Incidence of Gasoline Taxes in Canada: An Event Study Approach to Estimating Pass-through

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ABSTRACT

This study investigates the city-level pass-through rates of provincial and carbon tax changes on wholesale and retail gasoline prices in Canada from 1998 to 2024. Focusing on tax increases and decreases, the analysis measures pass-through rates to explore the impact of tax policies on gasoline prices across Canada. This study also analyses the tax incidence of medium/small cities and large cities separately to examine regional pass-through rates. Data is collected from Kent Marketing Ltd and Statistics Canada to create panel datasets for an event-based difference-in-difference model. Event plots show an immediate response in retail gasoline prices following tax changes; however, retail prices begin to adjust even before the implementation of tax policies. The estimated pass-through rate of gasoline tax increases on retail prices is 100% in the 9-week window and 88% in the 17-week window. For tax decreases, the pass-through rates are even higher, at 120% in the 9-week window and 140% in the 17-week window. The analysis also reveals the significant impact of tax changes on retail prices in medium/small cities and large cities. However, the study finds that the impact of gasoline tax changes on wholesale prices is statistically insignificant for both the 9-week and 17-week windows. Additionally, results from the 9-week window gasoline tax analysis without fixed effects and covariates are insignificant, underscoring the importance of accounting for these factors. In conclusion, the findings of this study emphasize the crucial role of provincial and carbon tax policies in shaping retail gasoline prices, while highlighting the limited impact on wholesale prices in Canada.

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CHAPTER ONE

INTRODUCTION

1.1 Motivations and Objectives of the Study

Gasoline tax policies in Canada have been adjusted or changed several times over the last 25 years, either through implementing and increasing carbon tax or changing provincial tax rates. The change in gasoline taxes emphasizes the need to understand how these changes affect retail and wholesale gasoline prices. The impact of fuel taxes on gasoline prices is important because these tax policies have the potential to influence household consumption of gasoline, which can reduce overuse of non-renewable natural resources, reduce traffic problems and accident risk, and eventually contribute to the wellbeing of society. There are common debates among researchers and policymakers about the pass-through of gasoline tax policies on prices and suggest that tax plays an important role in changing gasoline prices (Chouinard & Perloff, 2004; Barron et al., 2004; Doyle & Samphanthark, 2008; Alm et al., 2009; Erutku, 2019; Jametti et al., 2013; Marion & Muehlegger, 2011; Silvia & Taylor, 2016; Gittens, 2019; Stolper, 2016). For instance, Silvia and Taylor (2016) estimate Washington's 100% pass-through rate for gasoline and diesel taxes. Tsvetanov (2022) found 79% pass-through rates in the US after suspending the gasoline tax in 2022. In contrast, Sun et al. (2022) reported that in China, 49% of the diesel taxes were passed on to consumers. The estimated pass-through rate explains how tax policies are distributed among consumers, retailers, and wholesalers. The pass-through rate also describes the impact of gasoline tax changes on consumer’s purchasing prices. The extent to which the changes in gasoline tax policies are passed to the wholesale and retail prices is crucial to understanding the effectiveness of tax changes.

Gasoline tax policy has become an important topic of discussion due to increasing carbon taxes and the reduction or suspension of provincial taxes (Wood, 2024; Global News, 2023). Carbon taxes play an important role in increasing gasoline tax rates in Canada. The gasoline carbon tax has increased significantly, with an intention to reduce greenhouse gas emissions in Canada. Starting April 1, 2023, the carbon tax on gasoline increased to $65 per ton of emissions, translating to an additional 3 cents/litre of gasoline at the pump, bringing the total carbon charge to approximately 14 cents/litre. Ontario, Manitoba, Saskatchewan, Alberta, Yukon, and Nunavut are set to see annual increases in the carbon tax from 2023 to 2030 (Aziz, 2023). The carbon tax increased in Newfoundland and Labrador, Nova Scotia, and Prince Edward Island on July 1, 2023 (Aziz, 2023). This increase in the gasoline carbon tax is a key element of Canada's ongoing efforts to cut carbon emissions and reach net zero by 2050 (Aziz, 2023). The effectiveness of the carbon tax in lowering greenhouse gas emissions relies on how much of the tax is passed on to consumers. The provincial gas tax in Canada also increased several times in the last decades, which also could have an impact on gasoline prices. Therefore, this study estimates the pass-through of gasoline tax increases including both provincial and carbon tax rates to understand the aggregate impact of gasoline tax increases on retail and wholesale prices.

Recently, Canadian provinces have decreased gasoline tax rates to deal with the sharp increase in gasoline prices. Alberta launched a “gas tax holiday” on April 1, 2022, pausing its 13 cents/litre provincial fuel tax on gasoline and diesel (Galay, 2022, French, 2022, Wood, 2024). Alberta returned from a “gas tax holiday” on January 1, 2024, and imposed a 9 cents/litre provincial tax (Wood, 2024). A key argument for implementing a policy like suspending the gasoline tax is that it addresses the price burden on consumers (Tsvetanov, 2022). Gas tax holidays lead to lower prices, with the estimate for Alberta showing that 87% to 93% of the tax savings were passed on to consumers in the short term (Wood, 2024). Galay (2022) stated that gasoline prices in Alberta declined by more than 13 cents/litre after the "gas tax holiday" and the full benefit of the tax holiday was passed to the consumers. Starting July 1, 2022, Ontario lowered its gasoline tax by 5.7 cents/litre and its fuel tax by 5.3 cents/litre which last until December 31, 2024 (Wood, 2024; Sun, 2023). Newfoundland and Labrador also reduced its provincial tax from 14.5 cents/litre to 7.5 cents/litre in 2022 (Kent Marketing Ltd., 2024) and continued until 2024 (Sims and Haubrich, 2024). The benefit of decreasing the provincial gasoline tax is significantly and immediately passed to the consumer's retail price in both Ontario and Newfoundland and Labrador (Sun, 2023). Manitoba suspended its 14 cents/litre provincial excise tax from January 1, 2024, and continued until December 31, 2024 (Manitoba Finance, 2024; Wood, 2024; Sims and Haubrich, 2024). Alberta also paused its 6.73 cents/litre carbon tax from May 31, 2019, to December 31, 2019 (Kent Marketing Ltd., 2024). Both provincial and carbon taxes are decreased several times by the provinces in Canada. The main purpose of the reduction of gasoline tax rates or gasoline tax holidays is to ease the financial burden on consumers at the gas station by decreasing gasoline prices. Understanding the extent to which the benefit of tax decreases is passed to the consumer's retail price is crucial to achieving the goals of gasoline tax decrease policies in Canada. However, there are limited studies that consider all the tax decrease incidences of all provinces from 1998 to 2024 in Canada to estimate pass-through of gasoline taxes. Therefore, the study estimates pass-through of gasoline tax decreases on the retail and wholesale prices in Canada.

The effects of gasoline tax changes may not be consistent across Canada, as medium/small cities and large cities display unique characteristics that can influence the impact of these taxes on gasoline prices. Specifically, differences in demand patterns and transportation options between these cities can play a critical role in shaping tax incidence. The price elasticity of gasoline demand varies across cities. Rural households in the U.S. have a lower price elasticity of -0.17 compared to urban areas, which have a price elasticity of -0.3 (Wadud et al., 2009). Price elasticities play an important role in analysing how changes in gasoline taxes affect retail and wholesale prices. Additionally, the availability of public transportation is also related to the price elasticity of gasoline demand. Cities with public transit have an average price elasticity of 0.22, while those without public transit have an average of 0.12 (Barla et al., 2015). Residents in rural regions tend to drive more due to the limited availability of public transportation options such as buses, trains, and metros in rural areas, unlike in urban cities (Blow and Crawford (1997). However, Saelen and Kallbekken (2011) noted that the availability of other transportation options did not greatly affect how people responded to the change in fuel taxes. Given these differences in price elasticity and transportation options, this study analyses the gasoline tax incidence in Canada's medium/small cities and large cities to fully understand the overall impact of gasoline tax policies on consumers.

The main goal of this study is to examine the pass-through of gasoline tax changes in retail and wholesale gasoline prices in Canada as well as large cities and medium/small cities, using a dataset spanning 1998 to 2024. This study considers weekly retail and wholesale price and tax data for 63 and 54 cities, respectively, across eight provinces. This study aims to focus on two types of fuel taxes imposed on the retail and wholesale prices of gasoline in Canada: provincial taxes and carbon taxes. Specifically, the study aims to estimate the pass-through rate of gasoline tax increases and decreases considering both provincial and carbon taxes. This study proposes to use the magnitude of retail and wholesale prices response to tax change "events" to ascertain the overall tax incidence over an extended period. Over 26 years, this study observes 35 tax change events for gasoline in Canada where 28 events for tax increases and seven events for tax decreases. Considering all events, a city-level aggregate pass-through rate is calculated for gasoline, for which this study follows the Cengiz et al. (2019), which analyses the effect of minimum wages on low-wage jobs in the US using an event-by-event difference-in-difference approach.

This study specifically ascertains the following research questions:

1. What proportion of gasoline tax that consumers pay when the gasoline tax changes?
2. How is gasoline tax incidence distributed among consumers, retailers or wholesalers?
3. Is tax change immediately passed to the consumers, or does it take time?
4. What are the pass-through rates of the gasoline tax in medium/small and large cities?

To obtain the answers to the above questions, this study begins with an analysis of tax incidence over a 9-week window for all cities in Canada, and separately for medium/small and large cities. After that, to check robustness, this study examines tax incidence over a 17-week window using methods similar to those used in the 9-week window. Finally, this study does another robustness test that uses the same 9-week window but does not consider any fixed effects and covariates. The impact of fuel taxes on gasoline's retail and wholesale prices is estimated by utilising the following steps:

1. Firstly, this study creates event-specific weekly panel datasets for retail and wholesale prices of gasoline separately, including the treatment cities and all other clean control groups for each event.
2. After creating the longitudinal panel datasets, this study classifies the whole event-based panel dataset into two segments to aggregate the events. The segments are: 1) gasoline tax increases, and 2) gasoline tax decreases. This study analyses each segment separately.
3. After that, this study generates event plots to explore the treatment effects with variation of time using the estimated event-specific point estimates for each event week, derived from the difference-in-difference regression.

4. Finally, this study analyses the difference-in-difference model to estimate the post-treatment effect of tax incidence on the retail and wholesale price of gasoline. This study estimates pass-through rates using the difference-in-difference estimates.

This study assesses the treatment group effects on gasoline prices through the event-based analysis with dummy explanatory variables. The study allows for a precise measurement of how new taxes or changes in existing taxes directly affect the retail and wholesale price of gasoline in Canada. The study investigates the impact of tax changes on gasoline prices over time, focusing on how quickly these changes are reflected in retail prices. The study also expects that any adjustments to taxes may result in an immediate effect on gasoline prices, with minimal delay in the pass-through to consumers.

The study finds the pass-through rate of gasoline tax increases for the 9-week window to retail prices is 100%. Previous studies also support the findings of a 100% pass-through rate for gasoline retail prices (Silvia and Taylor, 2016; Stopler, 2016; Alm et al., 2009). Additionally, the study finds the pass-through rate of tax decreases in the 9-week window is 120% for the consumer's retail price in Canada, similar to the results in Marion & Muehlegger (2011). The study also estimates pass-through rates for large cities and medium/small cities. This study finds a significant impact of tax policy changes on Canada's retail gasoline prices. However, pass-through rates for wholesale prices are insignificant. Overall, the findings of this study indicate that tax changes significantly affect retail gasoline prices in Canada as well as in medium/small and large cities.

1.2 Organization of the Study

This study has seven chapters that investigate the effect of changing gasoline taxes on retail and wholesale prices in Canada. Chapter 1 discusses the motivation and objectives of the study.

Chapter 2 provides literature on gasoline tax policies and the background of the gasoline market in Canada. Chapter 2 also discusses the studies of gasoline tax incidence in other countries. Chapter 3 presents the methodology of this thesis which includes the theoretical background of the tax incidence, the empirical method, and the data used for analysis. Chapter 4 presents the results of the econometric model for the 9-week window tax incidence. Chapter 5 presents the findings of the robustness check and discusses the overall impact of tax incidence. The conclusion with limitations and recommendations of the study is discussed in Chapter 6.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Institutional Background

In Canada, gasoline tax is classified into several layers such as federal and provincial excise taxes, the Goods and Services Tax (GST), and Provincial Sales Taxes (PST) (Jammiti et al., 2013; Preville, 2016; Natural Resources Canada, 2011; Holmes et al., 2022). The federal excise tax on gasoline is the same across Canada, added on top of other costs like crude oil prices and refining expenses. Each province also has its excise tax. GST is applied to the total price of gasoline in all provinces. In New Brunswick, Nova Scotia, and Newfoundland, this tax is included in a combined tax called the Harmonized Sales Tax (HST). Quebec, however, charges a separate PST on the total cost of gasoline (Jammiti et al., 2013). Canada has had a fixed federal gasoline tax of 10 cents/litre and a 5% federal GST since 1995 (Holmes et al., 2022). Ad valorem sales taxes are charged as a percentage of the retail price (Holmes et al., 2022).

The complexity of Canada's tax structure leads to significant variations in gasoline prices across Canadian cities and provinces. Provincial taxes on gasoline include a provincial excise tax and, where applicable, sales or carbon taxes. These taxes vary by province, ranging from 9 cents/litre in Alberta to 16.5 cents/litre in Newfoundland and Labrador, with an average of approximately 13 cents/litre added to the retail gas price (McGinley, 2011). In 2010, combined federal and provincial taxes contributed 34 cents/litre to the price at the pump. Additionally, Vancouver, Montreal, and Victoria are the three Canadian municipalities that impose a transportation tax, which adds an extra 4.8 cents/litre (McGinley, 2011).

In Canada, gasoline taxes are set at federal, provincial, and regional levels. For example, British Columbia has a regional gasoline tax of $0.17/litre in Metro Vancouver, plus a provincial tax of $0.1517/litre and a federal tax of $0.1/litre (Wood, 2015). There is a discussion in Ontario about a plan to add a 5 cents/litre regional gasoline tax in the Greater Toronto-Hamilton Area (GTHA), which would have brought the total gasoline tax to 29.7 cents/litre (Wood, 2015). However, the provincial government decided not to change the tax. This shows that regional gasoline taxes are possible in Canada and could be considered for the GTHA (Wood, 2015).

Canadian energy policy has undergone various modifications considering gasoline taxes; changes in taxation can affect everything from consumer prices at the pump to government revenue and environmental goals. The reactions often vary depending on how these changes impact different groups, such as consumers, businesses, and environmental advocates. Gasoline taxes in North America face challenges related to public acceptance, environmental concerns, and the impact of regional tax variations. Hsu (2010) empirically analyzed the politics and psychology of gasoline taxes in North America in 2006. Hsu (2010) observes that increasing gasoline prices due to a rise in tax rates leads to a significant and immediate decline in gasoline consumption. Hsu (2010) also investigated the factors that influence the willingness to support gasoline tax. Firstly, Hsu (2010) found that technological solutions to improve the environment were an important reason for the lack of support for a tax increase in gasoline, so users felt no need to reduce consumption to reduce carbon emissions. However, technological solutions for motor vehicles would not be helpful if gasoline consumption is not reduced. Secondly, encouraging public transport over cars could help people to accept a gasoline tax increase willingly (Hsu, 2010).

Climate change is a major global issue, and Canada is not exempt from these concerns. Canada's greenhouse gas emissions have steadily risen by 16.5% from 1990 to 2022, however, it reduced by 7.1% between 2005 and 2022 (Environment and Climate Change Canada, 2024). A carbon tax on gasoline is applied to deal with the consequences of climate change and greenhouse gas emissions. However, after a strong debate among economists and policymakers, past literature suggested carbon tax as the most effective and efficient policy for addressing greenhouse gas emissions in Canada (Antweiler and Gulati, 2012; Harrison, 2012; Rivers and Wigle, 2018). Chaput (2012) stated that Canada, though responsible for just 1.5% of global greenhouse gas (GHG) emissions, ranks among the highest in per capita emissions. To investigate the relationship between gasoline tax and carbon emissions in Canada, Chaput (2012) developed an empirical model using monthly data from 1987 to 2010 and found that a 10-cent hike in gasoline tax could reduce carbon emissions by 0.39% in Canada. On July 1, 2008, British Columbia was the first province that launch a carbon tax to reduce carbon emissions in Canada, starting at \$10 per ton of CO_2 equivalent emissions and increasing by \$5 annually to \$30/tCO_2e by July 1, 2012. This tax applies to fuel purchases and usage across the province (Antweiler and Gulati, 2012). A revenue-neutral carbon tax is the most cost-effective way to cut greenhouse gas emissions compared to other policies like fuel economy rules, clean fuel standards, or zero-emission vehicle mandates.

More specifically, Rivers and Wigle (2018) investigated different methods for reducing emissions from road travel in Canada. Findings showed that the cost of a carbon tax could be greatly reduced if the tax revenue was used to lower other taxes, making it revenue-neutral. This approach encouraged people to drive less, choose greener transport options, use cleaner fuels, and buy more fuel-efficient vehicles. In contrast, other policies did not provide all these benefits. Despite the advantages of fuel and carbon taxes in achieving environmental goals, policymakers often stay away from these measures due to their political unpopularity, favouring less controversial regulations instead (Rivers and Wigle, 2018; Antweiler and Gulati, 2012).

The literature has extensively covered the structure of gasoline taxes, historical tax changes, and their effects on gasoline prices. However, there is limited research on the impact of recent policy changes, such as the implementation of carbon pricing mechanisms and the reduction of excise taxes in specific provinces. While several studies have investigated provincial variations in gasoline taxes and their effects, there is a need for a comparative analysis that explicitly examines how different provincial tax changes impact retail gasoline prices. An event study approach could offer timely insights into the effectiveness of these policies in influencing gasoline prices in Canada.

2.2 Review of the Gasoline Market in Canada

Several past research focused on the pricing behaviour of the gasoline market in Canada and how it responds to variations in time, ownership, fuel efficiency, and policy regulation. Specifically, Noel (2003) focused on examining the responsiveness and adjustment patterns of retail gasoline prices to changes in underlying costs, such as wholesale fuel prices across 19 Canadian cities over 574 weeks. The study identified three key pricing behaviours. The first, standard cost-based pricing, involved retail prices closely following changes in wholesale prices. The second, sticky pricing, referred to instances where retail prices were slow to adjust despite changes in wholesale prices. The third, steep asymmetric pricing, was characterized by a quicker increase in retail prices when wholesale prices rose, but a slower decline when costs fell. This analysis sheds light on how retailers respond to fluctuations in their cost structures and the presence of potential pricing inefficiencies or strategic behaviour in gasoline markets. This study also examined the impact of these pricing patterns on welfare and policy and compared the findings to similar gasoline markets in the United States.

