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An Empirical Research on the Impact of Gasoline Taxes on Consumer-Level Retail Prices

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Abstract: This paper uses provincial-level gasoline retail price data in Canada to study the effect of tax reform on gasoline retail prices. It uses a dynamic difference-in-difference strategy to estimate the dynamic treatment effect of tax reform to see the dynamic changes of treatment effect in post-reform periods. We find that on average, the tax cut tends to be close to or around the full passthrough rate to the gasoline retail price. The treatment effect does not diminish over time and it is immediate after the tax reform. This means that the gasoline tax cut goes directly to consumers, it will work as a great macroeconomic tool in fighting the current inflation. The implications of effective gasoline taxation policy allow governments to adjust the gasoline taxation when needed to fight off inflation knowing that almost full taxation changes would pass down to the retail level. We conducted an additional robustness check to the robustness of our results.

Keywords: gasoline taxes, consumer level retail prices, dynamic difference-in-difference method

1. Introduction

Global energy demand has been increasing in recent years. Due to the recent Russian-Ukraine war, global energy prices rose to an all-time high. For individuals, this significantly raises the cost of living, for businesses, this raises the production cost of products and services forcing the price of products and services to go up, as a result causing an even higher upward pressure on inflation. In 2022, the high inflation and global gasoline prices prompted the Canadian government to consider reducing gasoline taxes to alleviate some of the inflation pressure as a policy response. In economics, gasoline taxation is an effective macroeconomic tool for governments. Gasoline retail price is positively correlated with the transportation cost of goods and services, as a result, high gasoline prices can increase the cost of production and distribution which increase the production cost, and ultimately increases the price of good. By reducing gasoline taxes, the government lowers the retail prices of gasoline, doing so will reduce the transportation cost for businesses which could potentially help in fighting high inflation. The reduction of gasoline taxes in Canada is a favorable economic measure undertaken to address the issue of high gasoline prices and inflation. This policy helps mitigate the impact of price increases by reducing tax burdens, thereby stimulating production, consumption, and overall economic growth. To evaluate the effectiveness of gasoline tax reforms on retail-level gasoline prices, this study employs a difference-in-difference model. By comparing data before and

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after the implementation of the tax cut policy and examining the differences between groups that have implemented the policy and those that have not, this model allows for a comprehensive analysis of trends and variations between control and treatment groups. Furthermore, this study aims to investigate the causal relationship between gasoline tax reforms and retail gasoline prices. By considering economic factors such as economic growth and alleviating pressure on citizens through reduced fuel costs, we aim to analyze selected data in a comprehensive manner.

This study aims to examine and rationalize the economic background and research objectives previously mentioned. To achieve this, we will build upon existing academic literature in section two, utilizing their findings and methodologies in the context of Canadian markets. Consequently, section three will exclusively employ recent Canadian data and trends to gain insights into how changes in tax policies impact gasoline prices at the pump during the post-pandemic period. In section four, we will apply empirical equations and models to the Canadian gasoline markets, enabling a deeper understanding of the behavior of retail prices through various analyses, including comparisons of retail prices and mobility patterns. Specifically, we will utilize difference-in-difference models to assess the long-term impact of tax reforms on prices. Furthermore, this paper will be strengthening our findings through robustness checks and additional forms of validation. Section five will present the outcomes of our analysis of Canadian gasoline markets and consumer behaviors. It will then apply our insights to assess the overall impact of the policy. Finally, the sixth and final section will conclude our research paper by summarizing our results, discussing their implications, and highlighting potential applications for future policy considerations.

