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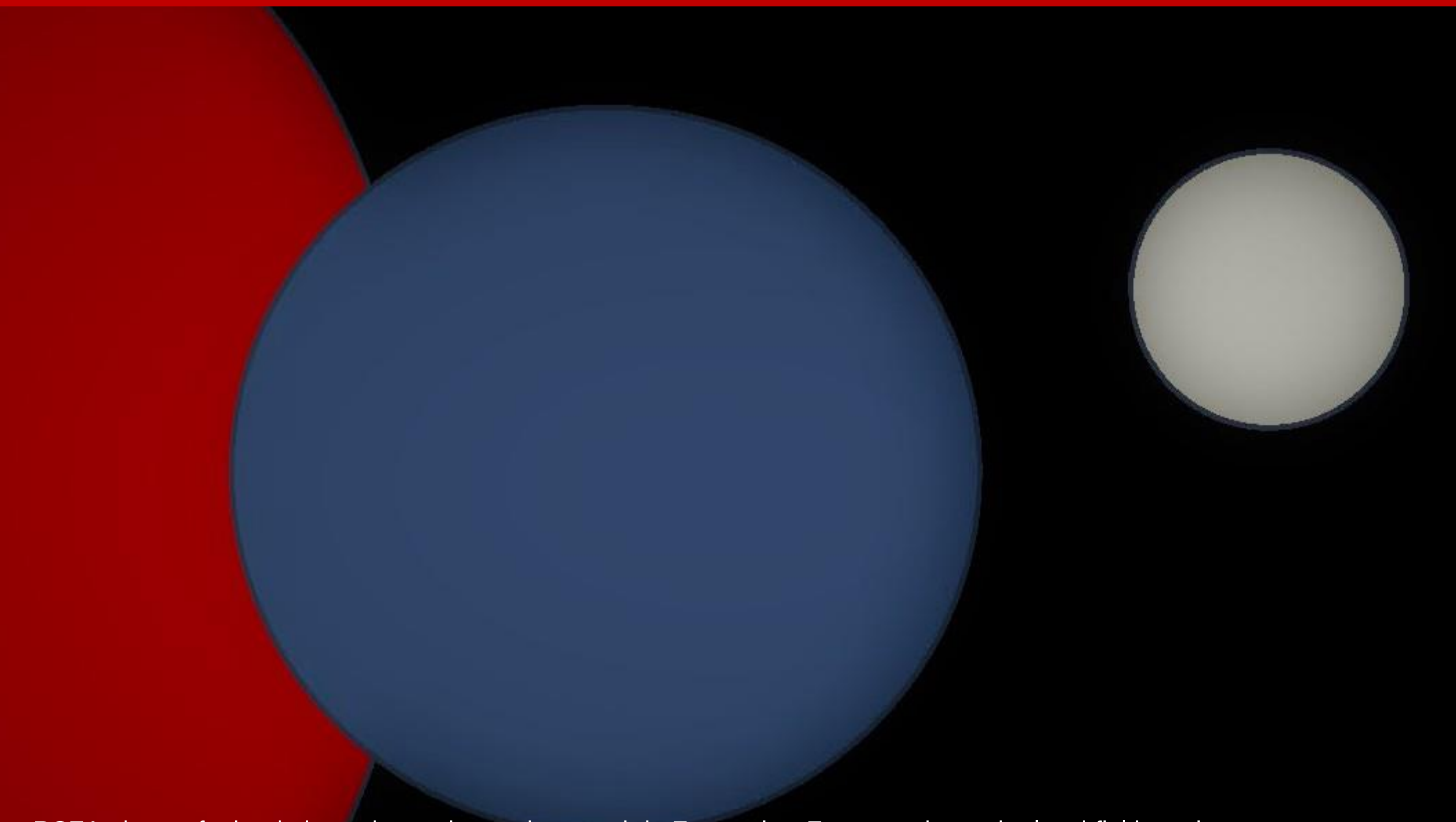

Convergence in retail gasoline prices: Insights from Canadian cities*

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Abstract

This paper investigates the extent of convergence club formation in retail gasoline prices. Our study provides new insights through the use of a large disaggregated panel database for Canada that comprises three types of gasoline grades, namely regular, medium and premium, for a sample of 44 cities over a period of almost two decades. The paper analyses gasoline price data that are inclusive or exclusive of taxes. The findings suggest that the retail gasoline markets are not integrated in terms of requiring multiple numbers of convergence clubs to explain relative price movements across cities. In addition to this, wholesale gasoline prices cities are probably less integrated than retail prices. Key drivers of retail price divergence across cities include distances between cities and the need to be explicit on distinguishing fuel quality. These findings are robust to the inclusion or exclusion of taxes in retail gasoline prices.

JEL Classification: C33, Q43, R10

Keywords: Convergence, clubs, gasoline prices.

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1 Introduction

Retail gasoline prices across geographical areas are determined by a range of influences that include crude oil prices, various supply and demand factors, price regulation as well as taxes. Within many countries, gasoline taxes can vary significantly by province or state and in some cases, by city.[1] But what is less clear is the extent to which gasoline price behaviour across regions and cities is consistent with the presence of a single national market. This is an important issue as there are implications if markets in different geographic areas have diverged and respond differently to energy price shocks. If convergence across cities is present, then local tax policy or regulation may be compromised through factors such as cross-border arbitrage. There may be other fiscal issues to take into account insofar as relative price dynamics may impact on regional budgets, which are in turn influenced by retail gasoline sales. Since gasoline retail sales are subject in part to local taxation, local fluctuations in gasoline prices and fuel demand impact on the revenue streams for local authorities and the viability of their expenditure programmes.

In reflecting upon the regional variation in gasoline prices, there are a number of additional implications. First, the welfare of households is affected by the gap between the actual retail price paid for gasoline and the willingness to pay, i.e. consumer surplus. The extent of fluctuations in gasoline prices and price convergence can have implications for consumer surplus and welfare across cities. In addition to this, gasoline prices impact directly on the running costs associated with private and public transport. Transportation and commuting costs feed into measurements of regional costs of living. Related to this is an expectation of fair pricing on the part of gasoline consumers. When comparing and contrasting gasoline prices across cities, consumers have an expectation of fair pricing insofar as observed price dif-

[1] See, for example, the provincial comparisons reported by Natural Resources Canada at https://www.nrcan.gc.ca/energy/fuel-prices/18885, or the Tax Foundation at https://taxfoundation.org/state-gas-tax-rates-2019/ for US state taxes.

ferentials reflect differences in factors such as fuel quality, local taxation and variations in the cost of transporting fuel to different cities. However, variations in gasoline prices that are perceived as based on local market power for example, might not necessarily be regarded as fair pricing. Second, the degree of competition in the gasoline market and sensitivity of consumer demand to gasoline prices will affect the extent to which a fuel tax increase is passed onto consumers in terms of higher retail fuel prices. If retail gasoline prices across cities are converged, then the scope for local taxes to raise local consumer prices is limited. This will mean that the energy tax burden is more likely to be borne by the producers rather than consumers, and so firms located in high tax regions will be disadvantaged (Dreher and Krieger, 2010; Suvankulov et al., 2012). Finally, the extent of common gasoline price behaviour across geographical areas is important from the point of view of understanding the nature and intensity of regional business cycles and consumer prices. Fuel prices are a key ingredient in the construction of national and regional consumer price or cost of living indices. As a key energy source, fluctuations in gasoline prices impact significantly on regional aggregate economic output. The extent to which regional gasoline prices are converged has the potential to influence the relative responses of regional consumer prices and output to shocks that affect the gasoline market.