Suvankulov et al. (2012) explored how price regulation in Nova Scotia and New Brunswick, which started on July 1, 2006, affected price changes in the Canadian retail gasoline market. Here, price regulation was the minimum and maximum price set by the Department of Service Nova Scotia and Municipal Relations in Nova Scotia and the minimum gasoline price set by the Public Energy and Utilities Board in New Brunswick. The study used monthly price data from 60 Canadian cities between 2000 and 2010. The results showed that the impact of price regulation on price changes was mixed. The study found that in New Brunswick, gasoline prices in nine cities aligned with the average price of Canada, with reduced volatility. However, in Nova Scotia, gasoline prices in six cities were more volatile and higher than Canada's average prices. Similarly, Carranza et al. (2015) studied the long-run impact of price floor on the retail market structure of gasoline in Québec. A detailed econometric analysis was used using station-level data from 1991 to 2001 of five cities in Québec. The results showed that the policy of price floor slowed industry changes, making it harder for large stations to enter the market and helping smaller stations stay in business. The study also suggested that the policy reduced per-station sales and increased gasoline prices which decreased gasoline market efficiency in Québec.

On the other hand, Mann (2016) investigated asymmetric relationships among the daily prices of crude oil, rack (wholesale) gasoline, and retail gasoline from 2008 to 2011 using the threshold co-integration technique. Evidence showed that crude, rack and retail prices vary until they align with a set markup margin, with deviations only adjusting when reaching certain limits. This means the "rockets and feathers" effect, where prices rise quickly but fall slowly, was not observed. Holmes et al. (2022) investigated the convergence of retail gasoline prices across 44 Canadian cities over nearly two decades. Using a comprehensive dataset that included prices for regular, mid-grade, and premium gasoline, both with and without taxes, it examined how gasoline prices behave in different cities and whether these cities form groups with similar price movements, known as "convergence clubs". The study found that Canadian retail gasoline markets were not fully integrated. This means that instead of moving together as one market, prices in different cities often from multiple convergence clubs. These clubs represented groups of cities where gasoline prices followed similar patterns but were different from those in other clubs. For instance, cities within the same province are more likely to belong to the same convergence club, suggesting regional factors play a strong role in price formation. However, distances between cities, differences in fuel quality, transportation costs and specific provincial tax regimes also contributed to price divergence in different convergence clubs.

In the Canadian gasoline industry, firms can be categorized into two main types: vertically integrated firms and independent retailers. Vertically integrated firms manage operations across the entire supply chain, from crude oil exploration and production to refining and retail sales, and they operate on both national and regional scales. Independent retailers, on the other hand, focus solely on downstream activities and do not own refineries (Sen and Townley, 2010). The retail gasoline industry in Canada is characterized by a mix of refiner-owned brands and non-refiner marketers. In 2016, there were 69 distinct companies involved in the marketing of retail petroleum brands across Canada, with 41 operating in Ontario alone (Kent Group Ltd., 2017). A significant portion of these companies are non-refiners, meaning they do not produce fuel but instead focus on marketing and distribution. In Ontario, refiner-owned brands, such as Petro-Canada, Shell, and Esso, accounted for 53% of the province’s 3,228 retail gasoline stations in 2016 (Kent Group Ltd., 2017). This trend mirrors the national level, where refiner-owned brands also represented 53% of Canada’s 11,931 retail fuel stations (Kent Group Ltd., 2017). The remaining stations either sold fuel under their brand or offered unbranded products (Kent Group Ltd., 2017).

The Canadian gasoline retail market has undergone significant transformation from the late 1970s to the 2000s, driven by mergers, acquisitions, and key regulatory changes. For instance, Petro-Canada is one of the largest refiner-owned brands that grew substantially from 1979 to 1985 through various acquisitions, positioning its place among the top three gasoline retailers in Canada (Eckert and West, 2005). Meanwhile, in 1990, the market saw another significant shift when Imperial Oil Limited, known for its Esso brand, took over Texaco Canada Inc (Eckert and West, 2005). During the same period, the oil industry experienced notable mergers in Canada. This transformation in the Canadian gasoline retail market during the 1990s reduced the number of gas stations by 40% (Eckert, 2014). Analysis of data from 12 cities between 1990 and 2005 reveals that regulatory changes and market entry events were crucial in shaping this transition. Notable regulatory shifts included the removal of price ceilings in Nova Scotia (1991), the introduction of price ceilings in Newfoundland (2001), and the adoption of a price floor in Quebec (1997) (Eckert, 2014). Additionally, retail gasoline markets were influenced by the entry of ARCO into Vancouver in 1998 and the expansion of grocery and big-box retailers like Safeway and Walmart (Eckert, 2014).

In Canada, the number of gasoline stations plays an important role in the gasoline market (Eckert and West, 2005; Sen and Choi, 2009; and Sen and Townley, 2010). The number of gas stations fell from 23,952 to 22,000 between 1980 and 1989 (Sen & Townley, 2010). This downward trend continued, and by 2000, the number of stations declined again by 40%, reaching just 13,250 (Sen & Townley, 2010). Between 1991 and 1997, a 27% reduction in retail gasoline outlets was observed across ten Canadian cities (Sen & Townley, 2010). On the other hand, retail gasoline prices increased by 9%, market concentration rose by 16-22%, and average sales per outlet surged by 22%. From 1980 to 2001, sales of gasoline in the retail market increased by 9.3% in Canada (Eckert and West, 2005).

Kalibrate Canada (2023) further reported that, by the end of 2022, there were 11,893 retail gasoline stations in Canada, representing 3.1 outlets per 10,000 people. The number of stations has remained stable at around 12,000 since 2008, following a significant decline in earlier decades. Esso-branded stations accounted for 17% of all sites, while Parkland Fuel Corporation, a lesser-known company, marketed 18% of stations. Despite the presence of large oil companies, only 22% of stations had their prices set by integrated refiner marketers, with the majority, 78%, controlled by dealers or non-refiner marketers. Sen and Choi (2009) suggest that the number of local competitors implies gasoline supply had negative effects on each retail outlet's pricing decision and market share. This study utilized a panel dataset on station-specific retail prices of five cities in Canada for 2007. The results showed that having one more gas station within a 3 km radius was linked to a drop in gas prices of about 0.03 to 0.04 cents/litre. Additionally, if another station from the same company was present, prices tended to fall by 0.15 cents per litre, suggesting that more supply may result in a lowered gasoline price in Canada.

Gasoline demand elasticity measures how much the consumers' demand for gasoline will change in response to price changes. Understanding gasoline demand elasticity is crucial for policymakers, particularly in the context of energy policy and taxation. Given the country's vast geography, varying climate, and significant reliance on automobiles for transportation, gasoline demand has been the subject of extensive research that found an inelastic demand in response to gasoline prices in Canada (Gallini, 1983; Nicol, 2003; Barla et al., 2009; and Chang and Serletis, 2014). Nicol (2003) suggested that in both Canada and the United States, the gasoline demand was inelastic in response to changes in price or income. To estimate elasticities, data from the Canadian

Family Expenditure (FAMEX) survey and the United States Consumer Expenditure (CEX) survey were used. It found that gasoline demand in Canada was more sensitive to changes in price compared to the United States. Chang and Serletis (2014) examine the demand for gasoline in Canada by analyzing annual spending data from the Canadian Survey of Household Spending between 1997 and 2009. This study estimated an inelastic gasoline demand, ranging from -0.738 to -0.57 in response to price fluctuations.

Several past studies have examined how changes in tax policy affect the gasoline demand in Canada. Rivers and Schaufele (2012) provide the first evidence of how a carbon tax affects North American households' short-term gasoline choices. They analyzed monthly data on gasoline prices and consumption from British Columbia and Ontario between January 2000 and July 2008. Their findings showed that a five-cent increase in gasoline prices led to a 1.8% decrease in consumption in the short term. However, a five-cent increase in the carbon tax resulted in a much larger 12.5% decrease in gasoline use. This indicates that people are more responsive to carbon tax changes than to regular market price changes in British Columbia and Ontario.

Antweiler and Gulati (2016) look at how different types of fuel taxes—such as carbon taxes, provincial and municipal excise taxes, and sales taxes—affected gasoline uses and car purchases in the short term. They also considered cross-border trips to avoid mistakes due to the favourable Canada-US exchange rate from 2010 to 2014. Their study found that from 2007 to 2014, gasoline use per person dropped by about 15%. The results suggest that without British Columbia's carbon tax, fuel consumption per person would have been 7% higher, and the average vehicle would have been 4% less fuel-efficient.

Lawley and Thivierge (2018) studied how British Columbia’s carbon tax affected household gasoline use. They used household spending data and adjusted for two possible issues:

major improvements in public transit and increased cross-border trips between BC and Washington. The study applied log-linear and log-log models to analyze the impact of gasoline prices and carbon taxes on gasoline demand. They found that the price sensitivity of gasoline demand ranged from –0.004 in Alberta to –0.008 in Quebec. Their results indicated that a 5 cent/litre carbon tax reduced use by an average of 8%.

Most of the existing studies have highlighted gasoline prices, gasoline demand and supply and the responsiveness of consumers to gasoline price changes while some studies on gasoline tax incidence in Canada. Erutku (2019) and Sun (2023) studied the impact of tax policy on gasoline prices, related to this thesis. Erutku (2019) examines how carbon pricing affects the wholesale gasoline markets in Ontario and Quebec. The study estimated the carbon price based on the cost of emission allowances from quarterly auctions in Quebec's regional carbon market (RCM) and the Ontario cap-and-trade program (OCTP). The study looked at how this carbon price was passed on to gasoline prices in both provinces, both together and separately. From ordinary least squares regression, jointly, it found that both provinces' pass-through rate of carbon pricing was equal to 1. Individually, in Ontario, it ranged from 126% to 138%, and in Quebec, it was 75%.

Sun (2023) studies the impact of excise tax reduction in Ontario on July 1, 2022, on consumers retail price of gasoline. It used city-level data and a dynamic difference-in-difference model with a 26-week window. Here, the cities in Ontario were considered as treated groups. However, cities in Manitoba, Saskatchewan, British Columbia, and New Brunswick with unchanged tax policies were considered as control groups. To check robustness, it analyzed Newfoundland & Labrador's tax reform that occurred on June 2, 2022. The findings showed that the pass-through rate was close to 100%. However, there is a lack of detailed, event-specific analyses that examine the immediate effects of all tax change events on gasoline prices for the period of 1998 to 2024. Hence, in this thesis, I consider all the tax change events applying an event-based difference-in-difference approach that could shed light on how consumers and retailers adjust to tax changes over time in Canada.

2.3 Empirical Studies on Tax Incidence

Several studies focus on fuel tax incidence in the US and other countries. Muehlegger (2004) examines how state-level regulations on gasoline content affected price hikes in California, Illinois, and Wisconsin. It used a model based on refiners' production decisions to simulate wholesale prices for jet fuel, diesel, and four types of gasoline in these states. Then it created a hypothetical dataset where gasoline met the federal reformulated gasoline (RFG) standards of all three states. Results from sensitivity tests showed that gasoline compatibility with federal reformulated gasoline (RFG) regulation significantly affects the gasoline price hike.

A study by Chouinard and Perloff (2004) investigate the impact of gasoline taxes at both the federal and state levels on wholesale and retail prices using monthly data in the USA from 1989 to 1997. Findings from the reduced-form equation showed that the pass-through rate of federal tax is 47% and state tax is 67%. Barron et al. (2004) also found around a 67% pass-through rate of the state excise tax on gasoline retail price for 2000 in the USA. They used bi-weekly data and the difference-in-difference method to analyze the pass-through rate.

Doyle and Samphanthark (2008) mainly focus on the impact of changing gasoline tax policies on the retail prices of neighbouring provinces in the USA. The pass-through rate was 80 - 100% of the ad-valorem gasoline tax of Indiana and Illinois in 2000. Alm et al. (2009) analyses the pass-through rate of state excise taxes from 1984 to 1999. Monthly data from 50 US states were used, and results from the reduced form analysis showed a 100% pass-through of state excise tax to the retail price of gasoline. Marion and Muehlegger (2011) analyse the impact of gasoline and diesel fuel taxes on prices, using monthly retail data from U.S. states between 1983 and 2003. They found that state taxes were passed on to consumers at a rate of 122%, while federal taxes had a pass-through rate of 110%.

Li, Linn and Muehlegger's (2012) purpose was to measure how consumers react to gasoline taxes directly. The study analyzed consumer behaviour over short periods by looking at vehicle miles travelled (VMT) for the intensive margin, and vehicle fuel economy (miles per gallon, MPG) for the extensive margin. Total gasoline consumption was determined by combining these two factors. The research used two different data sets: one with state-level data on gasoline consumption and another with household-level data on VMT and MPG. The estimated results showed that rising gasoline taxes significantly reduced gasoline consumption much more than comparable increases in gasoline prices.

Silvia and Taylor (2016) analyse Washington's gasoline and diesel excise tax incidence using weekly station-level retail price data from January to December 2003. They noticed that the pass-through rate from the difference-in-difference regression was 100%. Stopler (2016) studies the pass-through of diesel tax incidence in Spain using station-specific daily retail price data from 2007 to 2013. It used a 6-month window with 12 weeks before and after-tax change for the event study. Findings from the difference-in-differences regression showed that the average pass-through rate was 100% but around 70% to 120% at the station level.

Using confidential household data, Spiller, Stephens, and Chen (2017) estimate how a 60-cent federal gasoline tax increase would affect households differently based on their location and demographics, focusing on variations in gasoline price elasticity and tax burdens. The study found that the average price elasticities of gasoline demand are -0.74, and rural and suburban households are more responsive to gasoline prices. People in urban cities typically live closer to work and services and have better access to public transportation, making it easier for them to reduce their driving compared to those in rural cities. Therefore, the tax burden was higher in rural cities than the large urban cities.

Sun et al. (2022) studied how diesel consumption taxes affect retail prices in China, accounting for time and province differences. They then used a Three-stage Least Squares (3SLS) method to estimate how changes in diesel prices impact diesel consumption and carbon emissions. The study found that about 49% of diesel taxes in China are passed on to retail prices, and the market share of oil companies plays a significant role in this pass-through rate. Additionally, the increase in diesel taxes in 2014/2015 led to a 1.64% reduction in annual diesel consumption and a 0.096% decrease in annual carbon emissions in China.

Harju et al. (2022) investigated the diesel carbon tax incidence on retail gasoline prices using station-level data from Finland. It used gasoline prices as a comparison of diesel retail prices. The results of the difference-in-difference analysis showed that retail price increased by 0.80 cents with a one-cent rise in carbon tax. This result implies that the economic burden of the diesel carbon tax is divided between both the demand and supply sides of the market, although consumers bear most of the burden.

While extensive research has been conducted globally on the rates at which gasoline and diesel taxes are passed on to consumers, producers or retailers and their broader economic and environmental impacts, similar comprehensive studies are sparse in the Canadian context. The global evidence on gasoline tax incidence demonstrates varying pass-through rates depending on the region and tax type. Empirical studies on tax incidence are also illustrated in tabular form in Appendix A. Therefore, conducting a thorough study on how federal carbon and provincial gasoline taxes affect prices in Canada is important. By addressing these gaps, the proposed research aims to contribute to a clearer understanding of gasoline tax incidence in Canada, offering valuable insights for policymakers seeking to balance economic inflation, environmental objectives, and consumer welfare.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology section of this thesis outlines the framework and methods used to study how changes in gasoline tax affect retail and wholesale prices. The methodology encompasses several key components. First, the methodology elucidates the analytical framework adopted to assess the impact of gasoline tax changes. Next, it outlines the data collection process, detailing the sources of data utilized in the analysis and the way of creating a panel data set for this study.

3.2 Theoretical Background

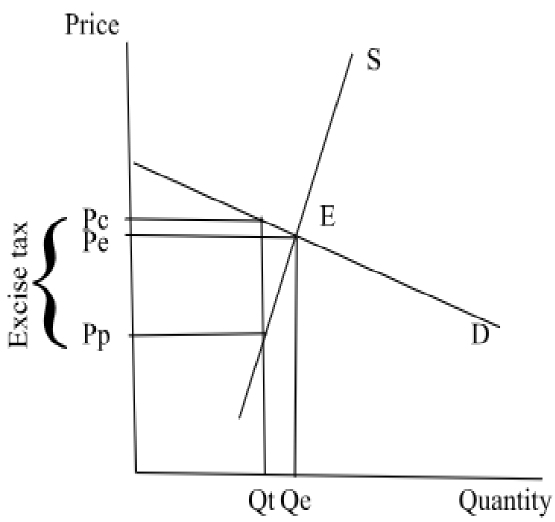
Tax incidence investigates how the burden of a tax is shared between consumers and suppliers. Pass-through is an integral part of tax incidence analysis. Pass-through rates explain the rate at which tax changes are passed into the consumer's market price. Equation (1) shows the relationship of the pass-through rate with the price elasticity of demand and price elasticity of supply. The pass-through rate per unit of tax t is a function of the price elasticity of demand ε_d and price elasticity of supply ε_s. Equation (1) derives from Stopler (2016):

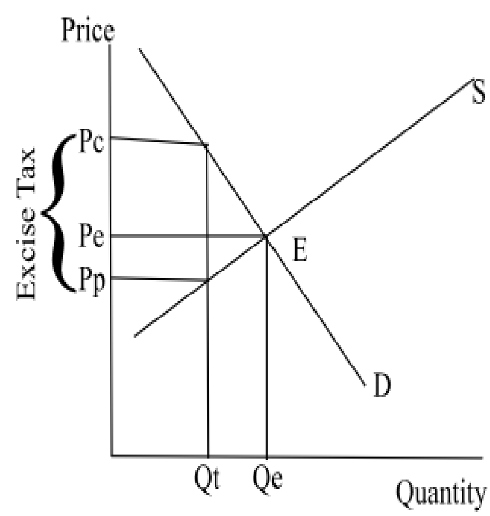
(1) $$\frac{dPc}{dt} = \frac{\varepsilon_s}{(\varepsilon_s - \varepsilon_d)} = \frac{1}{1 - \frac{\varepsilon_d}{\varepsilon_s}}.$$

Equation (1) also indicates that the amount of tax passed through to consumer prices goes up when the supply is elastic, and the demand is inelastic. This means the pass-through rate increases if supply is more elastic than demand, and consumers bear most of the tax burden. However, the pass-through rate decreases when supply is less elastic than demand (Shapiro, MacDonald, & Greenlaw, 2022).