2. Literature Review

Harju et al. examine the transmissibility of a large number of carbon tax increases on retail prices through the use of difference-in-difference models [1]. The observed dataset is monthly pricing data from gas stations and compares the pass-through rate of taxes on diesel and gasoline. Furthermore, the article collects odometer readings and fuel consumption of Finnish vehicles through the statistics office, which is used to examine consumer mobility and consumption. Harju et al.'s paper demonstrates the impact of a carbon tax on high-income areas is inversely proportional to the impact on low-income areas which indicates that different income levels will result in different effects of tax cut passthrough. This is indeed similar to our assumption. The contrast between realistic rural areas and urban areas for passthrough was particularly striking in the in-depth survey. Rural areas are significantly higher than urban areas, and there is a substantial difference of one euro cent increase in diesel carbon tax that is 0.91 cents versus 0.77 cents [1]. This paper takes a different approach and compares provincial-level data instead of rural and urban data. Furthermore, this paper does not consider income levels as one of our controlled variables. It applies a different set of constraints to limit the variation and correlated effect in a similar style to that of Harju et al.'s paper. Similarly, Rivers & Schaufele suggest a series of factors such as individual consumer preferences, demand, and environment that may lead to different relationships between changes in demand and price. They indicate that "the carbon tax causes a larger change in demand than equivalent changes in market prices" [2]. Similarly, this paper raises a tangential conjecture that consumer inelasticity may influence the causal relationship between oil prices and oil tax policies.

Interestingly, Antweiler & Gulati support the above hypothesis. They argue that "without BC's carbon tax fuel demand per capita would be 7% higher" [3]. In addition, they perceive a relationship between price and elasticity. Brons et al. confirm the demand for gasoline is price inelastic in the short-run and long-run" [4]. Antweiler & Gulati conclude that gasoline demand is inelastic in the short term [3]. Hence, if consumers are inelastic to changes in oil prices; defined as demand insensitive, then reducing the oil tax may not significantly increase mobility or induce more consumption. Moreover, since consumer demand is not affected by price changes, a reduction in oil

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taxes may only have a small impact on government revenues. Therefore, the elasticity of demand will affect both gasoline price and mobility which partly supports our research conjecture. It is important to note that a further investigation into tax reforms on gasoline and its relationship with consumer mobility and consumption is also conducted within our analysis. This paper's results are somewhat in agreement with the results found in Antweiler & Gualti's conclusions.

3. Data Description

This paper utilizes two datasets to examine the effects of tax reforms on gasoline prices and consumer mobility. The first dataset consists of weekly historical pricing and tax data at the city level, with a focus on the variable called Tintaxexc, which encompasses various taxes imposed on gasoline at the pump, including sales tax, excise tax, carbon tax, and other related charges. The specific tax reform of interest pertains to Ontario, where a reduction of 5.7 cents in the provincial excise tax was implemented on July 1st.

Certain variables were excluded from the datasets to adhere to necessary constraints when constructing empirical models. To ensure the parallel trend assumption between the treatment and control groups, all provinces included in the dataset needed to exhibit similar trends during the pre-treatment period leading up to the observed tax reform. Based on an analysis of historical tax changes in 2022, the pre-treatment period was defined as January 1st to July 1st. The controlled variables consist of Manitoba, Saskatchewan, British Columbia, and New Brunswick, while Ontario serves as the treatment variable [5]. Alberta is excluded from the control group due to a decrease in the federal carbon tax of approximately 11 cents on April 1st, which deviates from the pre-treatment linear trends assumption observed in other provinces. Prince Edward Island, Quebec, and Nova Scotia are also excluded from the control group due to tax reform changes occurring at various points in the pre-treatment period.

For the purpose of placebo testing, Newfoundland & Labrador is selected as a substitute for Ontario's outcomes. Newfoundland & Labrador is chosen due to its significant tax policy change on June 2nd and its relatively consistent trend compared to the selected controlled variables. Prince Edward Island and Nova Scotia are not utilized in the placebo test due to the relatively minor magnitude of their tax reform changes.