In this paper, we revisit the measurement of gasoline price convergence across geographical areas. We ask to what extent can observed movements in retail gasoline prices across cities and types of gasoline be regarded as consistent with the presence of a single converged national retail gasoline market? Also, to what extent might different tax regulatory regimes across cities affect convergence? In order to answer these questions, we conduct a case study of Canadian gasoline price data that is appropriately available at both city-level and for different fuel types. In contrast to the earlier studies of integration in regional gasoline prices by Suvankulov et al. (2012), and Holmes et al. (2013), our empirical modelling strategy is based on the concept of relative convergence proposed by Phillips and Sul (2007). This notion of convergence examines whether the ratio of any pair of variables converges towards unity in the long run. It offers three main benefits from the econometric viewpoint, namely: it does not require embarking on an initial analysis of the time-series properties of the underlying variables through the implementation of unit root and cointegration tests; it is useful when the variables under consideration exhibit heterogeneous trending behaviours; and it implies that the cross-sectional dispersion among the individual variables decreases over time (see Sul, 2019, ch. 7).

In addition to detecting overall relative convergence, if present, another feature of the work by Phillips and Sul is that they also propose a clustering algorithm test which can reveal whether club formation occurs. This test does not necessitate any specific assumptions regarding the non-stationarity of the gasoline price variables and allows for cases where individual price series may be transitionally divergent. Indeed, the approach advocated by Phillips and Sul (2007) enables the detection of convergence where other methods such as stationarity tests fail insofar as stationary time series methods are unable to detect the asymptotic co-movement of two time series and therefore erroneously reject convergence. Further advantages of our empirical modelling strategy are that it enables us to look into the factors driving convergence club membership, and that it can be implemented in a recursive fashion so that one can gain insights into the potential effects of policy changes on the formation of convergence clubs.

The paper proceeds as follows. Section 2 reviews the literature that has dealt with gasoline price convergence across Canada. Section 3 provides an overview of the Phillips and Sul convergence club methodology. Section 4 describes the data set, which consists of monthly prices for three types of gasoline in 41 cities over an eighteen year study period. The data permit us to distinguish and then analyse gasoline prices that are inclusive or exclusive of taxes. Section 5 summarises the main results of our analysis of convergence. Section 6 presents a pairwise probit regression model that allows us to consider potential drivers of club formation such as fuel quality, and distance between cities. Section 7 concludes.

2 Literature

There are but a limited number of comprehensive studies that explore gasoline price convergence across Canadian provinces and cities. Suvankulov et al. (2012) explore price regulation and relative price convergence across 60 Canadian cities. Using a nonlinear panel unit root testing approach, the authors find that Canadian retail gasoline markets are well-integrated across locales. However, the study also finds that the share of converging cities is characterised by a significant decline since mid-2006. The impact of province price regulation on national price convergence is found as mixed in terms of affecting price convergence to the national mean and price volatility. In terms of investigating the time series properties of Canadian gasoline retail prices, the literature has tended to instead provide more focus on a range of other issues of potential relevance that includes the applicability of Edgeworth price cycles (Eckert, 2003; Eckert and West, 2004a; Atkinson, 2007; Noel, 2007; Atkinson et al., 2014) and asymmetry between gasoline and crude oil prices using threshold methods (Godby et al., 2000; Honarvar, 2010).[2]

In terms of a systematic analysis over time of the degree of market integration and price competition in gasoline across regions, studies based on other countries are also limited. Evidence in support of regionally integrated gasoline markets is mixed. For example, Holmes et al. (2013) employ a pairwise unit root approach to examine regional integration in the US gasoline

[2]In other avenues of research, Sen et al. (2011) evaluate the efficacy of price ceiling legislation, Eckert and West (2004b) and Clark and Houde (2013) consider the impacts of price collusion in the Canadian in gasoline retail markets, price wars are investigated by Slade (1992), Sen (2005) explores the role of market share, Sen and Townley (2010) looks at the rationalisation of retail outlets and Nicol (2003) examines the income inelasticity of gasoline demand across Canadian provinces.

market. They find strong support for the view that the law of one price holds across US states. They uncover evidence that the speed at which prices converge to the long-run equilibrium depends not only upon the distance between states, but the more similar are states with respect to taxation, gas stations, and refining capacity. Paul et al. (2001) find evidence of a high degree of market integration between prices across five major US gasoline markets as evidenced by cointegration tests. However, they conclude that perfect market integration, characterised by a unity slope, is rejected in all but a few cases. There are several studies focusing on other countries that should also be considered. Akhmedjonov and Lau (2012), using a panel unit root testing approach, conclude that there is no fully integrated national energy market in Russia. They suggest that the peripheral position of diverging regions might be important, and also point to an unbalanced distribution of energy reserves and limited cross-border transmission capacity. In the case of China, Ma and Oxley (2010, 2012) employ panel cointegration and convergence clustering techniques and find that while regional gasoline price co-move over time, there is no fully integrated national market in China. Lastly, Cárdenas et al. (2017) and Nuñez and Otero (2017), using a pair-wise unit root approach, provide evidence that offers more support of regional integration in retail fuel markets in France and Brazil, respectively.[3]

In considering the determination of gasoline prices across regions, then the Law of One Price (LOOP) might incorporate the exploitation of arbitrage opportunities by efficient market consumers chasing lower prices. However, the retail price paid at a Canadian gasoline station comprises a number of

[3]Other recent studies on regional gasoline price behaviour focus on a range of specific issues relevant to regional price variation and adjustment. For example, Adilov and Samavati (2009), Bachmeier and Griffin (2003) and Borenstein et al. (1997) investigate asymmetries in the reaction of gasoline prices to increases and decreases in the price of crude oil. Chouinard and Perloff (2007) consider differences in government policies and other factors that affect demand, costs, and market power. Brown et al. (2008) examine wholesale gasoline market integration in the presence of changes in the number of competitors contrasted with geographic market segmentation induced by regulation.