Retail price tax incidence

The retail price tax incidence implies how tax is distributed between consumers and retailers. Figure 1 demonstrates the relationship of retail price tax incidence with price elasticities. In figure 1, suppose after imposing an excise tax t per unit of gasoline, the consumers pay the P_c price, the retailers receive the P_p price, and Q_t is the quantity purchased by the consumer and sold by the retailers. The excise tax rate is the difference between P_c and P_p. Before imposing tax, the equilibrium price was P_e, and the quantity was Q_e. The equilibrium point for the retail gasoline market is E, the intersection points for the gasoline demand curve D, and the supply curve S . The distance between P_c and P_e is the tax incidence on consumers, which is the extra amount a consumer pays for the tax imposed. Besides, the retailer's tax incidence is the distance between P_e and P_p , because retailers will lose this amount for the tax imposed.





A. Elastic demand and inelastic supply B. Inelastic demand and elastic supply

Figure 1. Tax incidence and elasticities for retail prices

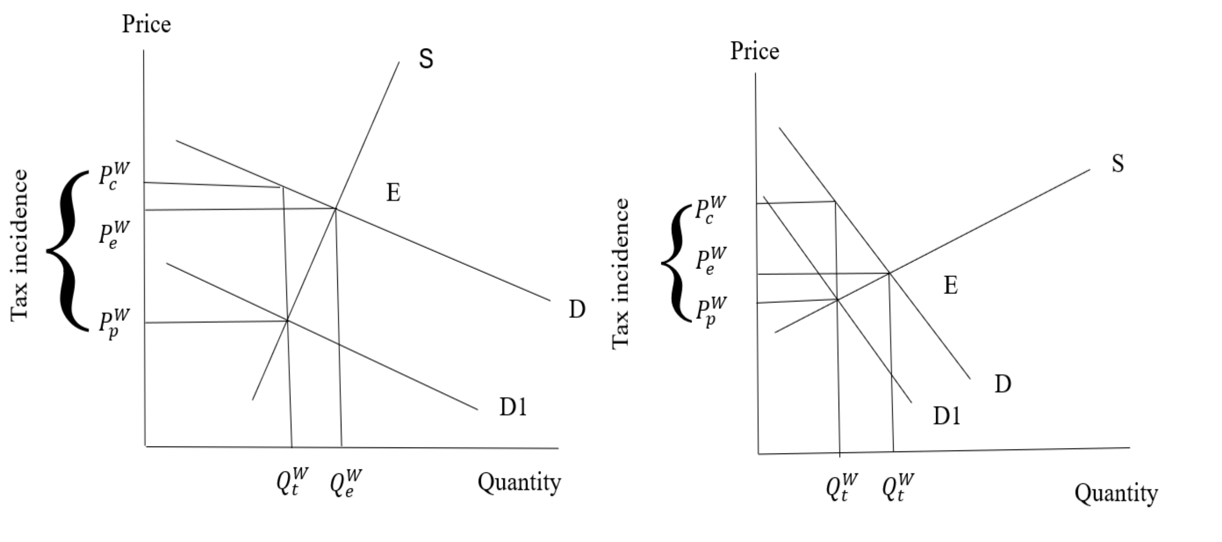
In figure 1(A), demand is elastic with respect to price, and supply is inelastic with respect to price, which means if the price increases with taxes, the consumer's demand is responding more than the retailer's supply. The incidence of tax on retailers $Pe - Pp$ is more than $Pc - Pe$ consumers' tax incidence. The pass-through of tax on consumers will decrease, and suppliers will bear more of the tax burden. In figure 1(B), demand is inelastic with respect to price, and supply is elastic with respect to price, which means supply is responding more than demand to price change. So, consumers will bear more tax incidence $Pc - Pe$ compared to the suppliers' tax incidence $Pe - Pp$.

Wholesale price tax incidence

The tax incidence of wholesale price indicates how tax is distributed between retailers and wholesalers. Tax is imposed on the retail price. There is no tax on wholesale price. But, when tax is imposed on retail prices, wholesale prices can also be affected. In figure 1, the price retailers receive falls after the tax is imposed, which can reduce demand on the wholesale market. As demand in the wholesale market falls, the price will adjust according to the price elasticity of demand and price elasticity of supply. Figure 2 represents the relationship between tax incidence and price elasticities for the wholesale market.

Suppose in the wholesale market in figure 2, the retailer's purchasing price is P_c^W, the wholesalers' selling price is P_P^W, and Q_t^W is the quantity purchased by the retailers and sold by the wholesalers after imposing a tax on the retail market. Before imposing the tax, the equilibrium point for the wholesale gasoline market was E, and the equilibrium price was P_e^W, and the quantity was Q_e^W. In figure 2(A), when the supply is inelastic and demand is elastic in the wholesale market, wholesalers' selling price P_P^W falls more than the increased price of retailers P_c^W to adjust the demand. Therefore, wholesalers absorb a larger share of the tax incidence $P_e^W - P_P^W$ than retailers

$P_c^W - P_e^W$. However, in figure 2(B), when the demand for gasoline at the wholesale market is inelastic and supply is elastic, wholesalers can pass a more significant portion of the tax incidence onto retailers. Therefore, retailers' tax incidence $P_c^W - P_e^W$ is higher than the wholesalers' tax incidence $P_e^W - P_P^W$.



A. Elastic demand and inelastic supply B. Inelastic demand and elastic supply

Figure 2. Tax incidence and elasticities for wholesale prices

The tax incidence of the retail market plays an important role in the tax incidence of the wholesale market. For instance, if the gasoline tax is entirely passed through to the final consumers' price in the retail market, then retailers' receiving price does not change. Therefore, the demand for gasoline in the wholesale market also does not change, which means that the gasoline tax change has no impact on the wholesale market. However, if tax is not entirely passed to the consumers' final price and retailers' receiving price fall due to gasoline tax increases, then gasoline demand in the wholesale market also falls. Eventually, gasoline tax increases affect wholesale market prices.

3.3 Empirical Model of Estimating Gasoline Tax Incidence

Pass-through is one of the most used economic tools to analyze wholesale and retail market tax incidence (Marion & Muehlegger, 2011; Silvia and Taylor, 2016; Stopler, 2016; Erutku, 2019; Sun et al., 2022). The critical empirical challenge is to control the other factors that affect gasoline retail and wholesale prices in the absence of tax change and estimate the pass-through rate only for tax change. Therefore, this study uses an event-based difference-in-difference (DID) (Stopler, 2016; Silvia and Taylor, 2016) method to assess the impact of the tax change on retail and wholesale gasoline prices.

The DID model is a statistical technique that allows us to compare changes over time between treatment and control groups. In the context of this study, the DID model allows us to assess the causal impact of tax policy changes on retail and wholesale prices. This study examines the price trends of treated groups over time compared to control groups. By comparing these trends, I can isolate the effect of the tax changes on prices. The key assumption of the DID model in this study is that, in the absence of tax changes, the gasoline price of the treated group would have followed a parallel trend to the control group. Through this comparative analysis, the DID model enables us to estimate the average treatment effect of gasoline tax changes on prices.

The cities that do not experience any tax changes within a specific window are considered as a control group for this study. This approach helps to compare the treated cities with the control group, allowing me to assess the actual impact of tax changes on prices. The control group in this study is chosen based on the assumption that, in the absence of the tax change, price trends for both the treatment and control groups would have remained similar. This assumption is fundamental for applying the DID model, as it allows us to attribute observed price differences primarily to the tax change.

To further reduce potential confounding influences, I include city-level covariates such as population density and household income. These covariates control for factors linked to gasoline demand and pricing, like urbanization, public transportation availability, and traffic congestion, which could otherwise distort the estimated impact of the gasoline tax. For example, areas with higher household incomes or population densities might have higher baseline gasoline prices independent of tax changes. However, population density and household income may not add much to the analysis. This is because these variables do not change significantly over the short timeframes being studied.

A primary advantage of this research design is the short observation period for each tax event, which naturally limits other changes that could interfere with the tax effect. The study's short observation window, combined with the choice of control cities that are relatively far from the treated cities, simultaneously reduces the chance of local factors affecting prices in both groups. This setup makes it easier to focus on the impact of tax changes. Over longer periods, numerous variables, such as changes in global oil prices, seasonal demand fluctuations, or shifts in local market conditions, can influence gasoline prices. By analysing a narrowly defined window, these extraneous factors are less likely to coincide with the tax change, thereby reducing noise in the data and strengthening the causal inference.

I use event study plots to provide a clear visual representation of the treatment effects over time. Event plots are also one of the best methods to assess the parallel trend assumption in the pre-treatment period of difference-in-difference analysis. Event plots also illustrate the duration of passing the treatment effects on the affected cities in the post-treatment period. For instance, the effect of implementing or changing the tax policy may be passed to price immediately or take more time. To explore such cases, the event study plot is one of the useful tools to visualize treatment effects for both the pre-treatment and post-treatment periods.

Cunningham (2021) explained that an event plot with its strong visual representation is central to a dynamic DID model. The "dynamic" part of a DID model refers to the treatment effects at different points in time. A dynamic DID model explains how the treatment effect changes over time before and after the intervention, showing how the impact evolves at different time points rather than just an overall average effect. For example, estimating the impact of tax change on prices one week or two weeks before and after the tax change. Event plots in the dynamic DID model could effectively communicate essential information about how the treatment and control groups are compared in their pre-treatment and post-treatment trends at different periods and identify treatment effects. The event-based difference-in-difference is one of the useful methods to deal with dynamic treatment effects within a longitudinal panel dataset. This study follows the framework of Cengiz et al. (2019), who apply an event-based difference-in-difference approach for a longitudinal panel dataset to examine the effect of minimum wages on low-wage jobs within an eight-year window around 138 state-level minimum wage changes.

For this study, event-specific panel datasets are created for both retail and wholesale prices using weekly city-level data from 1998 to 2024. After that, panel datasets are classified into two segments: tax increases and tax decreases. Here, the event is specified by the date on which the tax policy has been changed. Accordingly, there are 35 events in total considering provincial and carbon tax on gasoline: 28 events for tax increases and seven events for tax decreases. Each event-specific data set includes the treatment and control groups for a 9-week window by event week ($t = -4, \dots, 4$). The event week ($t = 0$) denotes the week the tax change takes place, where the change can be an increase or a decrease in the provincial and carbon tax rates; ($t = -4, .., -1$)

represents the pre-treatment period spanning four weeks before the tax change; and the post-treatment period corresponds with the four weeks after the tax change ($t = 1, .., 4$). I consider cities that experience tax change as the treatment group and all the other cities—with unchanged tax policy within the entire 9-week window as the control groups.

After creating the panel dataset, I begin with regressing equation (2) to estimate the weekly treatment effects. This provides weekly point estimates δ. I generate an event plot using these point estimates. The event plots explain how the impact of the treatment varies across different event weeks, providing insights into the dynamics of the treatment effect before and after the tax increase or decrease. The basic structure of the event-based difference-in-difference regression equations to estimate the point estimates for event plots is as follows:

$$(2) \qquad Y_{ijt} = \alpha + \beta D_{ij} + \gamma_t W_{jt} + \sum_{t=-4}^{4} \delta_t \left(D_{ij} \times W_{jt} \right) + \tau_{jt} + \pi_{ij} + \sigma PD_{ij} + \varphi HI_{ij} + \varepsilon_{ijt}$$

where, the dependent variable Y_{ijt} is the retail or wholesale price of gasoline for the i^{th} city of events j and time t; α is the constant; β is the effects of treatment group tax change on the gasoline retail and wholesale prices; D_{ij} is the explanatory variable where $D = 1$ if i is the treated cities and 0 for the control cities; W_{jt} is the time variable representing each event week ($t = -4, \dots, 4$), identified by ($W_{jt} = t + 5$) and γ is the coefficient for the time variable W_{jt}. The DID parameter δ represents the weekly point estimate of the impact of tax changes on the gasoline price. Here, $\sum_{t=-4}^{t=4} \delta_t \left(D_{ij} \times W_{jt} \right)$ is the summation of different DID parameters for each week.

Time-fixed effects τ_{jt} represent the systematic factors that influence gasoline prices across all cities on specific dates. In this study, Time-fixed effects τ_{jt} is the date of the first day of the week when gasoline prices are recorded in the Kent Marketing System, effectively controlling for time-specific shocks or trends that could affect gasoline prices uniformly across the treated and control groups. Meanwhile, π_{ij} represents the province-level fixed effects. Population density (PD_{ij}) and household income (HI_{ij}) are considered as the city-level covariates in the analysis where σ and φ are the estimated parameters respectively. The error term is ε_{ijt}.

After creating event plots, I analyse equation (3) to estimate the aggregate effect on the treated group after tax change. The basic structure of equation (3) is quite similar to equation (2). However, the time variable is different in equation (3), which is defined as $X = 1$ for the post-treatment period $(t = 0,..,4)$ and $X = 0$ for the pre-treatment period $(t = -4, \dots, -1)$. The estimated parameter ρ is the aggregate post-treatment effect of gasoline tax change. Meanwhile, the DID parameter θ is the average impact of tax changes on gasoline prices. The estimated parameter θ is used to calculate pass-through rates and discuss tax incidence for gasoline prices. The structure of the equation (3) is given below:

$$(3) \qquad Y_{ijt} = \alpha + \beta D_{ij} + \rho X_{jt} + \theta\left(D_{ij} \times X_{jt}\right) + \tau_{jt} + \pi_{ij} + \sigma PD_{ij} + \varphi HI_{ij} + \varepsilon_{ijt}$$

Finally, after analysing equation (3), I calculated the pass-through rate η of using equation (4). The pass-through rate η is estimated by dividing the average impact of the tax on retail prices θ by the average change in the tax $\overline{\Delta T}$.

$$(4) \qquad \eta = \frac{\theta}{\overline{\Delta T}}$$

I added another binary variable C into the panel data sets to estimate tax incidence for medium/small cities and large cities separately. Here, $C = 1$, which implies large cities and 0 for medium/small cities. I use $if\ C = 1$ in equation (2) and equation (3) to estimate the impact of tax changes in gasoline prices in the large cities, however, for medium/small cities using $if\ C = 0$. This binary variable C divides the panel datasets according to medium/small cities and large cities and estimates the DID parameter for each city. After that, using the DID parameter, I estimate pass-through rates for both medium/small cities and large cities.

In this study, I primarily analyze the tax incidence effects using a 9-week window. For the robustness check, I use a different window, specifically a 17-week panel dataset, which includes a total of 30 events. This dataset uses the same gasoline price data as in the initial 9-week analysis. For the 17-week window, the event week (t = 0) signifies the week when the tax change occurs, whether it is an increase or a decrease in provincial and carbon tax rates. Pre-treatment periods ($t = -8, .., -1$) represent the eight weeks before the tax change, while the post-treatment period spans the eight weeks following the tax change ($t = 1, .., 8$). In this analysis, cities affected by the tax change are considered the treatment group, while all other cities with unchanged tax policies throughout the entire 17-week window serve as the control groups. After compiling the entire data set, I utilize equation (2) and equation (3) to estimate the impact of tax increase or decrease on the retail and wholesale price of gasoline for the 17-week window. Afterwards, this study conducts a second robustness check by analyzing the tax incidence effects within the 9-week window, but this time excluding all fixed effect variables and covariates. Overall, conducting a robustness check provides a more comprehensive understanding of the relationship between gasoline taxes and prices. After estimating the difference-in-difference model of equation (3), firstly I test that the estimated coefficients of the DID parameter θ is not different to the mean value of tax change for the retail price of gasoline. For the retail price, a two-sided test is done. Secondly, whether the estimated coefficients of the difference-in-difference parameter θ are different from zero or not in the wholesale price of gasoline.

3.4 Data

I collect tax-included weekly city-level regular retail and wholesale price data from 1998 to 2024 from Kent Marketing Ltd to estimate the pass-through rate of gasoline taxes. Historical provincial and carbon tax rates data is collected at the province level from 1998 to 2024 using the same source Kent Marketing Ltd. I also collect population density and household income data from Statistics Canada for each city using five-year interval census data from 2001 to 2021. I consider 63 cities for retail and 54 for wholesale prices of gasoline of eight provinces in Canada as study areas that are presented in table 1.

Table 1. Provinces and cities of the study area

Provinces	Cities
AB	Calgary, Edmonton, Grande Prairie, Lethbridge, Red Deer, Lloydminster,
BC	Abbotsford, Fort St John, Kamloops, Kelowna, Victoria Prince George, Vancouver
MB	Brandon, Winnipeg
NB	Bathurst, Campbellton, Edmunston, Fredericton, Miramichi, Moncton, Saint John, Sussex, Woodstock
NL	Corner Brook, Gander, Labrador City, Stjohns
NS	Halifax, Kentville, New Glasgow, Sydney, Truro, Yarmouth
ON	Brampton, Brantford, Etobicoke, Guelph, Hamilton Kingston, Kitchener, London, Mississauga, North Bay, North York, Oshawa, Ottawa, Peterborough, Sarnia, Sault Ste Marie, Scarborough, St Catharines, Sudbury, Thunder Bay, Timmins, Toronto, Vaughan Markham, Windsor
SK	Moosejaw, Prince Albert, Regina, Saskatoon

<u>Events with treatment and control groups:</u>

An event-based panel dataset is created using provincial excise and carbon tax data. First, it identified the dates and treated provinces that experienced increased or decreased provincial excise or carbon taxes. Next, “week id" is created according to the calendar week in which the price data is collected. After that, "event id" is created according to the event dates, here event dates are the calendar date in which tax has changed. Table 2 displays treatment, and control groups and specifies gasoline treatment types. For most events, only cities of one province are in the treated group, and cities in other provinces are in the control group. However, I exclude events if an event cannot maintain the condition of the control group of this study[1].