4. Modeling and Results

4.1. Ontario

Econometrically, it uses the dynamic difference-in-difference method to study the dynamic treatment effect of the gasoline tax reform [6]. As the long-term treatment effect may vary from the short-term treatment effect, it is important to have a reference period3 just before the tax reform to compare against. The model design controls for fixed effects are similar to Rivers & Schaufele [2]. This paper proposes the following model:

$$Y_{st} = \lambda_t + \phi_s + \sum_{\Gamma=T_0}^{-2} \beta_\Gamma * Treatment_{s\Gamma} + \sum_{\Gamma=0}^{T_1} \beta_\Gamma * Treatment_{s\Gamma} + X_{st} + \varepsilon_{st} \quad (1)$$

Where Y_{st} is the average gasoline retail price of province S during period t. λ_t is the time-fixed effect that captures time-specific unobservable. ϕ_s is the province fixed-effect that captures geographic unobservable and time-invariant characteristics for the province. X_{st} is the baseline province with no treatment effect at time period t. β_Γ is the change in the outcome of the treated province relative to the non-treatment province in the time period Γ. $Treatment_{s\Gamma}$ is an indicator variable equals 1 if the province had a policy reform in time period Γ and 0 otherwise. T_0 is the lead, the time period before policy reform. T_1 is the lags, the time period after policy reform. Finally, ε_{st} is

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the S province-specific error term for period T. It excluded the reference period Γ = -1 specifically to avoid multicollinearity issues.

The primary identifying assumption in our analysis is that the parallel trends assumption holds for the entire year of 2022 in the absence of tax reform. While it is impossible to empirically test this assumption since we cannot observe the counterfactual scenario in our universe, we can examine the trends during the pre-treatment period to gather supporting evidence for the validity of the parallel trend assumption. Figure 1 illustrates the comparison of retail gasoline prices between the control group and the treatment group throughout 2022. It observes that the average weekly difference in gasoline prices between the two groups prior to the tax reform is approximately 8 cents per liter. The 95% confidence interval associated with each data point provides a reasonably precise estimate of the potential range for that data point. Notably, the 95% confidence intervals for gasoline prices in both the control and treatment groups, before the tax reform, mostly overlap and exhibit a very similar trend. This finding serves as supporting evidence that the gasoline prices in both groups satisfied the parallel trend assumption prior to the tax reform.

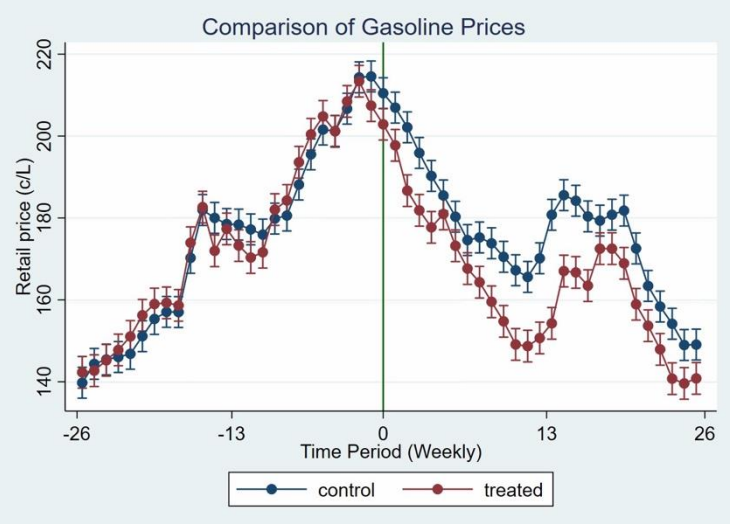

Figure 1: Comparison of gasoline prices of the control group and treatment group(ON), time period 0 is when the tax reform policy took place (Each data point has a 95% confidence interval as shown).

However, it did observe that the gasoline prices for both groups started to deviate from each other two weeks before the tax reform, and this trend of deviation continues throughout the tax reform period. Figure 2 presents the graph of our dynamic difference-in-difference estimation model. The X-axis is centered on the reference time period, which corresponds to the last week before the tax reform. In comparison to the reference period, the average dynamic treatment effect of the tax cut is approximately -13 cents per liter. The treatment effect of the tax cut appears to increase in the short run, reaching its peak after 13 weeks, and then gradually declines to a relatively stable level of around 5 cents per liter.