components. These components include a benchmark price, applicable taxes, wholesale and retail margins and transportation costs. Retail gasoline prices react quickly to international crude oil price changes. As with many other countries, taxes account for significant component of the price at the pump. Given that gasoline is characterised by associated environmental issues as well as an inelastic price elasticity of demand, there is the case for taxation at both national and sub-national levels. In this respect, the Canadian federal government plays relatively little role in crude oil and retail gasoline price setting. Instead, the Canadian provinces and territories are permitted to regulate their own taxes and other controls on retail gasoline. A number provinces and territories take a relatively more market-based approach to the gasoline market compared with others. According to Suvankulov et al. (2012), total taxes are about 30% of Canadian final gasoline prices ranging from 21-39%. This wide spectrum of tax rates, coupled with differentiated transportation costs, means that an absolute version of the LOOP based on the equality of gasoline prices is unlikely. However, relative convergence is perhaps more relevant. On the one hand, increased economic integration between provinces and territories and cross-border purchases might potentially drive of gasoline prices closer together. However, one might expect price differences to remain because of transportation costs and the tax regimes specific to each province and territory.

3 Econometric methodology: An overview

This section provides an overview of the convergence club approach proposed by Phillips and Sul (2007, 2009). Following these authors, the idea is to start by decomposing a panel data X_{it} using the time varying factor representation:

$$X_{it} = g_{it} + a_{it}, \tag{1}$$

where g_{it} indicates permanent common components that produce cross section dependence, a_{it} denotes transitory components, $i = 1, ..., N$ is the number of individuals in the panel, and $t = 1, ..., T$ is the number of time observations. In this representation, X_{it} is assumed to consist of two components: one that is common and the other one idiosyncratic. To separate one from the other, equation (1) is transformed using:

$$X_{it} = \left(\frac{g_{it} + a_{it}}{\mu_t} \right) \mu_t = \delta_{it} \mu_t, \tag{2}$$

for all i and t, where δ_{it} is a time varying idiosyncratic element, while μ_t is a time varying component that is common to all individuals in the panel (since it has no i subscript). Phillips and Sul model the term δ_{it} in equation (2) in a semiparametric form through the expression:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha}, \tag{3}$$

where δ_i is fixed, $\xi_{it} \sim iid(0, 1)$ across i but weakly dependent over t, and $L(t)$ is a slowly varying function such that $L(t) \to \infty$ as $t \to \infty$; an illustration of the function $L(t)$ is $\log(t)$. Phillips and Sul indicate that equation (3) ensures that δ_{it} converges to δ_i for all $\alpha \geq 0$. Within this framework, the authors propose a test of the null hypothesis of overall relative convergence based on:

$$H_0 : \delta_i = \delta \quad \text{and} \quad \alpha \geq 0, \tag{4}$$

against the alternative of divergence:

$$H_A : \delta_i \neq \delta \quad \forall i \quad \text{or} \quad \alpha < 0. \tag{5}$$

This testing procedure is implemented in three steps. In the first step it is necessary to construct the cross sectional variance ratio H_1/H_t, which is given by:

$$H_t = \frac{1}{N} \sum_{i=1}^{N} (h_{it} - 1)^2, \tag{6}$$

where h_{it} is referred to as the relative transition parameter; this term traces out the transition path of each individual i in relation to the average of the panel, in other words:

$$h_{it} = \frac{X_{it}}{N^{-1}\sum_{i=1}^{N} X_{it}}. \tag{7}$$

In terms of equations (6) and (7), the notion of relative convergence under consideration implies that, for a given number of time series in the panel N, $h_{it} \to 1$ and therefore $H_t \to 0$ as $t \to \infty$.

The second step involves the estimation of the so-called log t regression:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log t + \hat{u}_t, \tag{8}$$

for $t = [rT], [rT]+1, ..., T$, with $r > 0$. Here, Phillips and Sul use $L(t) = \log(t+1)$ and further observe that the estimate of the slope coefficient $\hat{b} = 2\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of α in the null hypothesis. The regression is estimated using a fraction rT of the observations, where the trimming parameter r is recommended to be set equal to 0.30 (in our empirical analysis we assess the robustness of our findings when this parameter is varied by taking on the values of 0.20, 0.25 and 0.30).

Lastly, in the third step the notion of relative convergence is tested through the use of a one-sided t test of the inequality part of the null hypothesis, that is $\alpha \geq 0$, where the test statistic is constructed using a heteroskedasticity and autocorrelation consistent standard error. Using a 5% significance level, the null hypothesis is rejected when $t_{\hat{b}} < -1.65$.

Phillips and Sul (2007, 2009) indicate that rejection of the null hypothesis of relative convergence does not rule out the possibility of convergence in subgroups of panel individuals. Thus, they develop a clustering algorithm to determine the number of potential convergence clubs, that also allows for the existence of a group with the time series that do not converge. The stages involved in the clustering algorithm are presented in Phillips and Sul (2007), while Phillips and Sul (2009) provide a version of the algorithm written in the GAUSS programming language. Subsequent work by Schnurbus et al. (2017) and Du (2017) offer versions of the algorithm in the open source R software and in Stata, respectively. The results of our empirical analysis are based on the Stata code (the interested reader is referred to these studies for more details).[4]

4 Data description

The retail gasoline price comprises several components. These include the crude oil price, the refining margin which is the difference between the wholesale gasoline price charged by the refiner and the price of crude oil (inclusive of transportation costs), the marketing margin which is the difference between the retail price of the refined product (before taxes are applied), the wholesale refined product price and finally, taxes.[5] Another consideration is whether or not prices are regulated. Although gasoline prices are not federally regulated, provincial governments have authority to do so at their discretion and may do so to reduce price volatility and to protect small independent retailers.

We use monthly data on the average retail price, self serve, of three types of gasoline grades, namely regular (*reg*), medium (*mid*) and premium (*prm*). The source of the data is Kent Group Ltd., which conducts (with funding provided by the Government of Canada) a daily survey for several fuel prices. Gasoline pump prices are collected directly from retailers (gas stations) for cities across Canada and includes sites from the major (branded) oil companies as well as independents. Pump prices include all applicable federal, provincial and urban (municipal) taxes as well as sales taxes where applicable. The ex-tax price represents the price of the fuel before any taxes are levied. Thus the price series used in this study, which are measured in CAD

[4] In an earlier application of the Phillips and Sul procedure to provincial real GDP per capita data, Hamit-Haggar (2013) concludes that Canadian provinces do not form a single convergence club. In other investigations of per capita income, Zhang et al. (2019) identify 4 convergence clubs for the 329 prefecture-level units in China that are analysed.

