 4.2. The Appendix Table 4 summarizes the means of the weekly working hours, the unemployment rates, and the LFP rates by gender and educational group in BC and the rest of Canada during the pre-policy period.

Table 4: Summary Statistics in the Pre-Policy Period

Variable	**Working Hours**		**Unemployment Rates**		**LFP Rates**	
Gender	M	F	M	F	M	F
			High-Educated			
BC	37.05	30.04	2.44	2.51	77.96	73.42
Rest of Canada	37.67	30.78	2.90	2.99	80.60	78.16
			Medium-Educated			
BC	36.61	28.38	2.98	2.97	76.03	67.16
Rest of Canada	37.82	29.38	4.91	3.74	78.24	70.04
			Low-Educated			
BC	35.11	27.36	4.08	3.23	62.61	48.04
Rest of Canada	36.64	28.25	6.11	4.17	61.72	46.19

Notes: M and F denote male and female samples. BC is the treatment group. The rest of Canada excludes the samples from MB. Data come from the Canadian LFS July 2005-June 2007.

References

Yamazaki, A. (2017). Jobs and Climate Policy: Evidence from British Columbia's Revenue-Neutral Carbon Tax. *Journal of Environmental Economics and Management 83*, 197–216.