Regarding the interpretation of the average dynamic treatment effect, the preferred explanation is that a tax cut of 5.7 cents per liter would not directly lead to a decrease of 13 cents per liter in retail gasoline prices. It is improbable that a tax cut of that magnitude alone could produce such a substantial impact. When examining Figure 2, particularly the 95% confidence interval of the post-treatment periods, we find that the treatment effect consistently falls within a range of approximately 5-6 cents per liter decrease in retail gasoline prices. This indicates that we cannot reject the hypothesis that the treatment effect hovers around this range for the majority of the post-treatment periods, as it aligns with the confidence intervals.

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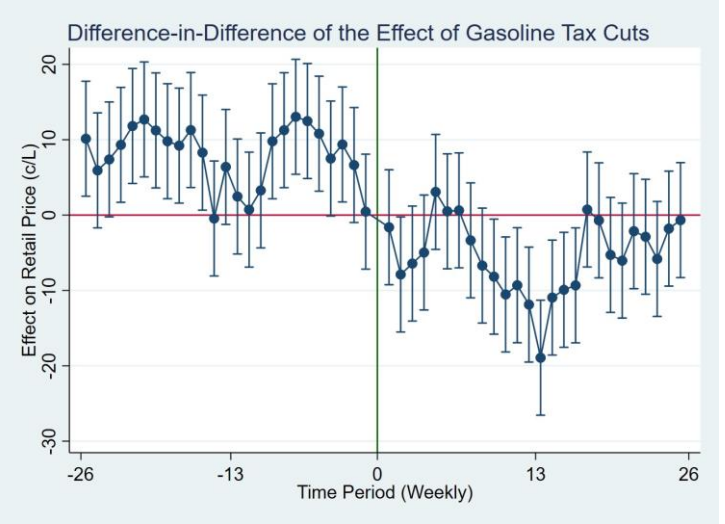

Figure 2: Result of the dynamic difference-in-difference estimation model on price (ON as treatment group).

It may be worthwhile to conduct a falsification test to investigate whether the significant dip observed during time period 13 is an unobservable characteristic that was not captured by the time-fixed effect and province-fixed effect. This additional analysis would provide valuable insights into the potential factors influencing the observed treatment effect and help validate the robustness of our findings.

4.2. Newfoundland & Labrador

This paper tests our model for another province to see if our hypothesis holds. We used the same criteria for control province selection and ended up with the same provinces in our control group. Note that the tax reform we are interested in happened on June 2nd 2022, in comparison the Ontario tax reform happened on July 1st 2022, this causes the referencing periods to be off by 4 periods. Newfoundland & Labrador is unique in the sense that a month prior to the major tax reform, there was a small tax change in the opposite direction, but this tax reform of 2 cents/L did not cause a significant price deviation as indicated by Figure 3.

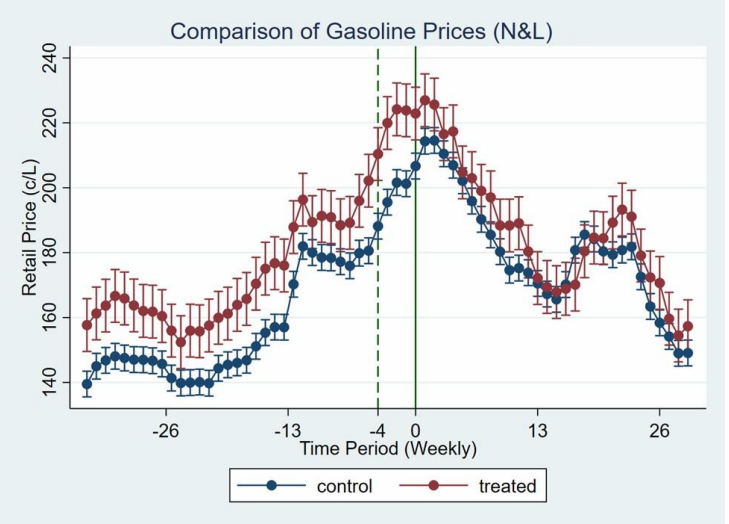

Figure 3: Comparison of gasoline prices of the control group and treatment group (N&L).