[5] See, for example, the Canada Energy Regulator at https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/snpsht/2017/09-02whgslnprcsdffr-eng.html?=undefined&wbdisable=true.

cents per litre, are analysed both excluding and including taxes.[6] In the specific case of retail gasoline, the surveys started in 1987 with a coverage of 13 cities, expanding gradually over the years to a coverage that reaches 77 cities in 2018. The choice of cities and study period to undertake our empirical analysis is therefore guided by the need to conform a consistent panel of data that guarantees the inclusion of the largest possible number of cities over the longest period of time available. Hence, we consider a total of 44 cities which provide information over a study period that spans from 2000m1 to 2018m12, for a total of T=228 time observations; see the list of cities in Table 1.[7] Since we employ monthly prices for regular-, medium- and premium-grade gasoline in these 44 cities, there is a maximum of $44 \times 3 = 132$ prices of gasoline to study. However, four and a half years of missing data in the city of Gaspe for medium-grade gasoline prevent us from including this series in the analysis though. All in all, we end up with 131 monthly time series of gasoline.

Figure 1 presents plots of the range of variation of the three grades of gasoline prices under consideration, both excluding and including taxes. Visual inspection of these plots reveals that within each gasoline type, the price series appear to behave as non-stationary processes that tend to move together as time passes. Hence, there could be support for the hypothesis of price cointegration not only across cities (for a given gasoline grade), but also across gasoline grades (for a given city); these two topics have received a great deal of attention in the literature that studies integration of gasoline markets in Canada and elsewhere; see, inter alia, Paul et al. (2001), Suvankulov et al. (2012), Holmes et al. (2013), Blair et al. (2017), Cárdenas et al. (2017) and Nuñez and Otero (2017).

[6] The data were downloaded freely from the website https://www.kentgroupltd.com/.

[7] This is the same group of cities analysed by Suvankulov et al. (2012) over the period 2000m1 to 2010m10. These authors also consider an extended database that consists of 60 cities and starts in April 2006. Here, we refrain from analysing this database in the interest of retaining the long-term view of the notion of convergence.

In the current context, the fact that we are dealing with N=131 individual time series poses a significant challenge on the use of traditional modelling approaches to test whether or not (fuel) prices are cointegrated. Indeed, a first approach based on the estimation of an N-dimensional vector error correction model of prices, as in Johansen (1988), is not feasible because N is a very large number. Alternatively, if one instead approaches the problem through the application of panel unit root or stationarity tests (e.g. Pesaran, 2007b; Hadri, 2000) to the $(N-1)$ price differentials that can be calculated against a reference price, the main drawback is that the findings may be sensible to the choice of the reference price. Lastly, a pair-wise analysis along the lines of Pesaran (2007a), which involves the calculation of all possible bivariate relationships that exist, while avoiding the issues surrounding the choice of a reference price, does not permit the possibility of identifying sets (clubs) of more than two prices that move in tandem over the long run. The club convergence methodology that we adopt in this paper is intended to overcome the limitations outlined before.

5 Club convergence analysis

Our empirical analysis is based on the 131 gasoline price series described above, which we consider in logarithms and after removing their underlying cyclical component using the regression-based Hamilton (2018) filter.[8] Preparation of the database for convergence analysis also involved discarding the first 30% of the sample period, that is the first 58 time observations, and

[8] In the original applications of their methodology, Phillips and Sul remove the cyclical component of the underlying series through the use of the Hodrick and Prescott (1997) (HP) filter. Here, we opt instead for using the more recent Hamilton (2018) filter. Indeed, Hamilton (2018) finds that an important limitation of the HP filter is that it introduces spurious dynamic relations. To overcome this, and other limitations, Hamilton recommends a regression-based procedure to remove the cyclical component of a series; for monthly data, this involves running an OLS regression of the variable of interest against its 24th to 35th lagged values plus a constant, and using the resulting fitted values as an estimate of the underlying trend component.

sorting the individual gasoline price series based on the time-series average of the last 10% of the sample; as a robustness test, we further experimented by varying both the trimming parameter (25% and 20%) and the sorting fraction (5% and 0%), and obtained qualitatively similar results.

Using prices that exclude (include) taxes, ordinary least squares estimation of the $\log(t)$ regression in equation (8) yields an estimate of the slope coefficient equal to -0.660 (-0.961), with an associated HAC standard error of 0.133 (0.054), and a t-statistic of -4.985 (-17.784). According to these results, the null hypothesis of overall relative convergence is decidedly rejected regardless of whether one excludes or includes taxes. In the latter case, this outcome is in sharp contrast to Suvankulov et al. (2012) who find evidence in support of stationary relative gasoline prices across Canadian cities for a shorter period of time. As noted by the authors, there has been a decline in the share of converging cities over recent years. Our results are therefore consistent with this insofar as a single convergent club is not sufficient to capture all the gasoline price series by the end of our study period.

The analysis now proceeds by examining the possibility of confirming smaller clubs of convergence through the application of the clustering algorithm outlined earlier. Table 2 presents the initial classification of convergence clubs, the statistical tests of potential club merging, and the final classification. As can be seen in the table, the evidence points towards the existence of four convergence clubs both excluding and including taxes. The composition of the four convergence clubs is summarised in the maps presented in Figures 2 to 4 when taxes are excluded, and in Figures 5 to 7 when they are included. Focusing on the prices that include taxes, the maps reveal that the majority of gasoline prices are being classified in clubs 1 and 2 (with 45 and 76 price series, respectively), and that the composition of these two clubs is somewhat mixed, in the sense that they include all three grades of gasoline. In turn, clubs 3 and 4, which respectively comprise two and eight price series, are more homogeneous in as much as they only include prices of regular-graded gasoline.

The information presented in the maps also appears to provide initial evidence supporting the view that geographical proximity may play a role in the formation of convergence clubs in the Canadian gasoline retail markets, which is an aspect that we examine in a more formal manner in the following section. A portion of the final price paid at the pump for gasoline goes to various levels of government in the form of taxes. Depending on location, customers pay a federal, provincial and, in some cases, a municipal tax on gasoline. In addition to this, a number of provinces have regulated their gasoline prices in terms of minimum price, maximum price and/or retail margin setting.[9]

Three types of taxes are applied. First, a fixed tax where the federal government charges an excise tax at a flat rate of 10 cents per litre on gasoline. This has been in effect since 1995. There is also a federal goods and services tax of 5% on gasoline. Provincial governments also collect gasoline taxes and these vary considerably by province. In addition to this, three municipalities in Canada (Vancouver, Victoria and Montreal) also apply taxes on gasoline. For example, Yukon and Nunavut respectively levy at 6.2 and 6.4 cents per litre of gasoline, while Newfoundland and Labrador, and British Columbia (Vancouver area) levy at 20.5 and 25.5 cents per litre. Second, ad valorem sales taxes based on a percentage of the retail price are applied. Provincial sales taxes apply to gasoline where they have do not have the harmonized sales tax (HST) as well as Quebec (QST). Nova Scotia, Newfoundland and Labrador, New Brunswick and Prince Edward Island have a provincial sales tax of 15%, Ontario has a rate of 13% and the QST is 9.975%. Third, there are now carbon taxes reflecting a carbon pollution price of $20 per tonne of carbon dioxide equivalent (CO2e) in 2019, rising by $10 per tonne annually to $50 per tonne in 2022. From April 2019, the federal government imple-

[9]These include Quebec and the Atlantic provinces (Prince Edward Island, Nova Scotia, Newfoundland and Labrador and New Brunswick).

mented a carbon pricing system in provincial jurisdictions that do not have a carbon pricing system that aligns with the federal benchmark. The federal government fuel charge will apply in Saskatchewan, Ontario, Manitoba, and New Brunswick. As an example of the range of federal and provincial carbon taxes, 0.94 cents per litre applies to Nova Scotia while 6.73 and 8.89 applies to Alberta and British Columbia respectively.