Table 2. Treatment and control groups for gasoline

Date	Province of Treated Cities	Province of Control Cities	Event id		
			Week id	9-week	17-week
11/Dec/01	NB	AB, BC, MB, NS, NL, ON and SK	206	1	1
9/Apr/02	NS	AB, BC, MB, NB, NL, ON and SK	223	2	2
17/Dec/02	NB	AB, BC, MB, NS, NL, ON and SK	259	3	3
4/Mar/03	BC	AB, MB, NB, NS, NL, ON and SK	270	4	4
10/Oct/06	NB	AB, BC, MB, NS, NL, ON and SK	458	5	5
1/Jul/08	BC	AB, MB, NB, NS, NL, ON and SK	547	6	6
7/Jul/09	BC	AB, MB, NB, NS, NL, ON, SK	600	7	7
6/Jul/10	BC	AB, MB, NB, NS, NL, ON and SK	652	8	8
29/Mar/11	NB	AB, BC, MB, NS, NL, ON and SK	690	9	9
5/Jul/11	BC	AB, MB, NB, NS, NL, ON and SK	704	10	10
1/May/12	MB	AB, BC, NB, NS, NL, ON and SK	747	11	11
3/Jul/12	BC	AB, MB, NB, NS, NL, ON and SK	756	12	12
7/Apr/15	AB and NB	BC, MB, NS, NL, ON and SK	900	13	13
7/Jun/16	NL	AB, BC, MB, NB, NS, ON and SK	961	14	14
3/Jan/17	AB	BC, MB, NB, NS, NL, ON and SK	991	15	15
6/Jun/17	NL	AB, BC, MB, NB, NS, ON and SK	1013	16	16
5/Dec/17	NL	BC, MB, NB, NS, ON and SK	1038	17	17
2/Jan/18	AB	BC, MB, NB, NS, ON and SK	1043	18	18
1/Apr/18	BC	AB, MB, NB, NS, NL, ON and SK	1056	19	19
1/Jan/19	NL	AB and NS	1095	20	20
2/Apr/19	NL, BC, SK, MB, ON and NB	NS	1108	21	21
4/Jun/19	AB	NS	1117	22	22
7/Jan/20	AB	BC, MB, NB, NS, NL, ON and SK	1148	23	23
7/Apr/20	NB, AB, SK and ON	BC, MB, NS and NL	1161	24	
7/Jul/20	MB	AB, BC, NB, NS, NL, ON and SK	1174	25	24
6/Apr/21	NL, BC, AB, SK, MB, ON and NI	NS	1213	26	25
6/Jul/21	NL	AB, BC, MB, NB, NS, ON and SK	1226	27	
5/Apr/22	AB, NB, BC, SK, MB and ON	NS	1265	28	26
5/Jul/22	ON	AB, BC, MB, NB, NS and SK	1278	29	27
4/Oct/22	AB	BC, MB, NB, NS, NL, ON and SK	1291	30	28
3/Jan/23	AB	BC, MB, NB, NS, NL, ON and SK	1304	31	
1/Apr/23	BC, AB, SK, MB and ON	NB, NS and NL	1317	32	29
1/Jul/23	NB, NS and NL	BC, AB, SK and MB	1330	33	
2/Jan/24	MB and AB	BC, NB, NS, NL, ON and SK	1356	34	30

[1] There are some exceptions in the event dates 6-Apr-21 and 5-Apr-22, where only cities of Nova Scotia are the control group, as carbon taxes had changed for cities in all other provinces on the same dates. Similarly, for 2-Apr-19, only the cities of Alberta and Nova Scotia are in the control group. This study dropped the cities of Newfoundland and Labrador from the event date of 2-Apr-19, New Brunswick from the event date of 7-Apr-20, and Alberta from the event date of 5-Apr-22 because, on the same date, there is an increase and decrease in the provincial and carbon taxes. The cities of Newfoundland and Labrador are also dropped from the event dates of 2-Jan-18, 5-Apr-22, and 7-Jul-22, as well as Alberta from 5-Dec-17 to maintain the condition of the control group for the event-based analysis. On 2-Jan-17, Manitoba (MB) suspended its provincial excise tax which is considered as an event for the tax decrease. In contrast on the same day, Alberta (AB) increased its provincial tax from zero to 9 cents per litre which is considered as an event for tax increase. So, I dropped AB from the 34th event of the tax decrease and MB from the 34th event of the tax increase to avoid bias in the control group. I also excluded two events from both the 9-week and 17-week panel data set for Newfoundland and Labrador on 9-May-22 and 2-Jun-22 because within one month there was an increase in the carbon tax but a decrease in the provincial tax. Furthermore, I also need to drop four events from the 17-week window to maintain the assumption of the control group: 1. April 7, 2020: New Brunswick (NB), Alberta (AB), Saskatchewan (SK), and Ontario (ON); 2. April 1, 2023: British Columbia (BC), Alberta (AB), Saskatchewan (SK), Manitoba (MB) and Ontario (ON); 3. July 1, 2023: New Brunswick (NB), Nova Scotia (NS), and Newfoundland and Labrador (NL); 4. January 3, 2023: Alberta (AB).

Explanation of the variables for the event-based difference-in-difference model:

Table 3 provides a detailed description of the variables used to analyse the event-based difference-in-difference model in this study. These variables include treatment indicators, control factors and fixed factors. Here, the dependent variables are retail and wholesale prices and the independent variables are treatment and post-treatment dummy variables for tax changes.

Table 3. Explanation of the variables for the event-based difference-in-difference model

Variables	Definition	Unit
Date	First day of the week when retail and wholesale price data recorded	
City	Name of 63 cities adjusted according to date, price, and tax data	
Province	Name of 8 provinces adjusted according to cities	
Provincial tax	the weekly provincial excise tax rate imposed on gasoline	cents/litre
Carbon tax	The weekly carbon tax rate imposed on gasoline	cents/litre
Federal tax	The weekly federal tax rate imposed on gasoline	cents/litre
Transit tax	Weekly transit tax of Vancouver and Victoria cities	cents/litre
Retail Price	The weekly regular retail price of gasoline	cents/litre
Wholesale Price	The weekly wholesale price of gasoline	cents/litre
Event	Dummy variable, event = 1 for week's experienced tax change and 0 for otherwise	
Week id	Weekly dates are specified with the ordinal number	
Event week	Dummy variable event week = (-1, -2, -3, -4) for four weeks before tax change event week = 0 for the week of tax change and event week = (1,2,3,4) for four weeks after tax change	
Treatment	Dummy variable Treatment = 1 for the treated cities of the tax change in the event Treatment = 0 for control cities of no tax change in the same event	
Post-treatment	Dummy variable. Post-treatment = 1 for post-treatment periods after tax change Post-treatment = 0 for pre-treatment periods before tax change	
Event id	Number of events specified with ordinal number	
Population density	The average number of populations per square kilometre of each city in Canada from 2001 to 2021	
Household Income	Total incomes of all members of the household from 2001 to 2021	

Relationship between taxes and prices of gasoline

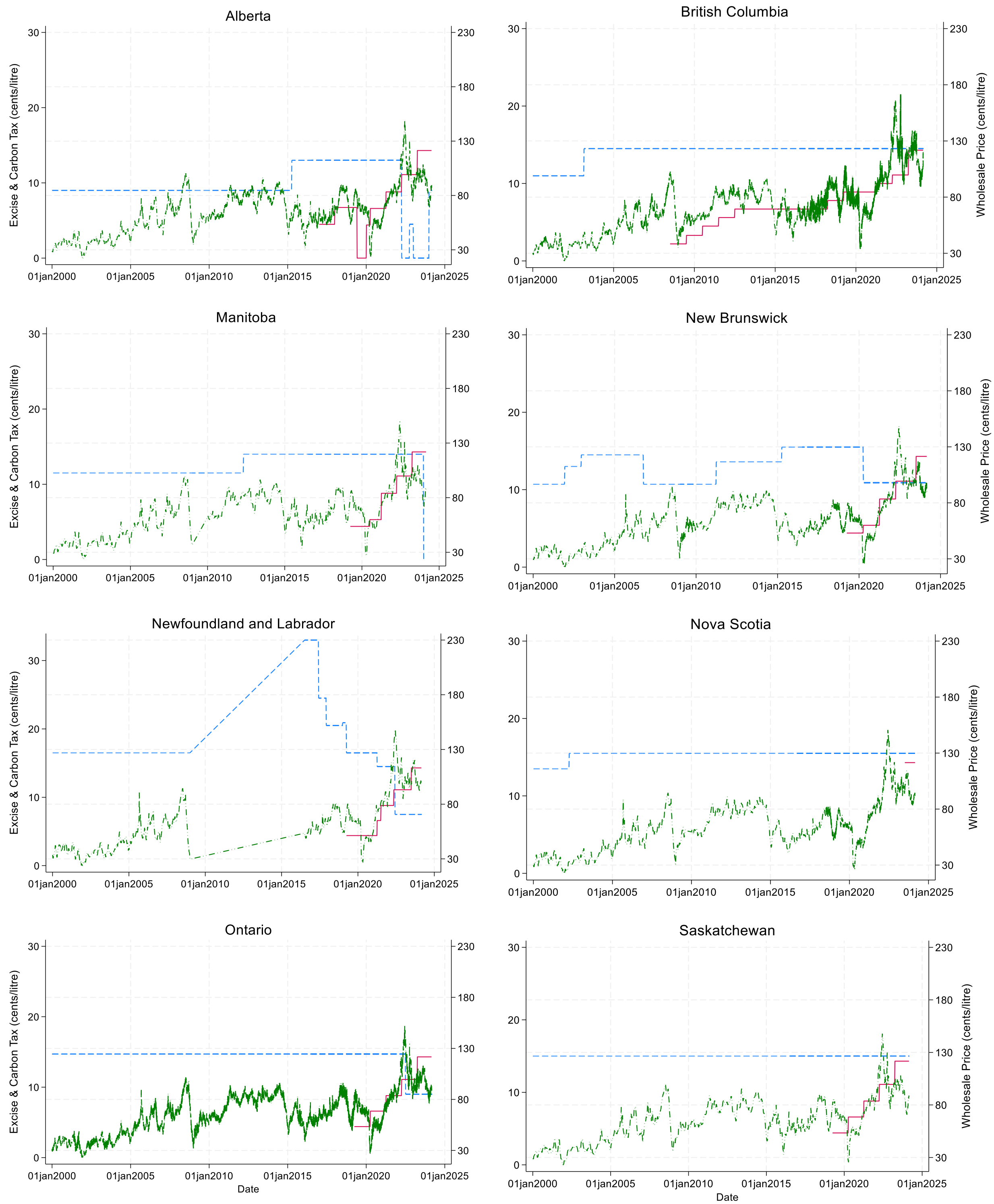
To analyze and understand the relationship between taxes and gasoline prices, I first consider real retail gasoline prices along with provincial and carbon tax rates from 1998 to 2024 across all provinces in Canada as illustrated in figure 3. After that, I create figure 4 for wholesale prices with provincial and carbon tax rates for the same period and in the same provinces in Canada.

In Alberta, there is a gradual increase in retail gasoline prices, with significant peaks occurring around 2014 and 2021-2022. The highest price increases occur around 2021-2022. Following this peak, prices started declining again in 2023. The excise tax remained constant until 2015, however, there was a notable increase in 2015. The excise tax drop to zero in 2021, representing a zero-tax policy. The carbon tax was introduced in 2017 and gradually increased until it was eliminated in 2019. The carbon tax is reintroduced in 2020. Wholesale gasoline prices began to increase significantly after 2008, peaking around 2014. The lowest wholesale prices are in 2015, while the highest is in 2022.

In British Columbia, after 2007, retail prices begin to rise steadily, with significant peaks in 2008, 2014, and 2021-2022. Prices reached their peak in 2022 and then experienced a decline. The excise tax remained constant from 2000 to 2013. In 2014, the excise tax saw a small increase and remained steady through 2024. British Columbia introduced a carbon tax in 2008. The carbon tax continues to rise gradually over time after 2008. Wholesale gasoline prices in British Columbia show steady growth, with significant fluctuations between 2014 and 2022, peaking in 2020-2022.

In Manitoba, both retail and wholesale gasoline prices are stable. However, there is a significant increase in prices in 2022, followed by a decrease toward 2023. The excise tax was mostly stable from 2000 to 2012, however, there was an increase from 11.5 cents/litre to 14

Figure 3. Taxes and real retail prices of gasoline by province (1998-2024)



- - - Excise taxes —— Carbon taxes -..- Gasoline retail prices

Figure 4. Taxes and wholesale prices of gasoline by province (1998-2024)

cents/litre in 2012. The excise tax rate is constant between 2012 and 2023. In 2024, the excise tax dropped to zero and remained at this level. In New Brunswick, both retail and wholesale gasoline prices have fluctuated significantly over time. Excise taxes have changed more frequently in New Brunswick than in other provinces.

In Newfoundland and Labrador, there is a continuous increase in retail gasoline prices over the period, reaching the highest point in 2022 and then decreasing again. The provincial excise tax was constant from 2000 to 2016, increasing sharply and reaching a peak in 2016, After that excise tax rates decreased gradually. However, in Figure 3 for Newfoundland and Labrador, wholesale price data is missing from 2009 to 2015. However, wholesale prices are also highest in 2022. In Ontario, both wholesale and retail prices show a consistent increase with little fluctuation. The excise tax also remains stable from 2000 to 2022 and there is a decrease in the excise tax rates in 2022.

In Saskatchewan, both retail and wholesale prices have increased slowly over the years. However, excise taxes were stable over the years. The carbon tax was introduced in 2019 and continuously increased since then in Manitoba, New Brunswick, Newfoundland and Labrador, Ontario, and Saskatchewan. Nova Scotia is a unique case since the province only recently implemented the carbon tax in 2023. Both retail and wholesale gasoline prices remained stable until 2023, after which prices began to rise sharply. The excise tax also remains stable from 2000 to 2024.

Summary statistics:

Table 4 represents the summary statistics of continuous variables used in this study. It indicates the average retail price is 110.1 cents/litre with a standard deviation of 29.5 cents/litre. The prices range from 34.6 to 238.7 cents/litre. Besides, the average wholesale price is 70.9 cents/litre with a standard deviation of 22.3 cents/litre. The prices range from 22.4 to 172.8 cents/litre. Here, retail prices are tax included. The difference between retail and wholesale prices is 39.2 cents/litre.

Table 4. Summary statistics

Variable	Observations	Mean	Std. dev.	Min	Max
Retail Price (cents/litre)	61,948	110.1	29.5	34.6	238.7
Wholesale Price (cents/litre)	33,597	70.9	22.3	22.4	172.8
Excise Tax (cents/litre)	61,948	13.7	2.7	0	33
Carbon Tax (cents/litre)	61,948	8.3	3.4	0	14.3
Federal Tax (cents/litre)	61,948	10	10	10	10
Population Density	54,921	277	371	10	2469
Household Income	54,921	154393	291447	5545	2262470

Provincial excise taxes have a mean of 13.7 cents/litre and a standard deviation of 2.7 cents/litre, varying between 0 and 33 cents/litre. Carbon taxes average 8.3 cents/litre, with a standard deviation of 3.4 cents/litre, ranging from 0 to 14.3 cents/litre. The federal tax is constant at 10 cents/litre, with no variation. The total tax on average is 32 cents/litre. GST is also included in the retail price of gasoline. The GST is applied to the sum of the base price of gasoline plus any provincial fuel taxes, carbon taxes, and any other applicable charges. The GST rate is 5%. The remaining portions of the retail price after taxes cover the retailer's operating costs, transportation, and profit margins. Population density has an average of 277 population per square kilometre and a standard deviation of 371 people per square kilometre with values between 10 and 2469 people per square kilometre. Household income averages 154393.2 thousand CAD with a high standard deviation of 291447.4 thousand CAD, ranging from 5545 to 2262470 thousand CAD.

Table 5 describes the mean and standard deviation of gasoline wholesale and retail prices along with provincial excise and carbon taxes of treated and control groups for the 9-week window. The parentheses show the standard deviation for the study. For tax increases on retail prices, the treated group’s retail price rises by 4.3 cents/litre (from 126.3 to 130.6), with excise and carbon taxes increasing by 3.1 cents/litre (from 18.1 to 21.2). In contrast, the control group’s retail price increases by only 1.8 cents/litre (from 116.8 to 118.6), and taxes remain unchanged at 17 cents/litre. When examining tax decreases on retail prices, the treated group's price drops by 14.9 cents/litre (from 160.1 to 145.2), while the control group's price falls by just 3.2 cents/litre (from 135.1 to 131.9). The treated group's excise and carbon tax decreased by 5.7 cents/litre, while the control group's taxes remained stable.

Table 5. Summary statistics for the 9-week Window

Variable	Treated Group		Control Group	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Tax Increase on Retail Price				
Retail Price	126.3	130.6	116.8	118.6
	(30.6)	(32.4)	(26.4)	(28)
Excise and Carbon Tax	18.1	21.2	17	17
	(7.8)	(7.9)	(7.6)	(7.6)
Observations	1,380	1,725	4,264	5,327
Tax Decrease on Retail Price				
Retail Price	160.1	145.2	135.1	131.9
	(45.8)	(38.7)	(34.3)	(32.5)
Excise and Carbon Tax	22.6	16.9	18.8	18.7
	(11.1)	(11.6)	(9.3)	(9.3)
Observations	208	260	1,120	1,392
Tax Increase on Wholesale Price				
Wholesale Price	79.6	81.3	71	70.8
	(24.4)	(25.8)	(19.7)	(19.3)
Excise and Carbon Tax	18.6	21.8	18	18
	(8)	(7.1)	(8)	(8)
Observations	1,070	1,316	2,649	3,133
Tax Decrease on Wholesale Price				
Wholesale Price	103.9	96.4	85.2	82.3
	(34)	(27.3)	(27.4)	(23.7)
Excise and Carbon Tax	23.4	17.4	19.2	19.2
	(11.4)	(12.3)	(9.1)	(9.1)
Observations	156	195	940	1,156

For wholesale prices in Table 5, a tax increase results in the treated group's price rising by 1.7 cents/litre (from 79.6 to 81.3), while the control group's price decreases slightly by 0.2 cents/litre (from 71.0 to 70.8). The treated group sees a 3.2 cents/litre increase in excise and carbon taxes, while the control group's taxes remain unchanged. When analyzing tax decreases on wholesale prices, the treated group's price falls by 7.5 cents/litre (from 103.9 to 96.4), while the control group's price drops by 2.9 cents/litre (from 85.2 to 82.3). The excise and carbon tax decreased by 6 cents/litre for the treated group, with no change in the control group.

Table 6 explains the summary statistics of gasoline prices and taxes for the 17 weeks. Table 6 shows a similar trend to Table 5. For tax increases on retail prices, the treated group's price rises by 9.1 cents/litre (from 122.8 to 131.9), compared to the control group's smaller increase of 2.7 cents/litre (from 114.1 to 116.8). The excise and carbon tax increases by 2.6 cents/litre for the treated group, with no change in the control group. When taxes decrease, the treated group's retail price drops by 19.8 cents/litre (from 160.0 to 140.2), while the control group's price decreases by 5.8 cents/litre (from 130.8 to 125.0). The tax decreases by 5.9 cents/litre for the treated group, while it remains constant in the control group.