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Figure 3 displays the comparison of gasoline prices between the control and treatment groups before the small tax reform (before the dashed line), and it appears to support the parallel trend assumption. Both trends exhibit movements in the same direction and at the same time. Additionally, the gasoline prices in Newfoundland and Labrador are higher than those in the control group provinces prior to the tax reform. At time period -4, there is a small tax change resulting in a 2 cents per liter increase in gasoline prices. Time period 0 represents the major tax reform, where the provincial gasoline tax rate is reduced from 14.5 cents per liter to 7.5 cents per liter. Following the major tax reform, the time periods show a significant deviation from the previous trends, with a noticeable decrease in the price gap between the control and treatment groups. When examining the confidence intervals, it can be concluded that the gasoline retail prices differ between the control and treatment groups before the tax reform. However, after the major tax reform, the prices between the groups tend to overlap, making it challenging to reject the hypothesis that the prices between the control and treatment groups are the same.

Figure 4 presents a similar dynamic treatment effect to the Ontario gasoline tax reform depicted in Figure 2. Prior to the major tax reform, the coefficients exhibit a relatively linear pattern, and most of the 95% confidence intervals, which include 0, indicate that we cannot reject the null hypothesis that the treatment effect before the reform is zero. The coefficients of the last four weeks prior to the major tax reform are slightly higher on average due to the small tax increase of 2 cents per liter. In comparison to the reference period, the post-reform periods generally show negative coefficients, with most of them ranging from -10 cents per liter to -20 cents per liter. The majority of the 95% confidence intervals for the post-reform periods exclude 0 and include -7 cents per liter, providing support for our hypothesis that the tax reform has an impact on the price, and we cannot reject the notion that a 7 cents per liter tax cut on gasoline leads to a 7 cents per liter drop in gasoline price.

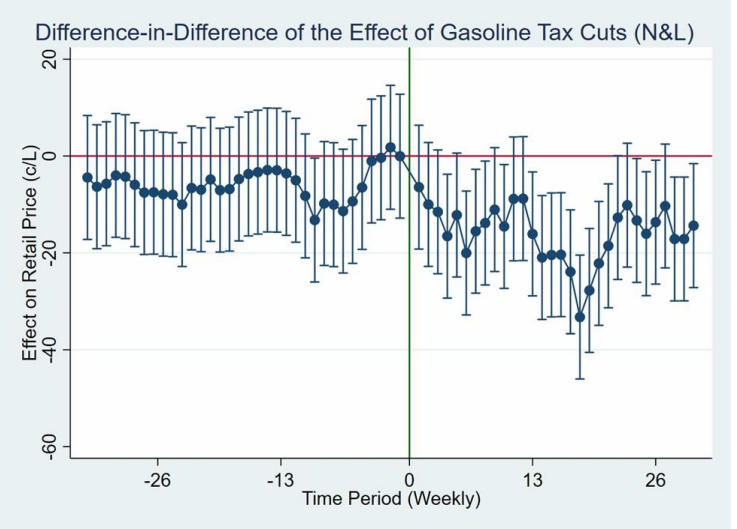

Figure 4: Result of the dynamic difference-in-difference estimation model for Newfoundland & Labrador.

When comparing the dynamic treatment effect in Newfoundland & Labrador (NL) to Ontario, it observes a similar trend where the treatment effect tends to increase in the short run, reaching its maximum at time period 17, and then gradually decreases to a relatively low level of around -10 cents per liter. It is worth noting that the short-run maximum effect is reached at time period 13 in Figure 2 and time period 17 in Figure 4. However, this discrepancy may not be directly caused by the tax reforms. Due to the difference in timing of the tax reforms, time period 13 in Figure 2 corresponds to the same date as time period 17 in Figure 4.