Here, it can be noted that despite the complexities of the Canadian fuel tax structure, qualitatively similar findings are observed for the price series that exclude taxes. At this stage, it is pertinent to reflect on the research conducted by Dreher and Krieger (2008, 2010) who investigate the impact of taxation on the convergence of diesel and petroleum prices in Europe. Using panel unit root testing, they conclude that the impact of taxation is to slow down retail price convergence. Yilmazkuday and Yilmazkuday (2016) using US price data at gas station level, find that the change in gasoline prices through time is to some extent explained by state-level taxes. In contrast, our findings for Canadian cities suggest that taxation may not have had an effect on the extent of convergence club formation in retail prices.

Another aspect worth examining is whether the lack of national convergence of gasoline retail prices that we just described is a retail phenomenon, or if it is being driven by multiple convergence clubs higher up the chain. Taking advantage of the fact that the website of Kent Group Ltd. also has available online wholesale prices, a convergence club analysis of such prices might help us understand why cities are classified into different clubs. Hence, we are able to conform a balanced data panel of wholesale prices for thirteen cities (see Table 1), two grades of gasoline (i.e., regular and premium) over the sample period between 2000m1 to 2018m12. The results of analysing wholesale prices using the same club convergence setup applied to retail prices are presented in Table 3. As can be seen, there is evidence that supports the existence of six convergence clubs with an additional non-convergent group consisting of gasoline prices in two cities. We already find that there are four convergence clubs for retail prices whether or not taxes are included. The presence of more convergence clubs driving wholesale prices suggests that if anything, retail market activity may have led to less divergence in gasoline prices across cities. In what follows, we proceed with a formal analysis of the determinants of club convergence in retail prices.

6 Drivers of club convergence

With evidence of multiple convergence clubs driving Canadian gasoline prices, we now examine a number of potential drivers behind these clubs. To this end, we begin by estimating a binary (probit) model to identify the variables that are expected to have an effect on the likelihood of any two gasoline price series being part of the same convergence club. Taking into account the number of cities and the three fuel types we consider, the probit regressions are based on all 8515 pairwise combinations. The first variable that we take into account is the logarithm of the distance between cities i and j.[10] In this case, we are specifically interested in testing whether shorter (longer) distances between cities are associated with an increase (decrease) in the likelihood of gasoline price pairs belonging to the same convergence club. Indeed, the idea behind is that geographic separation between cities may facilitate arbitrage mechanisms that bring gasoline prices into line. The second variable that we consider refers to a measure of the degree of homogeneity of the different gasoline grades, which we assume is given by their associated octane level.[11] Accordingly, we calculate the absolute value of the difference between octane levels in gasoline grades. The estimated coefficient (marginal effect) on this variable is expected to be negative, thereby sug-

[10]Distance is computed using the "greater-circle" formula based on information on latitude and longitude for each city centroid. When a pair of observations involves gasoline traded in the same city, then distance is set equal to one so that the logarithm of distance is equal to zero.

[11]In Canada, the octane level of regular, mid-grade and premium gasoline is 87, 89 and 91, respectively.

gesting that the likelihood of any two gasoline prices belonging to the same convergence club decreases as the gasoline types become more dissimilar in terms of their octane levels. Finally, for the case where the gasoline price data are inclusive of taxes, we also include an indicator variable that takes the value of one when two prices are in the same province (zero otherwise). This variable is intended to pick up the impact of common provincial tax levying or price regulation on club formation and so has an expected positive estimated coefficient.[12]

The results reported in Table 4 tell a similar story regardless of whether gasoline taxes are excluded or included in the analysis. Indeed, the marginal effects associated to distance and octane differential both have the expected negative sign and are statistically different from zero, at least at the 5% significance level. As for the "same province" indicator variable, the estimated marginal effect is also positive and statistically significant, suggesting that when any two gasoline prices are in the same province the probability that they belong to the same convergence club is greater. In contrast to Suvankulov et al. (2012) who find that the impact of price regulation on price convergence as mixed for their study period, our results suggest that similarity of tax regimes across provinces is important in terms of influencing the degree of retail gasoline price convergence.

Finally, in Figure 8 we summarise the results when we implement the notion of relative convergence due to Phillips and Sul in a recursive fashion, so that we start off by performing the estimation for the sub-sample 2002m12 to 2009m1, then 2002m12 to 2009m2, and so on until reaching the last observation that is available, that is over the complete sample period 2002m12 to 2018m12. As can be seen, the results indicate that the number

[12] In addition to the variables listed above, we also consider other potential determinants such as (the absolute value of the) city differentials in population density and in (the logarithm of) the number of gas stations. However, the estimated coefficients on these additional variables do not turn out to be statistically different from zero, and so are not included in the model specification that was finally chosen.

of convergence clubs has been gradually increasing over time. This finding is consistent with the observation made by Suvankulov et al. (2012) that the share of converging cities has been on decline since July 2006.

7 Conclusion and policy implications

We examine whether multiple numbers of convergence clubs could explain relative price movements across 44 Canadian cities for over two decades . We find that Canadian retail gasoline markets are not integrated. Insofar as employing gasoline price data that are inclusive or exclusive of gasoline taxes, this finding appears to hold despite the presence of different provincial and city regulatory tax structures. This does not necessarily mean that regulatory taxes are unimportant in assessing convergence. Once we allow for distances between cities and fuel quality, our second stage probit analysis suggests that city pairs from the same province have a higher probability of being part of the same convergence club. However, such an effect appears to be not strong enough to lead to a reduction in the number of convergence clubs. As for the implications of our findings, we may reflect on the expectation of fair pricing on the part of consumers insofar as the extent of divergence in terms of high club numbers is influenced by distance and fuel quality, but less clearly so by taxation. The lack of retail price convergence across cities suggests that province or city-level tax policy may not necessarily be compromised through factors such as cross-border arbitrage. Instead, local variation in gasoline prices is likely to mean that local authority revenues from energy taxes will affect budgets and spending programmes in varying degrees. A further tax implication resulting from the absence of converged retail prices is that energy tax burdens are likely to be borne by consumers rather than producers. This suggests that consumers rather than firms are disadvantaged in high tax regions. Turning to welfare considerations, cities with higher prices are likely to be characterised by a lower consumer surplus and a higher cost of living. Finally, a given energy shock is likely to result in more variation in aggregate across regions when examining the business cycle.