For wholesale prices, a tax increase leads to an 8.6 cent/litre rise for the treated group (from 126.9 to 135.5), while the control group's price falls by 1.3 cents/litre (from 119.4 to 118.1). Taxes in the treated group increased by 2.6 cents/litre, with no change in the control group. When taxes decrease, the treated group's wholesale price drops by 13.8 cents/litre (from 107.4 to 93.6), while the control group's price falls by 5.6 cents/litre (from 84.3 to 78.7). The excise and carbon tax decreases by 6.4 cents/litre for the treated group, while the control group's tax remains unchanged.

In both tables gasoline retail and wholesale average price increases from pre-treatment to post-treatment period with provincial excise and carbon taxes increasing in the treated groups. Similarly, prices decline with the decrease in taxes. In the control groups, tax rates remain unchanged between the pre-treatment and post-treatment periods, but retail and wholesale prices vary. However, the treated groups consistently show larger changes in prices than the control groups.

Table 6. Summary statistics for the 17-week Window

Variable	Treated Group		Control Group	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Tax Increase on Retail Price				
Retail Price	122.8	131.9	114.1	116.8
	(28.6)	(31.6)	(26.3)	(26.9)
Excise and Carbon Tax	17.7	20.3	16.3	16.3
	(7.5)	(7.3)	(6.8)	(6.8)
Observations	1,844	2,268	6,600	7,462
Tax Decrease on Retail Price				
Retail Price	160	140.2	130.8	125
	(43.8)	(37.1)	(34.9)	(32)
Excise and Carbon Tax	23.3	17.4	18.4	18.4
	(10.5)	(11)	(8.3)	(8.3)
Observations	336	378	1,648	1,860
Tax Increase on Wholesale Price				
Wholesale Price	126.9	135.5	119.4	118.1
	(27.9)	(31.2)	(27.4)	(23.9)
Excise and Carbon Tax	18.6	21.2	17.5	17.5
	(7.7)	(8.5)	(7.8)	(7.8)
Observations	1,358	1,660	3,981	4,283
Tax Decrease on Wholesale Price				
Wholesale Price	107.4	93.6	84.3	78.7
	(33.2)	(26.2)	(28.9)	(22.8)
Excise and Carbon Tax	25	18.6	18.6	18.6
	(10.5)	(11.6)	(9.3)	(9.3)
Observations	264	297	1,536	1,733

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the empirical findings and subsequent discussion derived from the event-based difference-in-difference model introduced in Chapter 3. This section outlines the results obtained from the analysis of a 9-week window event-based panel dataset, focusing on the primary objectives of the study. Each section is further divided into subsections dedicated to tax increases and decreases. Here, I illustrate the results concerning event plots and tax incidences.

4.2 Empirical Results of Tax Incidence for the 9-week Window

The event-based difference-in-difference regression model is used to regress the impact of tax increases on the retail and wholesale prices of gasoline for each week of the 9-week window. I consider one week before tax increase as a reference period, so the pre-treatment period -1 is omitted and normalized to zero for the estimation. Based on the reference period, point estimates for each week are estimated. However, I need to drop one event for a tax increase that happened in Newfoundland and Labrador on 9 May 2022 because of the decreasing tax on 2 June 2022 in the same province.

4.2.1 Event plot analysis of retail and wholesale gasoline prices for the 9-week window

I use event-based difference-in-difference regression equation (2) on the 9-week window panel dataset to estimate point estimates. Then, I plotted the point estimates for each week before and after the tax increase for the treated cities compared to the control cities to generate event plots. In event plots, the y-axis represents the coefficients of point estimates of each event week for the treated cities compared to control cities and the x-axis is the event week.

Tax increase in Canada

Figure 5 shows the event plot of tax increases in Canada for the 9-week window. Here, figure 5A represents retail prices and figure 5B for wholesale prices. Figure 5A shows the difference between treated cities and control cities three weeks and four weeks before the tax increase in the retail prices is consistent. Essentially, in figure 5A, the difference between treated and control cities in the gasoline retail prices increases from -0.5 cents/litre to 1.4 cents/litre over two weeks before the tax increase and the week the tax increase was implemented, i.e. event week 0.

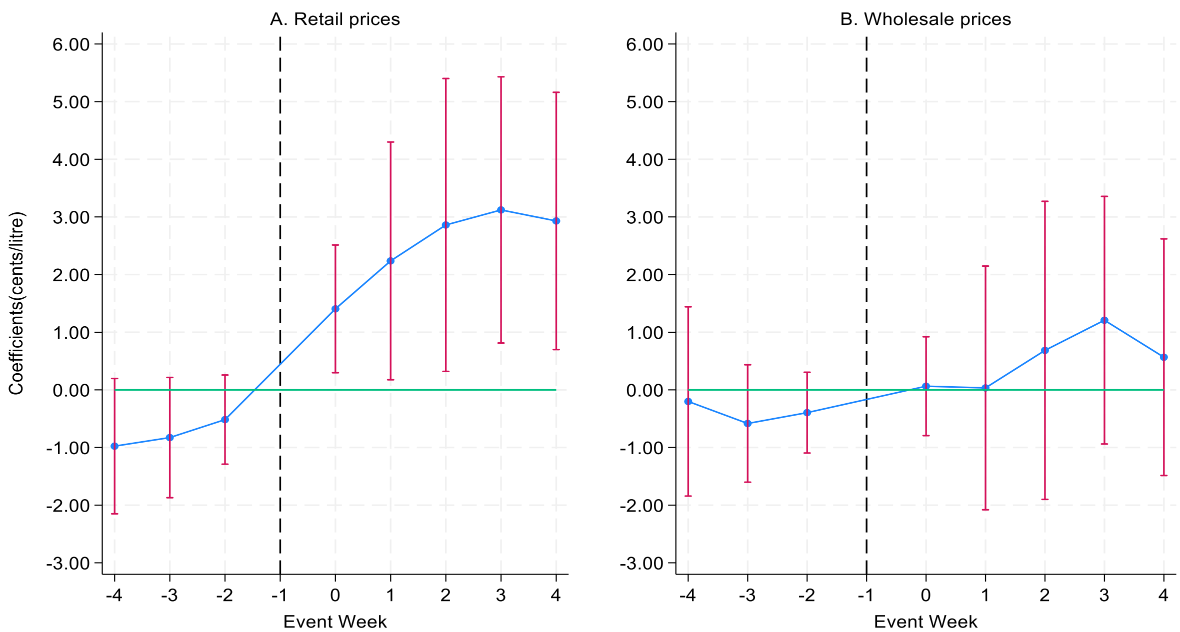


Figure 5. Event plots of tax increases in Canada: 9-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

The sharp increase in retail prices in figure 5A indicates that retailers immediately respond to the tax increase and pass it to the final consumer price. In the treated cities, the gasoline retail price steadily increased in the weeks following the event, peaking at a 3.1 cents/litre increase three weeks after the tax adjustment. This increase in retail prices represents the largest impact of the tax increases on retail prices and then it starts declining to 3 cents/litre in the fourth post-treatment period. Figure 5B represents no significant impact of tax increase on the wholesale prices of gasoline for each week before and after the treatment in the treated cities compared to control cities.

Tax Increase for Large and Medium/small Cities in Canada

Figure 6A shows the impact of a tax increase on retail gasoline prices in large cities for the 9-week window. In the pre-treatment period, the difference in retail price in the treatment and control groups is quite stable, it starts increasing two weeks before the tax increase. The retail prices in the treated cities compared to control cities continuously increase until three weeks after the tax increase and then decline, following the trend line of figure 5A.

Figure 6C represents the effect of a tax increase on retail gasoline prices in medium/small cities over the same 9-week period. There is a sharp increase in the retail price of gasoline in treated medium/small cities four weeks before the tax increase. Gasoline retail prices continue to increase until post-treatment period 3 and then stabilize. On the other hand, figure 6B and figure 6D depict the impact of tax increases on wholesale prices in large and medium/small cities respectively. Both large and medium/small areas exhibit similar trends in wholesale prices before and after the tax increase, indicating that wholesale markets may react uniformly regardless of the region.

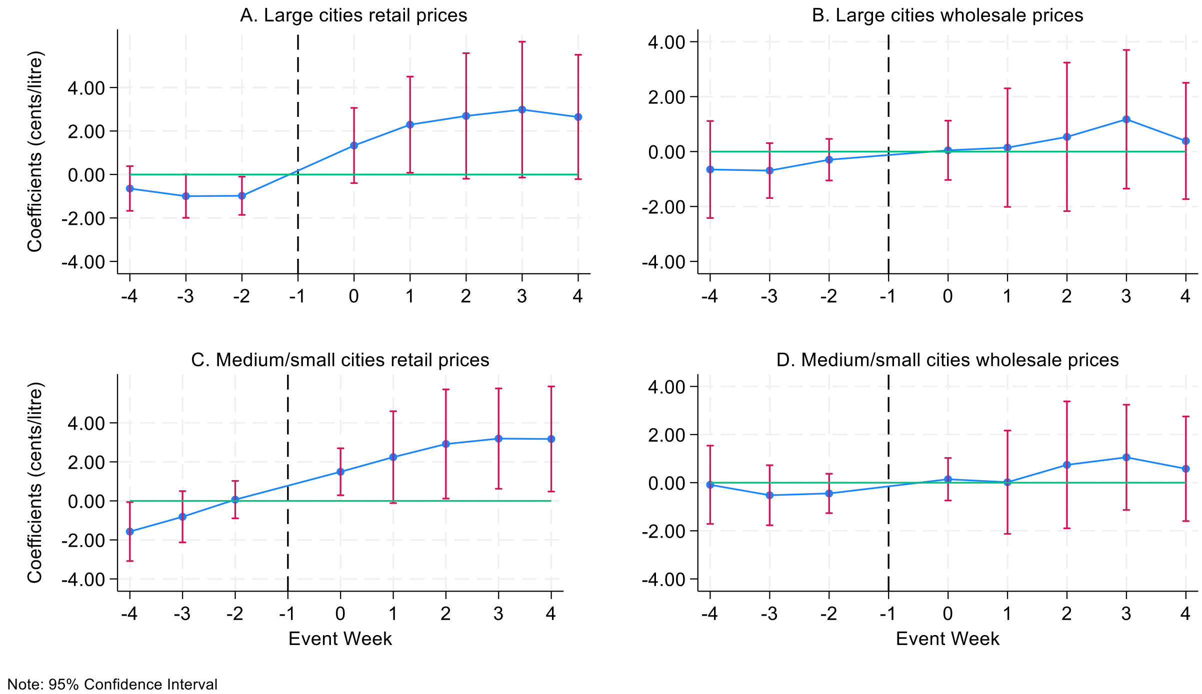


Figure 6. Event plots of tax increases in large cities and medium/small cities: 9-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

Tax Decrease in Canada

I use the same equation (2) event-based difference-in-difference model to analyze the gasoline tax decrease incidence for each week on the retail and wholesale price of gasoline. I evaluate point estimates using the panel data set for tax decrease including seven events. I incorporate both provincial and carbon taxes in identifying these events. I use the week before the tax decrease as a baseline, omitting it from the analysis and normalizing it to zero, to estimate point estimates for subsequent weeks. Then, I generate event plots using the point estimates for tax decreases.

Figure 7A found that the retail price of treated cities is 4.8 cents/litre and 4 cents/litre higher compared to controlled cities in the fourth and third weeks before the tax change. After that, there is a sharp decline to 0.89 cents/litre in the two weeks before the tax change. That means the difference between the treated group and the control group in the retail price of gasoline decreases before the tax decreases. Sun (2023) also finds gasoline retail prices in both the treatment and control groups begin to diverge before the implementation of the tax decreases. Sun (2023) analyses the effects of a tax reduction in Ontario and compares it to the incidence of a tax cut in Newfoundland & Labrador. Sun (2023) also finds that the tax cut had a notable effect in reducing gasoline prices in both provinces. These findings of Sun (2023) are consistent with the results of this thesis. In the post-treatment period in figure 7A, the retail prices of gasoline demonstrated a consistent pattern. Retail prices decreased steadily until one week after the tax change, eventually stabilizing at around 5 cents/litre. However, in the fourth week after the tax change, the prices began to rise again, reaching 2.5 cents/litre.

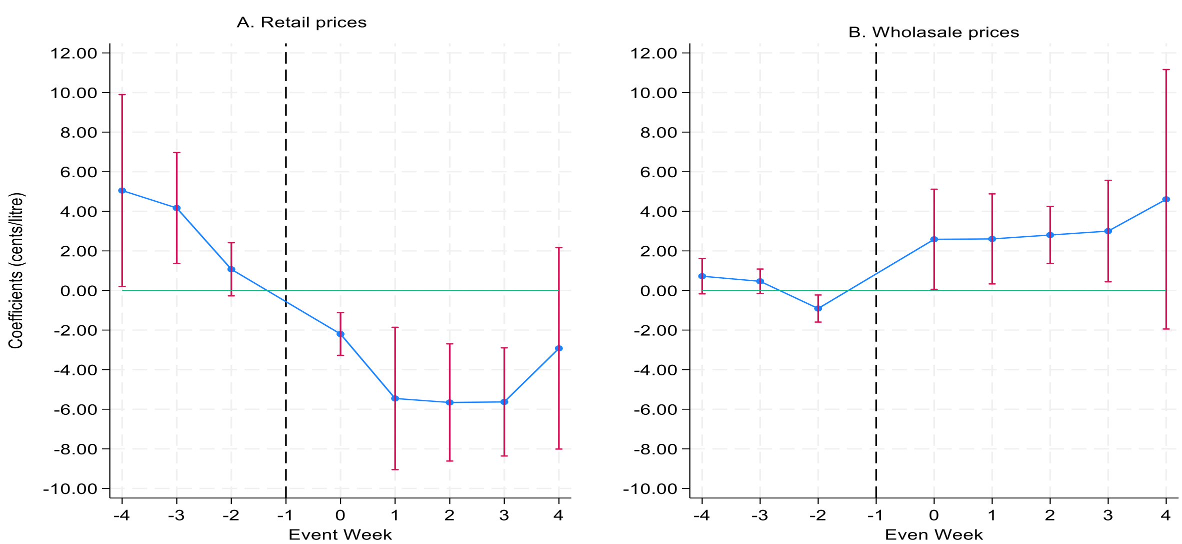


Figure 7. Event plots of tax decrease in Canada: 9-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

From figure 7B, before the tax cut, the wholesale price in both treated and controlled cities does not show any notable difference. However, there is an increase in the wholesale price from around 0.9 cents/litre to around 2.5 cents/litre between the second week before and the same week of the tax cut. After the third week in the post-treatment, the wholesale prices again increased.

Tax Decrease for Large Cities and Medium/small Cities in Canada

Figure 8A and figure 8C illustrate the weekly response of retail prices in the large cities and medium/small cities in Canada, respectively. In both cities, the retail price of treated and controlled cities is stable for three weeks before tax decrease, however, after that, it starts declining till post-treatment period 1. Retail prices stabilize between post-treatment periods 1 and 3 and then follow an upward trend in both large cities and medium/small cities.

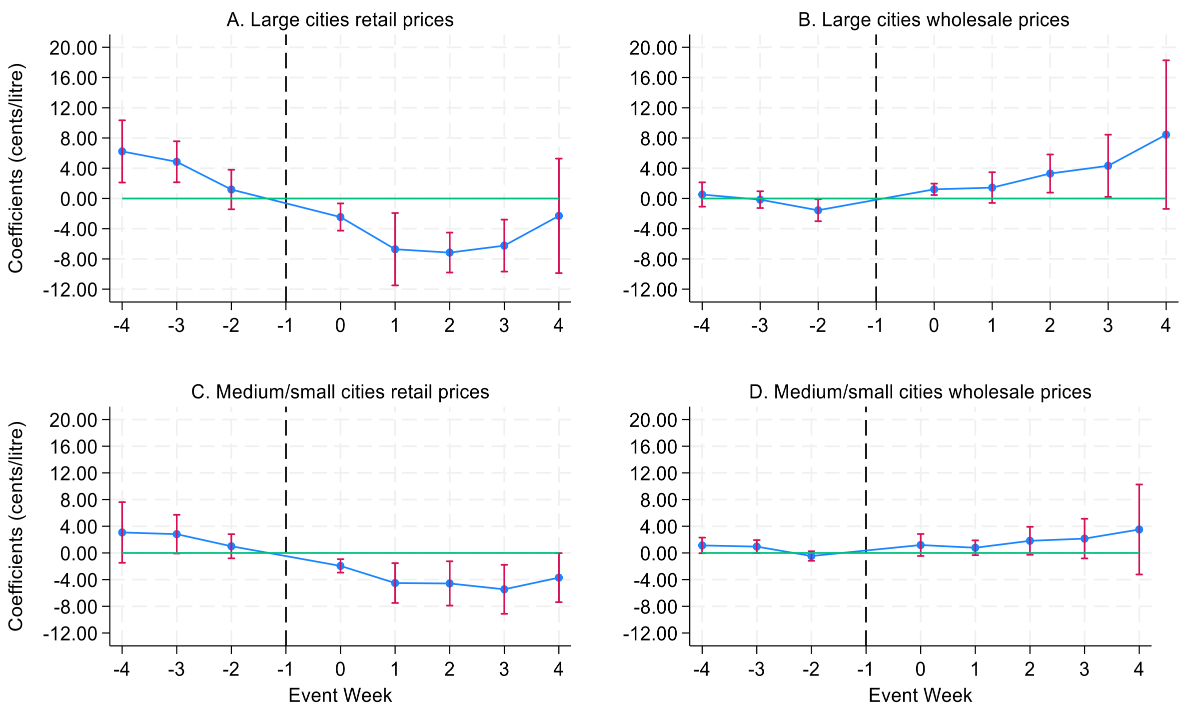


Figure 8. Event plots of tax decrease in large cities and medium/small cities: 9-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

4.2.2 Average tax incidence of retail and wholesale gasoline price for the 9-week window

The pass-through rate of tax on the retail and wholesale price of gasoline is estimated using equation (3) and equation (4). In the first part, I describe the incidence of tax increases in Canada as well as in medium/small and large cities. Secondly, I discuss the incidence of tax decreases in Canada as well as in medium/small and large cities.

Tax increase incidence:

Table 7 shows the results of the difference-in-difference analysis and incidences of tax increases for the 9-week window. The estimated coefficient of the retail price for Canada is 3.09 cents/litre, statistically significant at a 1% level of significance. The results of the 95% confidence interval show that there is no significant difference between the estimated coefficient of 3.09 cents/litre and the mean value of tax increases of 3.08 cents/litre. This finding of the 95% confidence interval implies that the pass-through rate of gasoline tax increases for retail price is not statistically different from 100%. The incidence of tax increase for the retail price in Canada is 100% indicating that a 1 cent/litre increase in tax in the treated cities would result in a 1 cent/litre increase in the retail prices.