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The selection of Newfoundland & Labrador for this test was intentional, as the province has a different tax reform date compared to Ontario. This allows us to compare and contrast the dynamic treatment effect in the post-treatment periods. We have shown that the short-run treatment effect reaches its maximum at the same time for both Newfoundland & Labrador and Ontario, despite the implementation of the treatment differing by 4 weeks. This finding supports the idea that the "big dip" observed in Figures 2 and 4 may be influenced by characteristics related to time in the control group provinces. Given the limitations of the data and techniques in this paper, it cannot definitively reject the possibility that the treatment effect of gasoline tax reform varies over time. However, we have found supporting evidence that the differences in treatment effect may be attributed to unobservable characteristics related to time in the control group provinces. Therefore, we favor the alternative explanation that the provincial-level gasoline tax reform policy does have a causal effect on gasoline prices.

4.3. Robustness Checks

The dynamic difference-in-difference method in Figure 2 and Figure 4 are based on the parallel trend assumptions. We assume that there is no spillover between provinces, for gasoline consumption, as provinces are geographically large enough that any attempt to travel across provinces to fuel is costly. We performed several robustness checks to confirm the validity of these assumptions. The robustness checks performed in Table 1 and Table 2 provide additional evidence in support of the parallel trend assumption and the impact of the tax reform on pump-level pricing.

Table 1 presents the results of the ANOVA test for the pricing data in the pre-treatment period. The small difference in the Sum of Squares and Mean Squared values between the controlled and treated groups (5.14) indicates that the pre-treatment trends in both groups follow a similar pathway. The associated p-value of 92.4% suggests that it cannot reject the hypothesis that the gasoline prices between the two groups prior to tax reform are the same. This aligns with the observation in Figure 1, where the gasoline prices of the control and treatment groups show a similar trend with small variations. Table 2, on the other hand, presents the ANOVA test results for the pricing data in the post-treatment period. The large difference in the Sum of Squares and Mean Squared values between the controlled and treated groups (44,895) indicates a significant divergence in the post-treatment trends. The p-value close to zero indicates that we can reject the hypothesis of the gasoline prices between the two groups being the same in the post-treatment period. This is consistent with the observations in Figure 1, where the prices between the control and treatment groups deviate significantly after the tax reform.

The results from both tables are in line with the findings from the figures, confirming the parallel trend assumption and the impact of the tax reform on pump-level pricing. The pre-treatment periods exhibit similar trends, while the post-treatment periods show a distinct divergence between the two groups. These robustness checks strengthen the validity of the assumptions made in the analysis of the July 1st tax reform's effect on pump-level pricing in the controlled group.

Table 1: Pre-treatment shock robustness check of price between controlled and treated groups.

Source	SS	df	MS	F	Prob > F
Between groups	5.14137372	1	5.14137372	0.01	0.9243
Within groups	606349.145	1064	569.877016		
Total	606354.286	1065	569.346747		

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Table 2: Pre-treatment shock robustness check of price between controlled and treated groups.

Source	SS	df	MS	F	Prob > F
Between groups	44895.29	1	44895.29	151.08	0.0000
Within groups	316171.353	1064	297.153528		
Total	361066.643	1065	339.029712		