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Table 1: List of cities included in the analysis

Province	City	Province	City
Alberta	Calgary⋆	Ontario	Hamilton
	Edmonton⋆		London⋆
	Lethbridge		North Bay
	Red Deer		Ottawa⋆
			Sault Ste. Marie
British Columbia	Kamloops⋆		St. Catharines
	Kelowna		Sudbury
	Prince George		Thunder Bay⋆
	Vancouver⋆		Timmins
	Victoria		Toronto⋆
			Windsor
Manitoba	Brandon		
	Winnipeg⋆	Prince Edward Island	Charlottetown
New Brunswick	Bathurst	Quebec	Chicoutimi
	Fredericton		Gaspe
	Moncton		Montreal⋆
	Saint John⋆		Quebec
			Sherbrooke
Newfoundland	Corner Brook		
and Labrador	Gander	Saskatchewan	Prince Albert
	St. John's		Regina⋆
			Saskatoon
Northwest Territories	Yellowknife		
		Yukon	Whitehorse
Nova Scotia	Halifax⋆		
	Sydney		
	Truro		
	Yarmouth		

Note: ⋆ indicates cities for which there is availability of both wholesale and retail gasoline prices over the whole sample period. For wholesale prices two types of gasoline are considered: regular and premium. For retail prices three types of gasoline are considered: regular, medium and premium.

Table 2: Classification of convergence clubs of retail prices

Initial classification				Tests of club merging				Final classification			
Club	β coef.	t-stat.	p-value	Club	β coef.	t-stat.	p-value	Club	β coef.	t-stat.	p-value
				Excluding taxes							
[1]	0.027	0.230	0.591	[1+2]	-0.207	-1.61	0.054	[1]	-0.21	-1.637	0.051
[2]	0.094	0.489	0.688	[2+3]	0.093	0.444	0.671	[2]	-0.147	-0.968	0.167
[3]	-1.147	-1.564	0.059	[3+4]	-0.094	-0.392	0.348	[3]	-0.134	-0.612	0.270
[4]	-0.002	-0.009	0.496	[4+5]	-0.046	-0.257	0.399	[4]	-0.452	-1.533	0.063
[5]	0.023	0.150	0.560	[5+6]	0.01	0.093	0.537				
[6]	0.179	1.272	0.898	[6+7]	0.012	0.068	0.527				
[7]	-0.134	-0.612	0.270	[7+8]	-0.466	-2.427	0.008				
[8]	-0.452	-1.533	0.063								
				Including taxes							
[1]	-0.186	-1.227	(0.110)	[1+2]	-0.209	-0.914	(0.180)	[1]	-0.209	-0.914	(0.180)
[2]	0.165	0.632	(0.736)	[2+3]	-0.309	-2.173	(0.015)	[2]	-0.140	-1.451	(0.073)
[3]	0.447	1.806	(0.965)	[3+4]	0.265	1.362	(0.913)	[3]	-0.961	-1.250	(0.106)
[4]	0.187	1.052	(0.854)	[4+5]	0.002	0.013	(0.505)	[4]	-0.079	-0.356	(0.361)
[5]	0.061	0.203	(0.580)	[5+6]	0.054	0.195	(0.577)				
[6]	-0.431	-0.526	(0.299)	[6+7]	-0.723	-1.341	(0.090)				
[7]	-0.489	-0.638	(0.262)	[7+8]	-0.270	-0.979	(0.164)				
[8]	0.076	0.172	(0.568)	[8+9]	-0.486	-2.649	(0.004)				
[9]	0.057	0.068	(0.527)	[9+10]	-0.765	-2.582	(0.005)				
[10]	0.101	0.131	(0.552)	[10+11]	-0.557	-1.023	(0.153)				
[11]	-0.77	-1.405	(0.080)	[11+12]	-0.949	-2.789	(0.003)				
[12]	-0.961	-1.250	(0.106)	[12+13]	-0.337	-1.720	(0.043)				
[13]	-0.079	-0.356	(0.361)								

Note: The numbers in brackets denote the number of convergence clubs. t-statistics are based on Newey and West (1987) heteroskedasticity and autocorrelation (HAC) standard errors. Lower tail probability values in parentheses.

Table 3: Classification of convergence clubs of wholesale prices

Initial classification				Tests of club merging				Final classification			
Club	β coef.	t-stat.	p-value	Club	β coef.	t-stat.	p-value	Club	β coef.	t-stat.	p-value
[1]	-0.650	-0.903	0.183	[1+2]	-0.796	-1.672	0.047	[1]	-0.650	-0.903	0.183
[2]	-0.249	-0.407	0.342	[2+3]	-0.548	-1.334	0.091	[2]	-0.548	-1.334	0.091
[3]	-0.716	-1.009	0.156	[3+4]	-0.908	-3.241	0.001	[3]	-1.144	-1.335	0.091
[4]	-1.144	-1.335	0.091	[4+5]	-1.168	-4.005	0.000	[4]	-0.651	-1.287	0.099
[5]	-0.159	-0.282	0.389	[5+6]	-0.651	-1.287	0.099	[5]	-0.527	-1.035	0.150
[6]	0.373	0.623	0.733	[6+7]	-0.784	-1.219	0.111	[6]	-0.428	-0.530	0.298
[7]	1.518	1.505	0.934	[7+8]	-0.040	-0.051	0.480	Group [7]	-0.922	-4.095	0.000
[8]	0.116	0.129	0.551	[8+9]	-0.626	-1.091	0.138				
[9]	-0.436	-0.522	0.301	[9+10]	-1.230	-3.722	0.000				
[10]	-0.428	-0.530	0.298	[10+11]	-0.993	-4.909	0.000				
[11]	-0.922	-4.095	0.000								

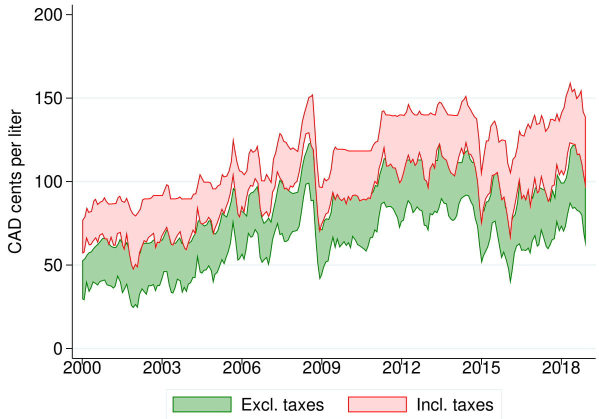
Note: The numbers in brackets denote the number of convergence clubs. t-statistics are based on Newey and West (1987) heteroskedasticity and autocorrelation (HAC) standard errors. Group [7] is a non-convergent club consisting of the prices in two cities. Lower tail probability values in parentheses.