In table 7, the estimated coefficients for retail price in the large and medium/small cities are 3.042 cents/litre and 3.183 cents/litre, respectively. Both are positive and statistically different from zero. The pass-through rates for both large and medium/small cities are 108% and 97% respectively. However, the estimated coefficients are statistically equal to the mean tax increase at a 95% confidence interval for both cities. These results mean that the 108% and 97% pass-through rates of tax increases for large and medium/small cities are statistically not different from 100%.

The tax increase incidence for wholesale price is 25%, however, the estimated coefficient of 0.796 cents/litre is statistically not different from zero. The lack of significance suggests that wholesalers are not adjusting their prices effectively in response to the tax increases in Canada. In both medium/small cities and large cities, estimators for wholesale prices are insignificant, implying that the tax increase does not significantly affect wholesale gasoline prices in both cities of Canada.

Table 7. Tax increase incidence for the 9-week window

Parameters	Canada		Large		Medium/small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	-3.603**	-2.862***	-4.919***	-3.745***	-2.911*	-2.029**
	(0.908)	(0.629)	(1.148)	(0.847)	(1.140)	(0.627)
Post (ρ)	8.837***	32.431***	11.299***	27.090***	12.960***	-5.491***
	(0.076)	(0.326)	(0.118)	(0.871)	(0.193)	(0.311)
Treated *Post (θ)	3.09**	0.796	3.042**	0.871	3.183**	0.775
	(0.895)	(0.874)	(1.273)	(1.120)	(0.902)	(0.933)
Population density (σ)	0.002***	0.00	0.005***	0.00	0.00	0.001**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household income (φ)	0.001*	0.00	0.001	-0.00	-0.051***	-0.010*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.011)	(0.007)
Constant (α)	50.98***	26.21***	48.38***	26.40***	56.53***	24.804***
	(0.995)	(0.754)	(0.866)	(0.575)	(1.032)	(0.943)
Province FE	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES
R-squared (R^2)	0.951	0.968	0.963	0.971	0.955	0.973
Number of events	28	28	28	28	28	28
Observations	10,675	7,675	5,179	4,087	5,496	3,588
Tax Incidence						
Tax Change ($\overline{\Delta T}$)	3.08	3.2	2.81	2.91	3.27	3.46
Pass-through (η)	100%	25%	108%	30%	97%	22%
95% C.I. on pass-through	(42%, 159%)	(-28%, 71%)	(14%, 202%)	(-48%, 109%)	(39%, 153%)	(-31%, 78%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter(θ).

Tax Decrease Incidence in Canada

Table 8 represents the findings of difference-in-difference analysis and tax decrease incidence for the 9-week window. In table 8, the coefficient tax decrease for the 9-week window of -6.942 cents/litre is negative and statistically different from zero. The results of confidence intervals reveal no significant difference between the estimated coefficients from the difference-in-difference analysis and the average tax decrease in retail gasoline prices, which means that the 121% pass-through rate of tax decreases for retail prices across Canada is statistically not different from 100%. This indicates that retailers are effectively passing most of the tax decrease benefits to consumers.

Table 8. Tax decrease incidence for the 9-week window

Parameters	Canada		Large		Medium/small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	0.760 (1.357)	-4.787** (0.981)	0.132 (1.425)	-5.753** (1.205)	0.560 (1.882)	-4.113** (0.936)
Post (ρ)	-5.556*** (0.276)	-0.303 (0.137)	-4.960*** (0.053)	- 0.272 (0.154)	52.102*** (0.539)	-0.298* (0.110)
Treated*Post (θ)	-6.942** (1.509)	2.325 (1.054)	-8.015*** (0.957)	3.270 (1.851)	-5.748* (1.936)	1.644* (0.606)
Population density (σ)	0.001 (0.00)	0.00 (0.00)	0.004** (0.001)	-0.001** (0.00)	0.00 (0.001)	0.00 (0.00)
Household income (φ)	0.00 (0.00)	-0.00 (0.00)	0.00 (0.001)	-0.00* (0.00)	- 0.096** (0.025)	0.00 (0.00)
Constant (α)	82.497*** (1.757)	52.125*** (1.133)	79.644*** (1.960)	52.439*** (12.727)	88.432*** (1.980)	52.776*** (1.467)
Province FE	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES
R-squared (R^2)	0.967	0.980	0.976	0.983	0.969	0.982
Number of events	7	7	7	7	7	7
Observations	2,807	2,684	1,364	1,350	1,443	1,333
Tax Incidence						
Tax Change($\overline{\Delta T}$))	-5.72	-3.86	-6.03	-4.3	-5.55	-3.59
Pass-through (η)	121%	-60%	133%	-76%	104%	-46%
95% C.I. on pass-through	(185%, 55%)	(5%, -126%)	(172%, 94%)	(27%, -181%)	(189%, 18%)	(-5%, -86%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ.

The estimated coefficients of large cities' tax decreases are -8.015 cents/litre, highly significant at a 0.1% level of significance and the pass-through rate is 133% where the average tax decreased by 6.03 cents/litre (Table 8). The estimated coefficients of medium/small cities' tax decreases are -5.748 cents/litre, significant at a 5% level of significance and the pass-through rate is 104% where the average tax decreased by 5.55 cents/litre. The results of the confidence interval reveal no significant difference between the estimated coefficients from the difference-in-difference analysis and the average tax decrease in retail gasoline prices for both large cities and medium/small cities. These findings imply that the pass-through rates for both cities are statistically not different from 100%.

For wholesale prices of gasoline, there is no significant difference between the estimated coefficient and zero in large cities and Canada, but the coefficient for medium/small cities is not different from zero. Overall, this suggests that tax decreases do not significantly affect the wholesale price of gasoline in large cities and Canada, but medium/small cities are significantly affected by tax decreases.

CHAPTER FIVE

ROBUSTNESS CHECK

5.1 Introduction

This chapter aims to assess the robustness of the estimated tax incidence results. Reliability and consistency can be ensured by testing the results under different conditions. I start by extending the analysis to a longer time frame using a 17-week window. The methodology used for the 17-week window analysis is similar to the original 9-week window. This also involves estimating the tax incidence and pass-through rates for large cities and medium/small cities over an extended period. To further verify the robustness of the initial results, the tax incidence using the original 9-week window is re-estimated but without considering any fixed effects or covariates. This simpler model allows us to see if the primary results hold when potential confounding factors are excluded.

5.2 Empirical Results of Tax Incidence for the 17-Week Window

The study investigates the robustness of the event-based difference-in-difference model concerning the incidence of gasoline tax changes on wholesale and retail prices using a 17-week window panel dataset. The dataset is structured to include an 8-week pre-treatment period and an 8-week post-treatment period for each event. Specifically, the analysis focuses on 25 tax increase events and six tax decrease events. Three events are excluded from the tax increase dataset to mitigate potential bias. This exclusion aims to ensure the accuracy of assessing pre-treatment and post-treatment effects. After creating the dataset, I regressed equation (2) to estimate the impact of tax policy change on the gasoline prices for each week. Equation (3) was employed to ascertain the aggregate impact of tax incidence.

5.2.1 Event plot analysis of retail and wholesale gasoline prices for the 17-week window

I generate an event plot using the point estimates derived for each week before and after the tax increase and decrease, comparing treated cities to control cities within the 17-week window. Employing the event-based difference-in-difference regression model, I evaluate the impact of tax changes on both retail and wholesale gasoline prices for each week of this extended period. I use the week before the tax increase or decrease as the reference period, excluding it from the pre-treatment period and setting it as zero for estimation.

Event plots of tax increase

Event plots for the effect of gasoline tax increase events on the retail and wholesale prices are illustrated in figures 9A and 9B respectively. Figure 9A shows little fluctuation in the pre-treatment estimates ranging from -0.7 cents/litre for eight weeks before the tax increase to -1.1 cents/litre for four weeks before the tax increase. Then, the difference in retail price between treated and control groups started increasing and reached -0.3 cents/litre for two weeks before the tax increase. The findings of the event plot suggest that gasoline retail prices in the treated group are increasing before tax hikes. This trend of the 17-week window event plot for tax increases is quite similar to the event plot of the 9-week tax increase incidences.

In essence, figure 9A observes that the difference in retail price between treated and control groups increased sharply from around -0.3 cents/litre to around 1.5 cents/litre across the two weeks before and during the tax increase week. This indicates an immediate response by retailers to the tax hike, passing it on to the final consumer's price. In affected cities, gasoline prices continue to climb in the weeks following the event, reaching a peak of about 2.2 cents/litre in the third week of post-tax adjustment. This marks the most significant impact of the tax increase on retail prices, followed by a gradual decline but with fluctuations in the fourth to eighth post-treatment periods, ranging from about 1.96 cents/litre to about 1.2 cents/litre.

Figure 9B shows that there was no notable effect of the tax increase on the wholesale price of gasoline in treated cities compared to control cities, both before and after the treatment. Across the entire period, the wholesale price of gasoline in treated cities remained consistently lower than that in control cities.

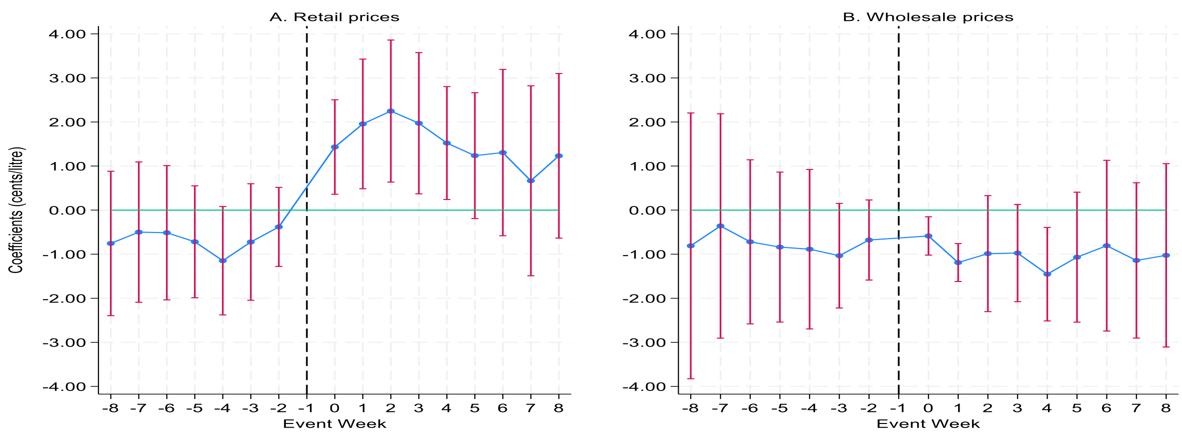


Figure 9. Event plots of tax increases in Canada: 17-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

In large cities retail prices, the difference between treated and control cities is consistent until two weeks before the tax hike. However, there is an immediate increase in retail prices in the treated large cities after implementing the tax. The retail prices reach the highest point after the second week of the tax increases then start to decline and stabilize after the fourth week of the tax increase (Figure 10A).

In medium/small cities, there is fluctuation in the pre-treatment period although the point estimates are closer to zero till six weeks before the tax increase (Figure 10C). Compared to large cities, retail prices in medium/small cities have become higher, however, in medium/small cities retail prices also declined after the second week of tax hikes. Comparing the event plots from the 17-week and 9-week windows for both large cities and medium/small cities, I find consistency in the impact of tax increases over both time frames.

Figures 10B and 10D demonstrate that the tax increase had no significant impact on the wholesale price of gasoline in large cities and medium/small cities respectively. Throughout the entire study period, the wholesale price of gasoline in large cities consistently remained lower than in medium/small cities. These findings are also consistent with the event plots of the 9-week window.

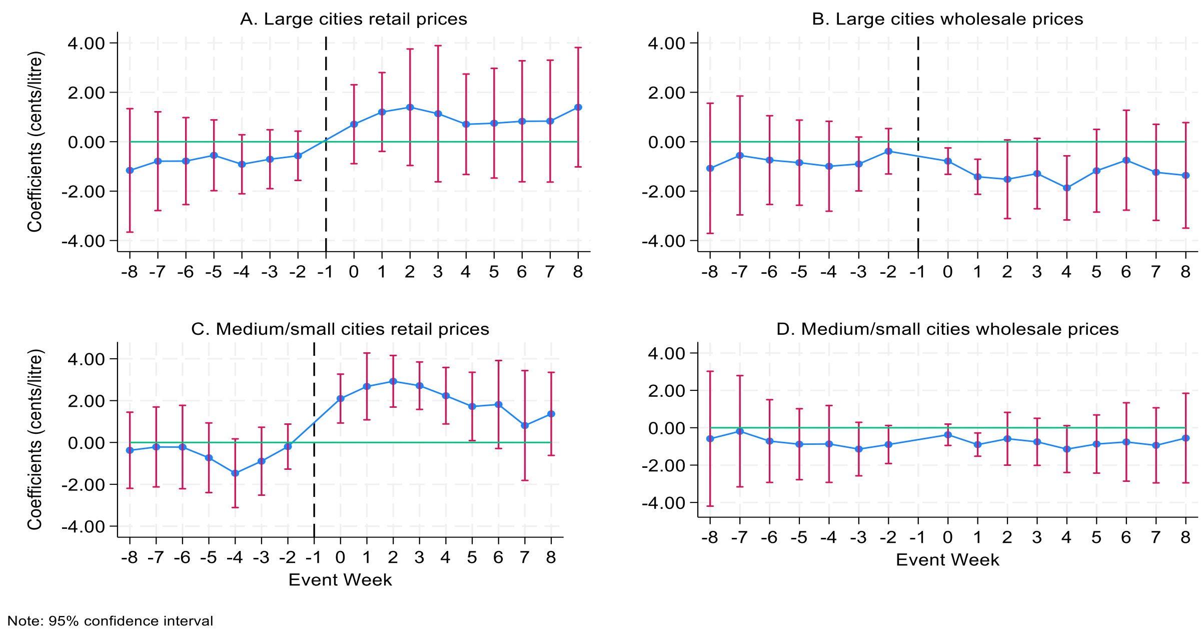


Figure 10. Event plots of tax increases in large cities and medium/small cities: 17-week window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

<u>Tax decrease in Canada</u>

Following tax increase, the tax decrease panel dataset is regressed using Equation 2 and generated event plot. Figure 11A shows that the pre-treatment coefficients are consistent between seven weeks before the tax decrease and four weeks before the tax decrease. However, after the fourth week of the pre-treatment period, there is a gradual decline in the retail price of treated cities, which becomes close to zero in two weeks before tax decrease implementation. These close-to-zero estimates indicate that there is no difference between treated and controlled cities' retail prices in the second pre-treatment period. Investigating the pre-treatment period in the 17-week window panel dataset suggests that the treated group has 6.4 cents/litre higher tax rates and 5.9 cents/litre higher retail prices than the control group on average. This also justifies the higher coefficients in the pre-treatment periods.

Consequently, the difference in the retail price between the treatment and control group continuously decreases and estimated coefficients are negative in the post-treatment period. This means the retail price in the treated cities is lower than in control cities after the tax cut. However, the difference in the retail price between the treatment and control group is stabilized at around 4 cents/litre after one week of tax decline persisting until the third post-treatment period. Subsequently, it slightly increases to 2 cents/litre in the fourth post-treatment period before continuing to decline steadily over the period thereafter.

Figure 11B shows wholesale prices exhibited no significant difference between treated and control cities before the tax cut. However, following the tax cut, wholesale prices in treated cities started to increase continuously until four weeks post-tax cut, followed by a reduction thereafter.

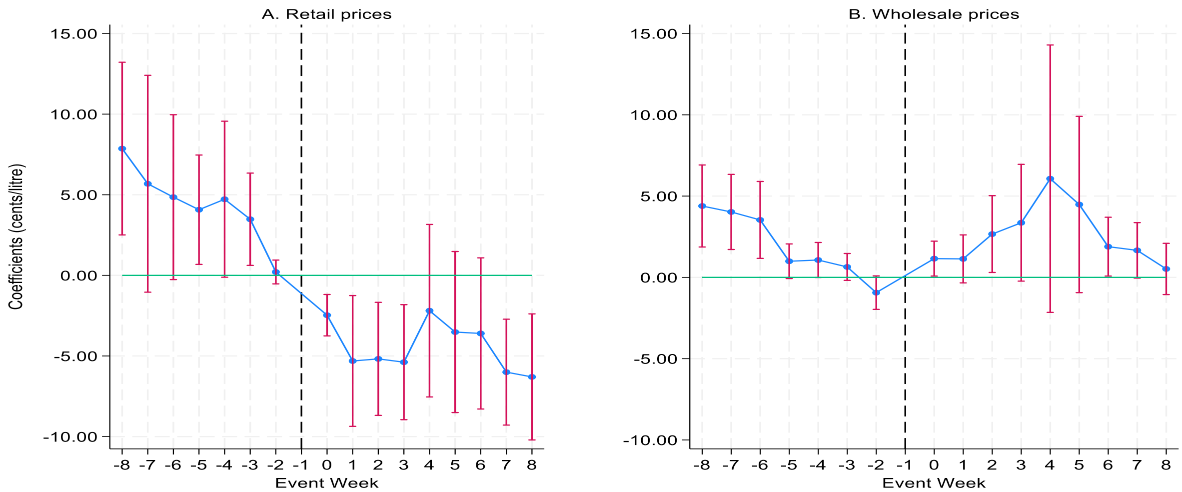


Figure 11. Event plots of tax decrease in Canada: 17-Week Window

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

In large cities (Figure 12A), retail price falls before tax cuts and keeps declining till the first week after the tax cut. However, in medium/small cities (Figure 12C), the difference in retail price between treated and controlled cities is consistent before the tax decrease and gradually declines after the tax cut. Event plots of the 9-week window for the impact of tax decrease on gasoline retail prices in large cities and medium/small cities showed a similar trend as the 17-week window. Figure 12B and figure 12D illustrate the impact of tax decrease on the wholesale price of gasoline in large cities and medium/small cities for the 17-week window respectively. The trends of wholesale price change due to tax cuts are quite similar, however, wholesalers pay more in large cities than in medium/small cities after tax cuts.