Conducting a placebo test is a valuable approach to strengthen the findings and address potential concerns. In this case, the placebo test was conducted using the dynamic difference-in-difference method for Newfoundland & Labrador gasoline price and tax reform policy. The test serves several purposes and provides additional insights into the research, it confirms the hypothesis of causality, stability of treatment effect over time, and differential treatment effects. The placebo test supports the hypothesis of causality by demonstrating similar results between Ontario and Newfoundland & Labrador. It reaffirms that a tax cut has a significant impact on lowering gasoline prices in both provinces. The placebo test provides supporting evidence that the treatment effect of tax reform does not significantly change over time. The observation that period 13 in Figure 2 corresponds to period 17 in Figure 4 suggests that the "big dip" observed could be attributed to unobservable factors related to time in the control group, rather than the actual tax reform. The placebo test confirms that Ontario and Newfoundland & Labrador have different treatment effects due to the different magnitudes of tax reform policy. Specifically, the 7 cents/L decrease in gasoline tax in Newfoundland & Labrador leads to a greater overall price decrease compared to the 5.7 cents/L decrease in Ontario, aligning with the expected outcomes. By conducting the placebo test, the study further strengthens the validity and robustness of the findings, providing additional evidence to support the hypotheses and conclusions drawn from the research.

5. Policy Implication and Limitations

The findings suggest that tax reform on gasoline prices has a substantial impact on service level price changes, with a pass-through rate close to 100%. This implies that policymakers can effectively utilize tax reform as a macroeconomic tool to combat inflation. Implementing a tax cut on gasoline results in a decrease in retail gasoline prices [7]. This reduction in gasoline prices has the potential to lower the transportation costs associated with goods and services, thereby reducing people's living expenses. Additionally, it may incentivize saving among individuals. These findings highlight the potential benefits of using tax reform to address inflationary pressures and provide economic relief to consumers. By implementing targeted tax cuts on gasoline, policymakers can effectively alleviate the financial burden on households and stimulate economic activity. It is important for policymakers to consider the potential positive impact of gasoline tax reform on reducing living expenses and promoting savings [8]. However, it is essential to balance these benefits with other factors such as environmental concerns and revenue implications [9]. Policymakers should carefully evaluate the broader implications and trade-offs associated with tax reform measures to ensure a comprehensive and sustainable approach to macroeconomic management [10].

There are several limitations to our analysis. The exclusion of provinces due to federal-level carbon tax changes limits the generalizability of the findings. The omitted provinces may have different characteristics and dynamics that could affect the treatment effect of gasoline tax reform. Therefore, it is important to acknowledge that the findings may not be applicable to those excluded provinces, and caution should be exercised when extrapolating the results. There could also exist heterogeneous treatment effect bias, provinces can vary in terms of their economic structure, demographics, and other factors, which may lead to heterogeneous treatment effects of gasoline tax reform [9]. The

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treatment effect observed in Ontario may not necessarily represent the treatment effect in other provinces, such as Alberta. It is essential to recognize the potential differences across provinces and consider the heterogeneity when formulating policy recommendations. The presence of potential unobservable characteristics related to time in the control group introduces the possibility of omitted variable bias. Failure to account for these unobservable factors may impact the validity of the dynamic treatment effect estimated for gasoline prices. It is important to acknowledge this limitation and recognize that there may be additional factors influencing the observed treatment effects.

6. Conclusion

This paper presents an analysis of the causal relationship between tax reforms and gasoline prices using provincial-level data. The dynamic difference-in-difference method is employed to estimate the treatment effect of tax cuts on gasoline prices. The findings indicate that tax reductions on gasoline lead to a decrease in the retail price of gasoline, thus confirming the causal relationship. In contrast to Harju et al.'s paper that examined the pass-through rate of carbon taxes, this paper finds a pass-through rate of more than 100% on average for the tax reductions in Ontario and Newfoundland & Labrador. One possible explanation for this result is that the 95% confidence interval for the data points does not provide enough statistical power to reject the null hypothesis that the treatment effect is less than or close to 100% of the tax reduction.

While the study does not reject the possibility of the treatment effect changing over time, it does provide supporting evidence for explaining the largest change in the treatment effect. This change may be attributed to unobservable characteristics related to time in the control provinces, as suggested by placebo tests. It is important to note that these findings are based on the specific context of the analysis and the data available. Further research is needed to validate and generalize these results. Additionally, considering the limitations and potential biases discussed earlier, caution should be exercised when interpreting the findings and making policy implications based on them.

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