Table 4: Probit model results for retail prices

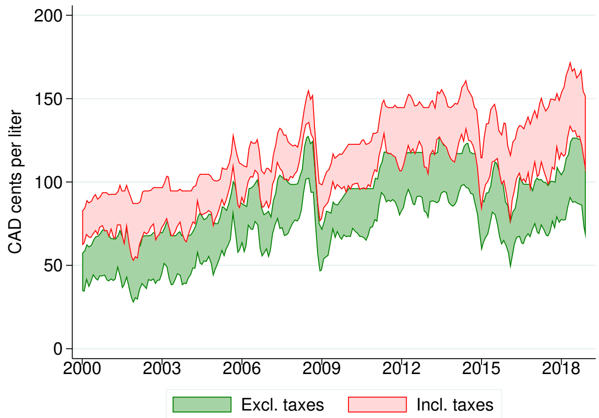
Variable	Marginal effects	
Excluding taxes		
ln(Distance)	-0.015‡	(0.003)
Abs. Dif. (Octane)	-0.062‡	(0.003)
Observations	8515	
Pseudo R^2	0.031	
Including taxes		
ln(Distance)	-0.010‡	(0.004)
Abs. Dif. (Octane)	-0.045‡	(0.004)
Same province	0.106‡	(0.020)
Observations	8515	
Pseudo R^2	0.018	

Note: The dependent variable takes value 1 when any two price series are members of the same convergence club (0 otherwise). Same province is an indicator variable that takes the value of one if a price pair involves the same province, and zero otherwise. White (1980) heteroskedasticity consistent standard errors in parentheses. † and ‡ denote statistical significance at the 10% and 5% levels, respectively.

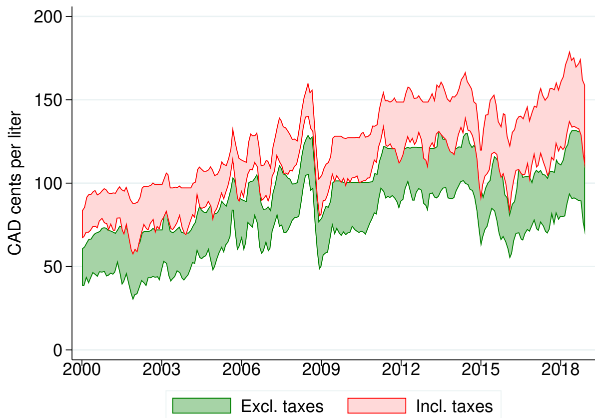
Figure 1: Range of variation of retail gasoline prices