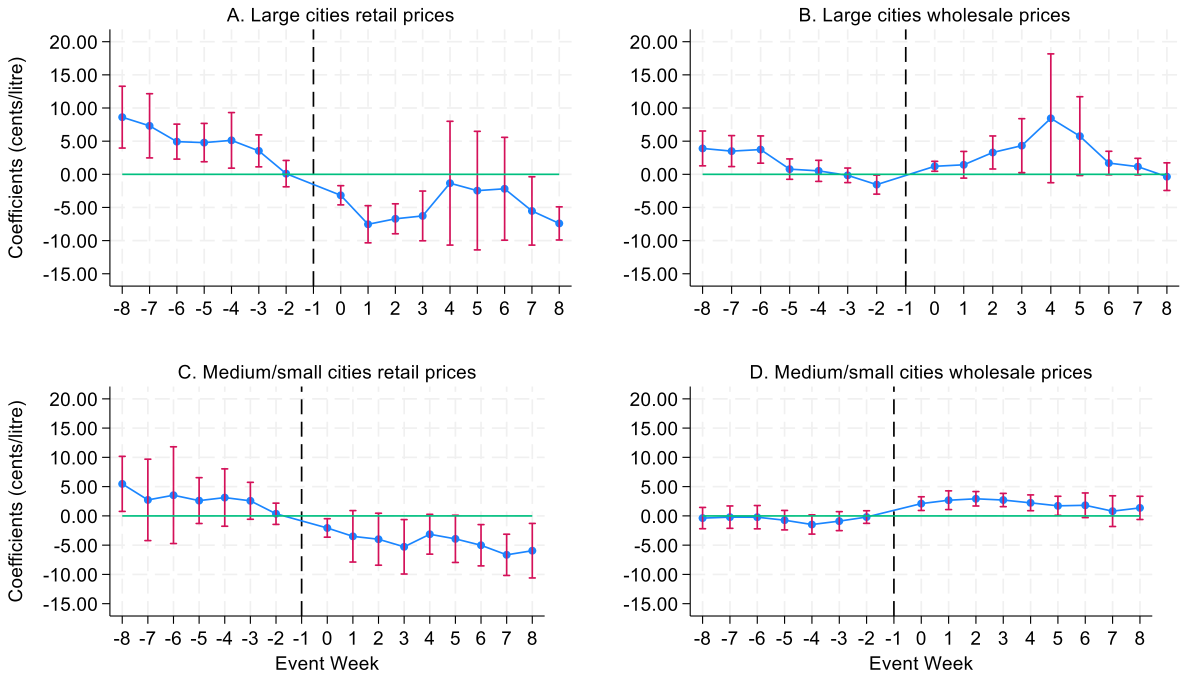


Figure 12. Event plots of tax decrease in large cities and medium/small cities: 17-week

Note: The red bars show the upper bound and lower bound of the 95% confidence interval, calculated using standard errors. Clustered standard error by grouping events.

5.2.2 Average tax incidence of retail and wholesale gasoline prices for the 17-week window

The pass-through rate of gasoline taxes to retail and wholesale prices is estimated using equations (3) and equation (4). In this section, first, I present the incidence of tax increases for Canada overall, along with medium cities and small and large cities. Next, I show the incidence of tax decreases across Canada, focusing also on medium cities and small and large cities.

<u>Tax increase incidence in Canada</u>

For the 17-week window in table 9, the significant estimated coefficients of tax increase for the gasoline retail price at a 1% significance level is 2.174 cents/litre. The estimated pass-through rate for this 17-week window indicates that consumers bear 88% of the tax burden over time. This suggests that retailers are passing on a substantial portion of the tax increase to consumers, although not the entire burden. Conversely, the findings from the 9-week window tax increase incidence showed a 100% pass-through rate, higher than the results of the 17-week window. However, the results of the 95% confidence interval indicate that statistically the pass-through rate of 88% in the 17-week window is not different from 100%, consistent with the results of the 9-week window for Canada.

Table 9: Tax increase incidence for the 17-week window

Parameters	Canada		Large		Medium/Small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	-3.505* (1.289)	-3.048** (0.847)	-4.225** (1.434)	-3.571** (1.204)	-3.496* (1.434)	-2.530** (0.629)
Post (ρ)	0.578 (0.313)	1.225* (0.496)	0.747 (0.387)	1.271* (0.556)	0.401 (0.293)	1.061* (0.503)
Treated*Post (θ)	2.174** (0.613)	-0.218 (0.435)	1.826* (0.613)	-0.415 (0.565)	2.586*** (0.598)	0.028 (0.553)
Population density (σ)	0.002*** (0.00)	0.00 (0.00)	0.006*** (0.00)	0.001 (0.00)	0.00 (0.00)	0.001** (0.00)
Household income (φ)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.043** (0.012)	0.015 (0.009)
Constant (α)	56.807*** (0.760)	28.531*** (0.509)	54.845*** (0.737)	28.681*** (0.754)	61.729*** (0.911)	26.887*** (0.699)
Province FE	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES
R-squared (R^2)	0.956	0.970	0.967	0.974	0.961	0.973
Number of events	25	25	25	25	25	25
Observations	15,485	10,447	7,374	5,659	8,111	4,788
Tax Incidence						
Tax Change ($\overline{\Delta T}$)	2.46	2.55	2.22	2.26	2.62	2.59
Pass-through rate (η)	88%	-9%	82%	-18%	99%	1%
95% C.I. on pass-through	(36%, 138%)	(-43%, 23%)	(4%, 157%)	(-66%, 30%)	(53%, 145%)	(-42%, 46%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ.

In large cities for the 17-week window, the coefficient of tax increase of 1.826 cents/litre is significant at a 5% level of significance, where the pass-through rate is 82%. In contrast, in medium/small areas for the 17-week, the tax increase coefficient is 2.586 cents/litre, significant at the 0.1% level, with a pass-through rate of 99%. The results of the confidence interval for the impact of a tax increase on the retail prices of gasoline over a 17-week window are consistent with the findings of the 9-week window, suggesting no significant difference between the estimated coefficient and the mean value of tax increases in the medium/small and large cities. Therefore, pass-through rates for both medium/small cities and large cities are statistically not different from 100%.

On the other hand, the coefficient of wholesale price tax increases is -0.218 cents/litre and statistically not different from zero. The pass-through rate is -0.09 in Canada, closer to zero. In both large cities and medium/small cities, the impact of tax increase on the wholesale price is also insignificant in the 17-week window consistent with the findings of the 9-week window. This suggests that the tax increase does not have a significant effect on the wholesale price of gasoline based on the data and analysis conducted in this study.

Tax Decrease Incidence

In table 10, the estimated coefficients on tax decrease for the retail price in the 17-week window are significant. Here, the tax decrease incidence of 140% suggests that retailers are responsive to changes in tax rates and are adjusting prices downward in response to tax reductions. The results of the confidence intervals imply that the estimated coefficient is statistically not different from the mean value of tax decreases, which means statistically the 140% pass-through rate is not different from 100% in the 17-week window. The incidence of tax decreases in the 9-week window is statistically consistent with the 17-week window. For the 17-week window, the estimated coefficients of large cities' tax decreases are -9.033 cents/litre, highly significant at a 1% level of significance and the pass-through rate is 130% which is consistent with the findings of the 9-week window. On the other hand, the estimated coefficients of medium/small cities' 17-week tax incidence are -6.941 cents/litre but insignificant. However, the result of the 9-week window's tax decrease incidence in the medium/small cities is significant.

Table 10: Tax decrease incidence for the 17-week window

Parameters	Canada		Large		Medium/Small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	2.446 (1.241)	-4.656 (1.968)	1.527 (1.928)	-5.817* (1.481)	2.069 (0.976)	-3.704 (2.327)
Post (ρ)	14.918** (2.210)	6.538* (1.752)	13.144** (2.739)	7.205* (1.932)	5.031* (1.880)	-18.66*** (0.232)
Treated*Post (θ)	-8.299** (2.030)	0.834 (1.173)	-9.033** (1.754)	1.654 (1.564)	-6.941 (2.827)	0.171 (0.929)
Population density (σ)	0.002* (0.00)	0.00 (0.00)	0.005** (0.001)	0.001** (0.00)	0.00 (0.00)	0.00 (0.00)
Household Income (φ)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.001* (0.00)	-0.10** (0.021)	0.00 (0.012)
Constant (α)	103.04*** (1.495)	67.145*** (2.083)	99.886*** (1.757)	67.56*** (2.288)	110.61*** (1.935)	67.737*** (1.937)
Province FE	YES	YES	YES	YES	YES	YES
Date FE	YES	YES	YES	YES	YES	YES
R-squared (R^2)	0.973	0.982	0.979	0.985	0.978	0.985
Number of events	6	6	6	6	6	6
Observations	3,753	3,464	1,819	1,751	1,934	1,713
Tax Incidence						
Tax Change($\overline{\Delta T}$)	-5.93	-6.39	-6.89	-6.39	-5.72	-6.40
Pass-through rate (η)	139%	-13%	131%	-26%	121%	-3%
95% C.I. on pass-through	(227%, 51%)	(34%, -60%)	(195%, 65%)	(36%, -88%)	(248%, 5%)	(34%, -40%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ.

Regarding wholesale gasoline prices, the findings of the 17-week window support the result of the 9-week window for tax decreases in Canada. These results suggest that tax decreases do not significantly affect the wholesale price of gasoline in Canada. However, the results of medium/small cities and large cities are different in the 9-week window from the 17-week window. The estimated coefficient for tax decreases in the 17-week window is statistically not different from zero in the medium/small cities but different from zero in the large cities. The results of the 17-week window indicate a significant effect on large cities and an insignificant effect on medium/small cities. However, the results of the 9-week window show a significant impact in medium/small cities but insignificant for large cities.

5.3 Empirical Results of Tax Incidence for the 9-week Window Without Fixed Effect and Covariates

I use the same 9-week window panel dataset, however, this time I do not include any fixed factors and covariates in the analysis. This approach helps to examine the importance of fixed factors and covariates that are used in the event-based difference-in-difference model to investigate the primary objectives of this study.

5.3.1 Event plot analysis of retail and wholesale gasoline prices of the 9-week window without fixed effect and covariates

I have generated event plots for retail and wholesale prices using point estimates from the event-based difference-in-difference regression (equation 2), excluding all fixed effects and covariates. This is applied to the 9-week window panel data set. I evaluate the point estimates for each week before and after the tax increase, comparing treated cities to control cities and creating the event plots based on these estimates.

Tax Increase in Canada:

Figure 13A shows the impact of the tax increases on retail gasoline prices over 9 weeks, excluding fixed effects and covariates. Here, retail prices continuously increase after the tax hike and in the 4th week after the tax increase the point estimate is 5.84 cents/litre. It is too high compared to the average tax increase and unrealistic too. Similarly, the wholesale price in figure 13B shows a positive and higher impact over the week than the primary 9-week window including fixed effects and covariate. Controlling fixed effects and covariates provides a more reliable and accurate estimate of the impact of tax increases on gasoline prices.

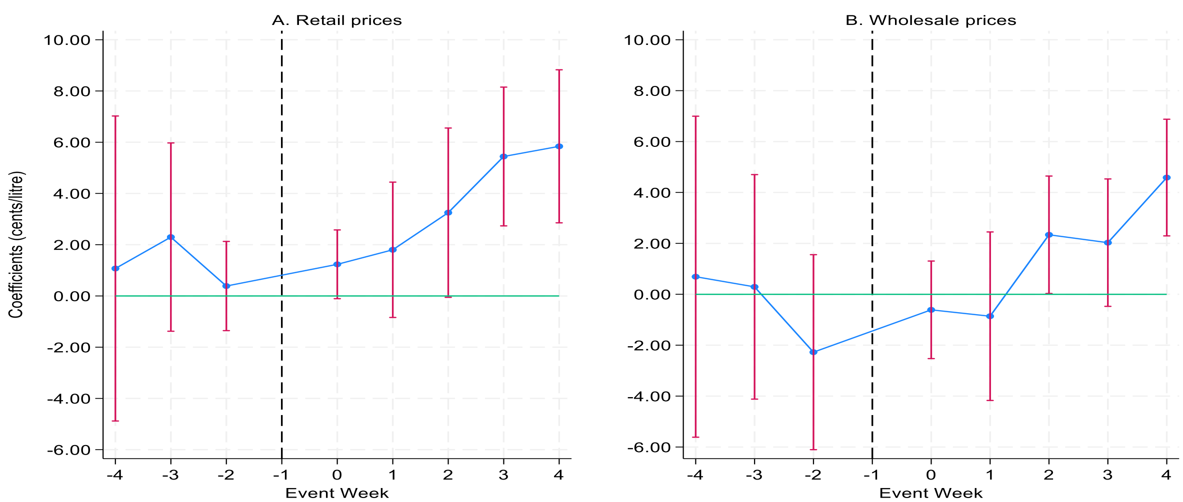


Figure 13. Event plots of tax increases without fixed effect and covariates in Canada: 9-week

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

The event plots of the impact of tax increase on both large cities and medium/small cities' retail and wholesale prices follow a similar trend in the case of excluding fixed effects and covariates in the 9-week window (Figure 14). A significant difference is noticed when fixed effects and covariates are considered in the analysis.

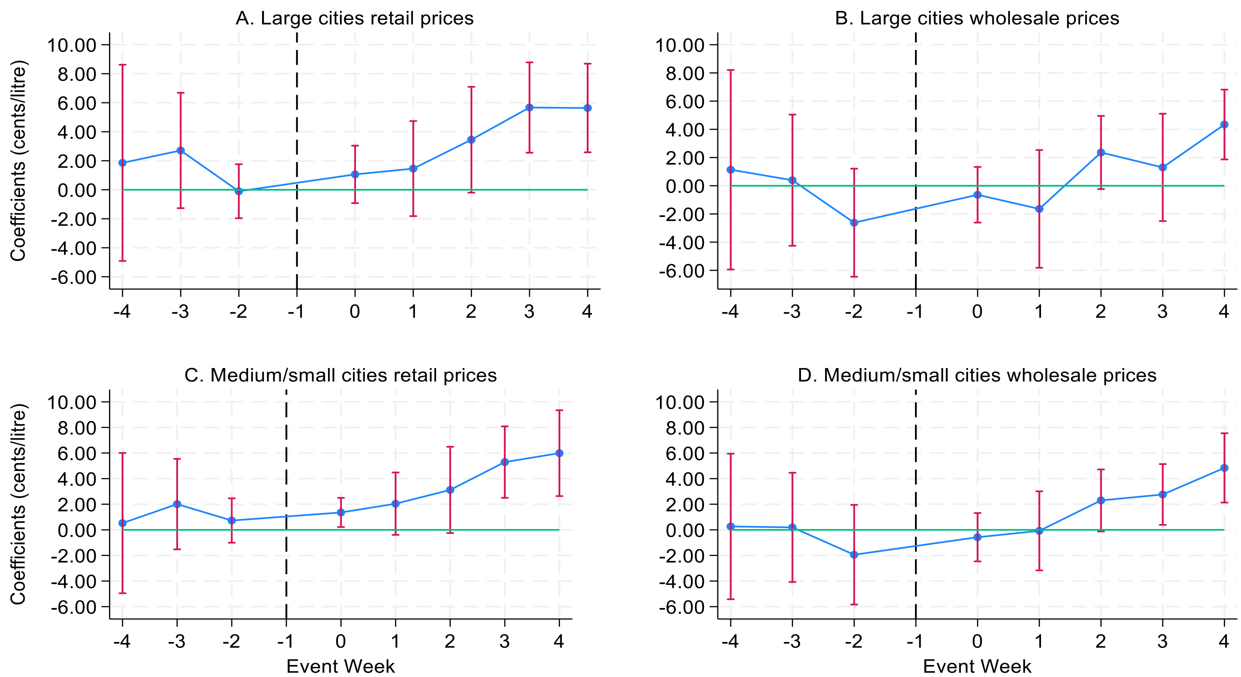


Figure 14. Event plots of tax increases without fixed effect and covariates in large cities and medium/small cities: 9-week

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

<u>Tax Decrease in Canada</u>

Retail and wholesale prices of gasoline both declined after the tax decrease in figure 15. However, a different scenario is noticed in the case of the 9-week window including fixed effects and covariates where the retail price is falling and wholesale price is going up after the tax cut. Figure 15A shows the maximum point estimate for the tax decrease impact on retail gasoline price without fixed effect and covariates is -10.72 cents/litre, which is also unrealistic compared to the mean tax decrease in Canada.

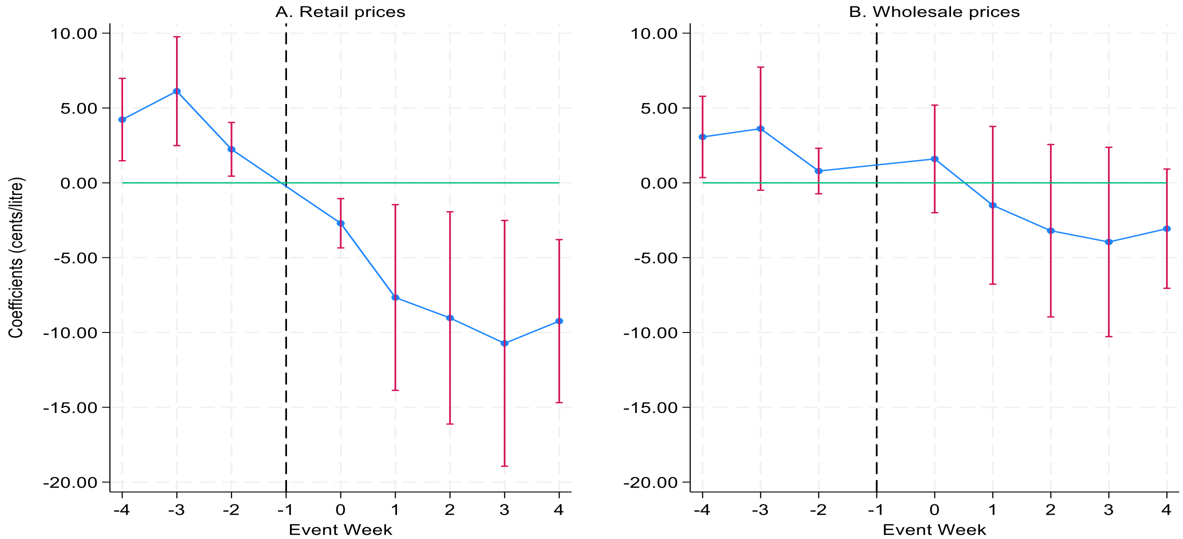


Figure 15. Event plots of tax decrease without fixed effect and covariates in Canada: 9-week

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

The event plots for the impact of a tax decrease on both large and medium/small cities' retail and wholesale prices in figure 16 follow a similar trend when excluding fixed effects and covariates in the 9-week window. However, a significant difference is observed when fixed effects and covariates are included in the analysis.

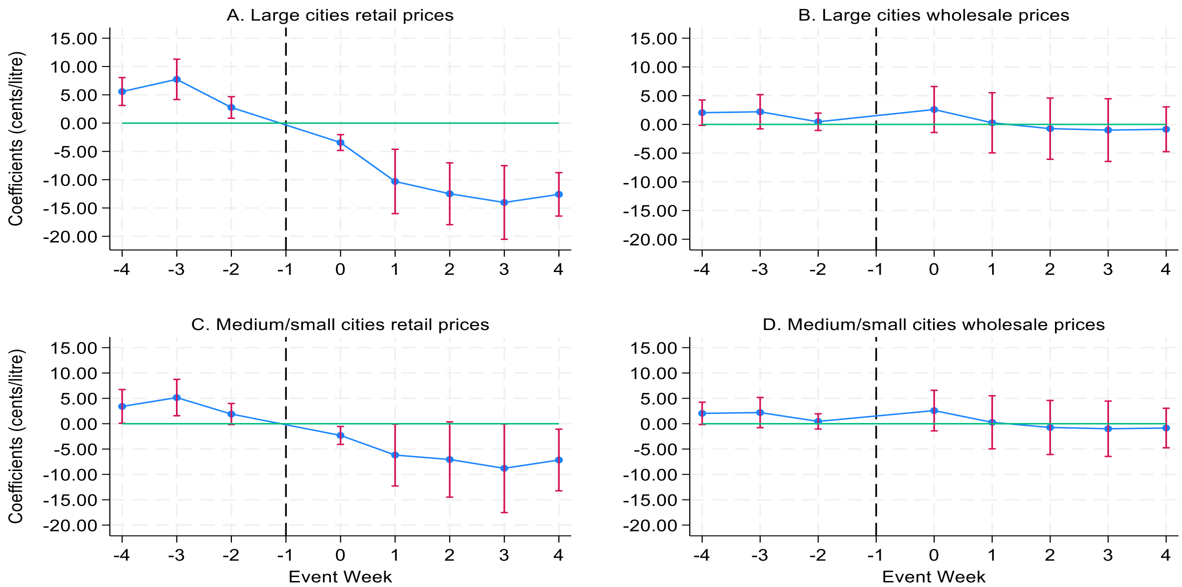


Figure 16. Event plots of tax decrease without fixed effect and covariates in large and medium/small cities: 9-week

Note: The red bars show the upper bound and lower bound of the 95% confidence interval. Standard errors clustered by events.

5.3.2 Average tax incidence of retail and wholesale gasoline prices for the 9-week window without considering fixed factors and covariates

Tax increase incidence in Canada

In table 11, the results of the tax increase incidence on retail and wholesale gasoline prices over a 9-week window without accounting for fixed factors and covariates are insignificant. This means that the observed changes in retail and wholesale gasoline prices due to the tax increase are not statistically significant in Canada and medium/small and large cities. The results of the confidence interval also find no significant relationship between the tax increases and gasoline prices in the 9-week window without considering fixed factors and covariates. This suggests that without adjusting for fixed factors and covariates, it is difficult to isolate the true effect of the tax increase on gasoline prices. Including these controls in the analysis helps to obtain more accurate and reliable results.

Table 11: Tax increase incidence for the 9-week window without considering fixed factors and covariates

Parameters	Canada		Large		Medium/Small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	9.411 (8.289)	8.578 (7.140)	12.670 (9.647)	9.613 (8.514)	7.157 (7.764)	7.539 (6.277)
Post (ρ)	1.756 (1.071)	-0.177 (1.857)	1.870 (1.084)	0.110 (1.857)	1.673 (1.079)	-0.479 (2.049)
Treated *Post (θ)	2.575 (1.976)	1.847 (1.985)	2.338 (2.045)	1.447 (2.136)	2.743 (2.003)	2.249 (1.961)
Constant (α)	116.88*** (4.767)	71.033*** (3.747)	114.80*** (5.355)	70.290*** (4.137)	118.30*** (4.476)	71.807*** (3.790)
Province FE	NO	NO	NO	NO	NO	NO
Date FE	NO	NO	NO	NO	NO	NO
R-squared (R^2)	0.028	0.040	0.041	0.042	0.020	0.038
Number of events	28	28	28	28	28	28
Observations	12,696	8,168	5,179	4,087	7,517	4,081
Tax Incidence						
Tax Change ($\overline{\Delta T}$)	3.08	3.2	2.81	2.91	3.27	3.46
Pass-through rate (η)	83%	57%	83%	50%	83%	65%
95% C.I. on pass-through	(-47%, 214%)	(-69%, 178%)	(-65%, 232%)	(-100%, 200%)	(-41%, 209%)	(-51%, 181%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ.

<u>Tax Decrease Incidence</u>

In table 12, while the tax decrease incidence on retail prices in Canada and large cities is statistically significant, the pass-through rates of 192% and 241% are economically unrealistic. On the other hand, the estimated results for tax decrease incidence are insignificant for retail prices in medium/small cities, as well as for wholesale prices in both medium/small and large areas, and across Canada. Confidence interval supports these results, confirming the significance for retail prices in Canada and large areas, while showing the insignificance for medium/small retail prices and wholesale prices in all cities in Canada.

Table 12: Tax decrease incidence for the 9-week window without considering fixed factors and covariates

Parameters	Canada		Large		Medium/Small	
	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale
Treated (β)	25.44 (18.80)	12.68 (12.03)	38.619 (18.282)	23.18 (15.40)	17.61 (18.99)	4.56 (7.64)
Post(ρ)	-3.91 (2.08)	-4.08 (2.68)	-3.145 (2.507)	-3.92 (2.30)	-4.41 (1.86)	-4.16 (3.12)
Treated * Post (θ)	-11.01* (3.64)	0.672 (4.39)	-14.586** (2.809)	-0.99 (5.78)	-8.91 (3.81)	1.25 (3.25)
Constant (α)	134.66*** (11.25)	87.07*** (8.03)	132.20*** (10.67)	85.52*** (7.25)	136.32*** (11.68)	88.39*** (8.98)
Province FE	NO	NO	NO	NO	NO	NO
Date FE	NO	NO	NO	NO	NO	NO
R-squared (R^2)	0.048	0.038	0.102	0.101	0.026	0.011
Number of events	7	7	7	7	7	7
Observations	3,403	2,918	1,364	1,351	2,039	1,567
Tax Incidence						
Tax Change ($\overline{\Delta T}$)	-5.72	-3.86	-6.03	-4.3	-5.55	-3.59
Pass-through rate (η)	192%	-17%	241%	23%	160%	-34%
95% C.I. on pass-through	(347%, 36%)	(261%, -295%)	(356%, 127%)	(353%, -306%)	(327%, -7%)	(186%, -256%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ.

5.4. Gasoline tax incidence using seasonal dummies and clustering provinces

After analyzing gasoline tax incidence for the 9-week window without incorporating fixed factors and covariates, this study conducts two additional experiments. These experiments aim to assess whether accounting for seasonal variations and clustering standard errors by provinces influences the primary findings for Canada. First, the study revisits the primary model for the 9-week window, introducing seasonal dummies for winter, summer, and spring, while clustering standard errors by events. Next, the same model is applied with seasonal dummies, but standard errors are clustered by provinces. In both analyses, fall is omitted as a reference category. The results from these additional analyses align closely with the primary findings for the 9-week window, as shown in Appendix B and Appendix C.

CHAPTER SIX

CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

6.1 Introduction

This chapter summarizes the main findings of the study on gasoline tax incidences in Canada, highlighting how tax changes influence gasoline prices in both medium/small and large cities. This chapter also discusses the limitations of the analysis and offers recommendations for future research and policy.

6.2 Conclusions

This thesis investigates the impact of gasoline tax changes on retail and wholesale prices using event-based difference-in-difference regression models. The study examines the effects of tax increases and decreases on the retail and wholesale gasoline market using the 9-week window and 17-week window datasets.

In the 9-week window, the study finds that consumers bear 100% of the gasoline tax increases, with retail prices adjusting promptly and significantly in response to tax hikes. Alm et al. (2009), and Silvia and Taylor (2016) agree that the entire burden of gasoline tax is passed on to consumers in the form of higher retail prices as they also found a 100% pass-through rate for retail price of gasoline tax. From the tax incidence perspective, consumers have limited ability to adjust their consumption of gasoline in response to price increases, leading to a relatively inelastic demand for gasoline in Canada.

Furthermore, the study finds that gasoline tax decreases lead to 120% pass-through to retail prices in the 9-week window. Marion & Muehlegger (2011) also found a 122% pass-through rate for retail prices and supports the results of tax decrease incidence of retail price in this study. Wholesalers, however, show limited responsiveness to tax changes, with wholesale prices remaining relatively stable. Overall, this result suggests that consumers get benefits from the tax decreases in the form of lower prices passed on by retailers.

The event plots result for tax increases and tax decreases suggest an immediate effect on the retail prices of gasoline. Analysing pre-treatment trends is a crucial step in validating the assumptions of a difference-in-differences (DID) approach, particularly the parallel trends assumption. This assumption states that in the absence of treatment (in this case, a tax change), the treated and control groups would have followed similar price trends. Deviations from this assumption can introduce bias into the estimated effect of the tax change. The study also finds that the difference in retail prices between the treated and control groups begins to change even before the tax is adjusted. This divergence introduces bias, as the DID model might incorrectly attribute these pre-existing differences to the treatment effect.

The anticipation behaviour could be a reason. The anticipatory behaviour of both consumers and retailers could also play a role in shaping retail prices in these cities before the tax adjustments (Coglianese et al., 2017). For instance, consumers' expectations of impending price hikes due to taxes might influence how they choose to spend their money, potentially causing a surge in gasoline demand at the stations before the tax change and subsequently driving up retail prices in treated cities. Anticipation behaviour has a tendency to influence consumers' purchasing patterns around tax changes. For instance, when a tax increase is announced, buyers tend to purchase more gasoline before the increase takes effect to avoid paying higher prices. This leads to a temporary increase in demand, which can push prices up slightly even before the tax is implemented. On the contrary, when a tax decrease is anticipated, consumers may delay their purchases or they may reduce the purchasing amount, waiting for the lower prices. As a result, demand can temporarily fall, which may lead to lower prices before the actual tax cut.

In the 17-week window, the study provides a more comprehensive understanding of how retail and wholesale prices respond over time following tax changes. The results confirm the robustness of the 9-week window findings, with consumers continuing to bear the burden of tax increases and benefiting from tax decreases over an extended period. The findings of medium/small cities and large cities indicate that retail prices are significantly impacted by both tax increases and decreases, while wholesale prices show limited sensitivity to tax changes. Overall, the impact of tax policy effectively passes to the retail prices all over Canada.

6.3 Limitations and Recommendations

This study, while offering important insights into gasoline tax incidence across different cities, faces certain limitations that could influence the findings. This section outlines these limitations and provides recommendations for future research to address them. One of the limitations of this study is that it considers 9-week and 17-week windows for the event-based difference-in-difference analysis. This study could enhance window size to increase total observations. Suppose this study considers a 20-week window with eight weeks before and twelve weeks after the tax change for the event-based panel dataset. However, in the 20-week window, this study can lose cities from the control group for events. For example, this study needs to drop the cities of Nova Socia from the event 11-Dec-01; cities of New Brunswick from the event 09-Apr-02, 04-Mar-03 and 5-Jul-11, cities of British Columbia from the event 17-Dec-02 and 29-Mar-11; cities of Alberta from the event 01-Apr-18, cities of Newfoundland and Labrador from the event 01-Apr-18 and 6-Apr-21. This study also needs to drop the event of Newfoundland and Labrador on 06-Jul-21. The dropping of control cities could narrow the control group effect and could bias the treatment group effect. For that reason, I selected the 9-week and 17-week windows for this study. However, the study is also constrained by the availability and scope of control groups for some of the examined events. This limitation may affect the robustness of the analysis, as the absence or insufficiency of control groups could impact the ability to accurately isolate the effects of tax changes from other influencing factors. Consequently, the conclusions drawn may not be fully generalizable or reflective of all possible scenarios. In future studies, researchers can enhance the control group by adding US data to estimate pass-through rates for gasoline tax policy.

Another limitation is that Quebec and Prince Edward Island are not included in this study due to data limitations and the presence of different tax systems in these provinces. As a result, the findings may not fully represent the gasoline tax incidence in these cities. Future research could aim to include these provinces by addressing the data limitations and adjusting for their distinct tax structures. Furthermore, the study concentrates on retail and wholesale prices of gasoline but does not account for diesel tax incidence. Diesel fuel is a significant component of the broader fuel tax landscape, and its exclusion means that the analysis might not fully capture the overall impact of fuel taxes in Canada. Including diesel tax incidence in future studies could provide a more comprehensive understanding of how different fuel types contribute to overall tax incidence and market dynamics.

Moreover, this thesis does not account for the effect of the federal GST on the analysis of gasoline price pass-through. Since the GST is applied on top of other taxes, including provincial fuel and carbon taxes, it could affect the total tax burden at the pump. This compounding effect may result in an underestimation of the true pass-through rate of taxes to retail gasoline prices. Future studies could explore the impact of GST to provide a more precise estimate of tax incidence. The study estimates separate regressions for large and medium/small cities but does not include a regression with an interaction term between large cities and medium/small cities dummy variables in the difference-in-differences analysis. Including this interaction term could have allowed testing whether the pass-through of tax changes differs significantly between large cities and medium/small cities. Future research could address this by incorporating interaction terms to examine potential variations in tax pass-through rates between these cities, offering a clearer understanding of regional differences. Finally, the model used in this study may overestimate or underestimate the tax pass-through effects due to biases in the pre-treatment trends, highlighting the need for future studies to refine the methodology by exploring alternative control groups to address potential violations of the parallel trends assumption.

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APPENDIX

A. Empirical studies on tax incidence

Author(s)	Data	Model	Pass-through
Marion & Muehlegger (2011)	Gasoline and diesel fuel tax using US state-level monthly retail price data from 1983 to 2003	First-difference	state tax 122%, federal tax 110%
Silvia and Taylor (2016)	Washington's gasoline and diesel excise tax using weekly station-level retail price data from January to December 2003	Difference-in-difference	100%
Stopler (2016)	Diesel tax incidence using station-specific daily retail price data from 2007 to 2013 in Spain	Event-based difference-in-difference	100%
Erutku (2019)	Carbon pricing to the wholesale gasoline markets of Ontario and Quebec in Canada	Ordinary least squares regression	Ontario, from 126% to138%, Quebec 75%
Sun et al. (2022)	Impact of diesel consumption taxes on retail prices in China	Three-stage Least Squares (3SLS)	49%
Harju et al. (2022)	Investigated the diesel carbon tax incidence on retail gasoline prices using station-level data from Finland	Difference-in-difference	80%
Sun (2023)	Impact of excise tax reduction in Ontario on July 1, 2022, on the retail price of gasoline, using city-level data	dynamic difference-in-difference model	100%

B. Gasoline tax incidence using seasonal dummies for Canada

Parameters	Tax Increase		Tax Decrease	
	Retail	Wholesale	Retail	Wholesale
Treated (β)	-3.603*** (0.908)	-2.862*** (0.629)	0.760 (1.357)	-4.800** (0.976)
Post (ρ)	6.727*** (0.059)	-2.482*** (0.218)	-5.556*** (0.276)	-0.304 (0.137)
Treated*Post (θ)	3.09** (0.895)	0.796 (0.874)	-6.942** (1.509)	2.332 (1.053)
Winter (x)	7.219*** (0.055)	5.592*** (0.00)	55.381*** (0.530)	30.609*** (0.136)
Summer (y)	57.572*** (0.109)	34.91*** (0.157)	93.841*** (0.514)	20.856*** (1.194)
Spring (z)	3.293*** (0.055)	57.54*** (0.257)	34.384*** (0.115)	27.512*** (1.126)
Population density (σ)	0.002*** (0.00)	0.00 (0.00)	0.001 (0.00)	0.00 (0.00)
Household income (φ)	0.001* (0.00)	-0.00 (0.00)	0.00 (0.00)	-0.00 (0.00)
Constant (α)	50.98*** (0.995)	26.218*** (0.754)	82.497*** (1.757)	52.478*** (1.077)
Province FE	YES	YES	YES	YES
Date FE	YES	YES	YES	YES
R-squared (R^2)	0.951	0.968	0.967	0.980
Number of events	28	28	7	7
Observations	10,675	7,675	2,807	2,684
Tax Incidence				
Tax Change($\overline{\Delta T}$))	3.08	3.2	-5.72	-3.86
Pass-through (η)	100%	25%	121%	-60%
95% C.I. on pass-through	(40%, 159%)	(-31%, 80%)	(185%, 56%)	6%, -127%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by events. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ. The fall dummy is omitted from the analysis.

C. Gasoline tax incidence using seasonal dummies and clustering province

Parameters	Tax Increase		Tax Decrease	
	Retail	Wholesale	Retail	Wholesale
Treated (β)	-3.603**	-2.862*	0.760	-4.800**
	(1.00)	(0.844)	(1.196)	(1.210)
Post (ρ)	6.727***	-2.482**	-5.556***	-0.304
	(0.342)	(0.440)	(0.726)	(0.336)
Treated*Post (θ)	3.09**	0.796	-6.942**	2.332*
	(0.679)	(0.420)	(1.279)	(0.951)
Winter (x)	7.219**	5.592***	55.381***	30.609***
	(1.395)	(0.126)	(2.292)	(2.230)
Summer (y)	57.572***	34.91***	93.841***	20.856***
	(2.912)	(1.101)	(3.771)	(2.309)
Spring (z)	3.293**	57.54***	34.384***	27.512***
	(0.719)	(1.370)	(2.825)	(3.55)
Population density (σ)	0.002***	0.00	0.001	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Household income (φ)	0.001*	-0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Constant (α)	50.98***	26.218***	82.497***	52.478***
	(3.190)	(2.785)	(2.697)	(2.090)
Province FE	YES	YES	YES	YES
Date FE	YES	YES	YES	YES
R-squared (R^2)	0.951	0.968	0.967	0.980
Number of provinces	8	8	8	8
Observations	10,675	7,675	2,807	2,684
Tax Incidence				
Tax Change($\overline{\Delta}T$))	3.08	3.2	-5.72	-3.86
Pass-through (η)	100%	25%	121%	-60%
95% C.I. on pass-through	(48%, 152%)	(-6%, 55%)	(185%, 56%)	-2%, -118%)

Note. *p<0.05, **p<0.01, ***p<0.001

Note: Here, the household income unit is a thousand Canadian dollars. Standard errors clustered by provinces. The 95% C.I. is the 95% confidence interval (upper bound, lower bound) for the DID parameter θ. The fall dummy is omitted from the analysis.