(a) Regular-grade gasoline



(b) Medium-grade gasoline



(c) Premium-grade gasoline

Figure 2: Convergence clubs regular-grade retail gasoline prices excluding taxes

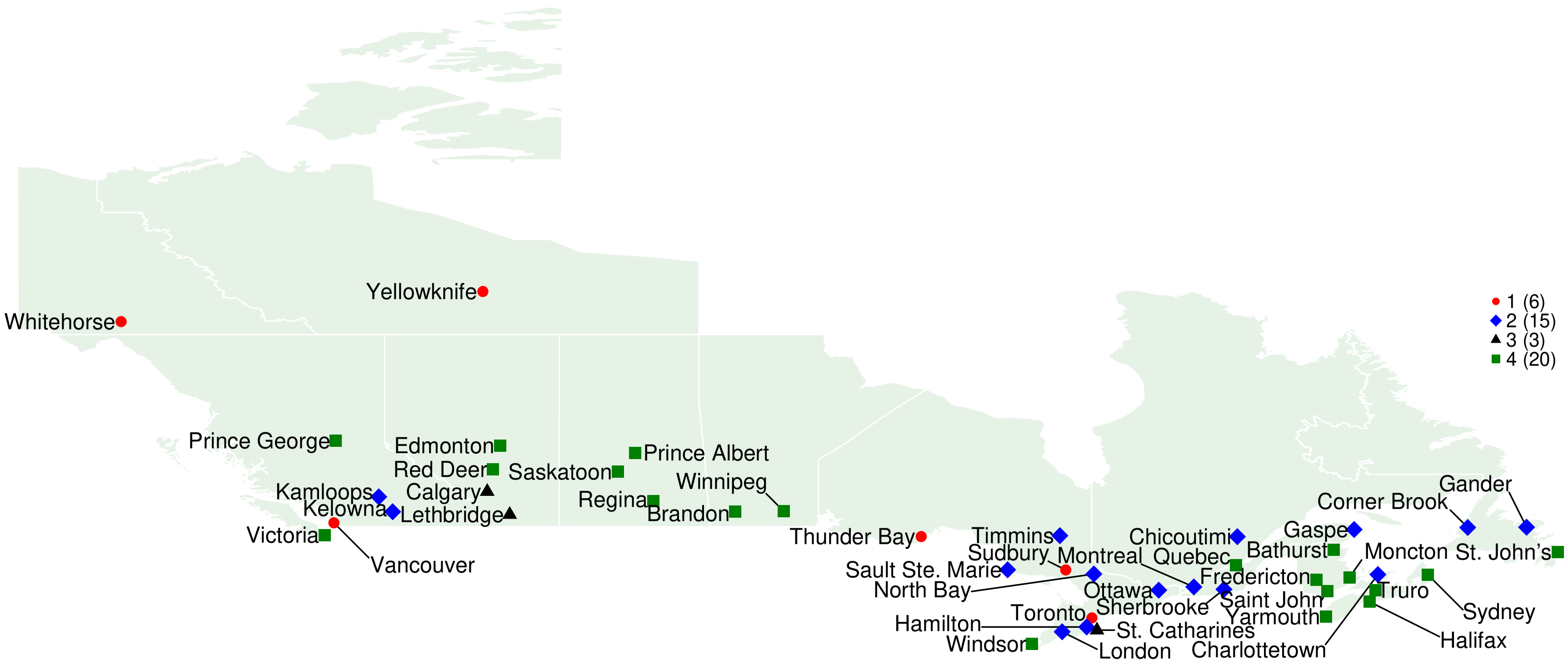


Figure 3: Convergence clubs medium-grade retail gasoline prices excluding taxes

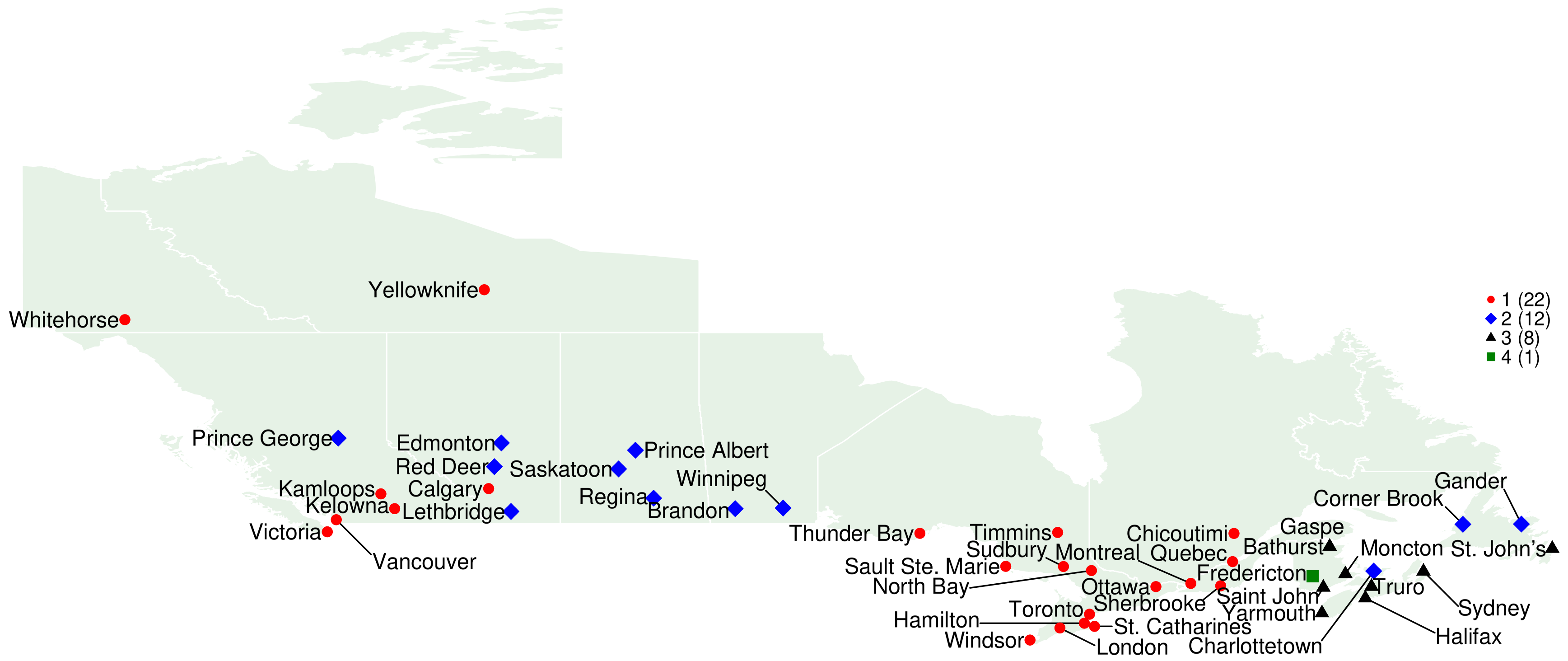


Figure 4: Convergence clubs premium-grade retail gasoline prices excluding taxes

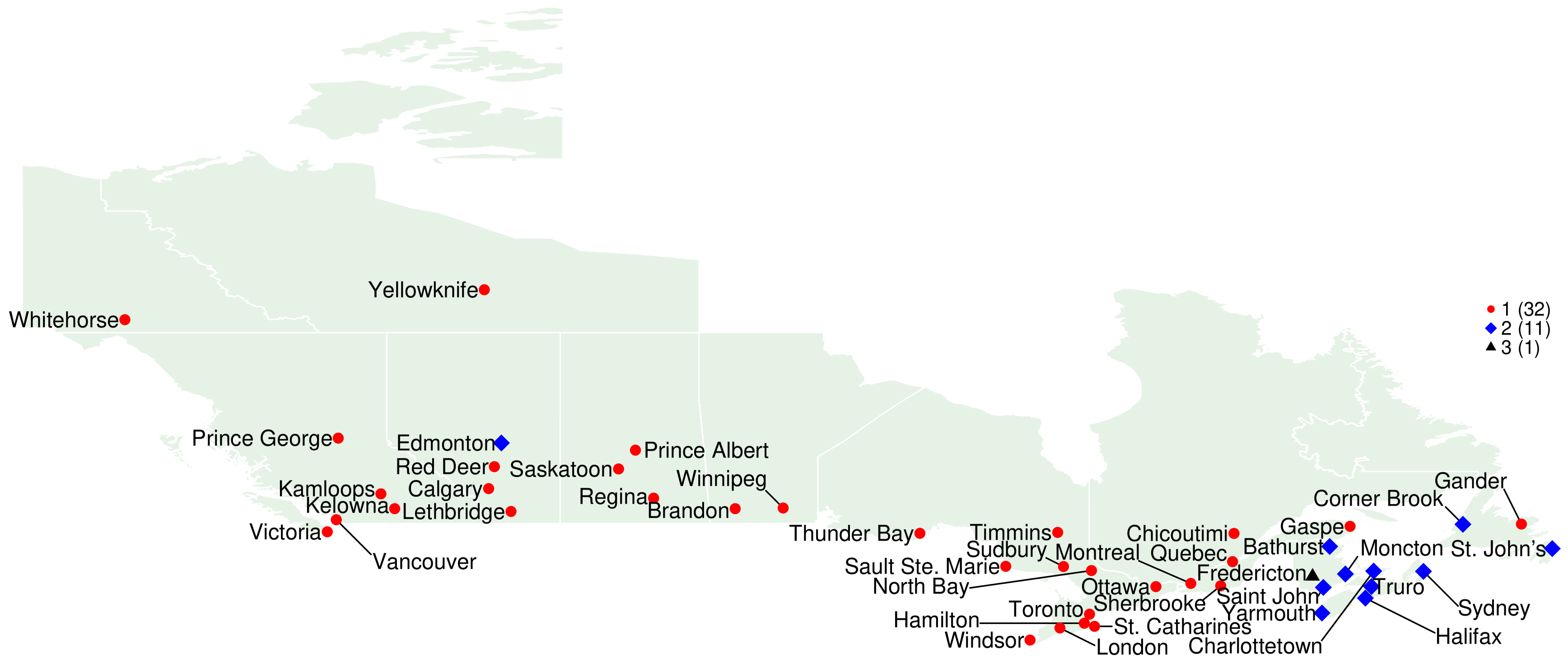


Figure 5: Convergence clubs regular-grade retail gasoline prices including taxes

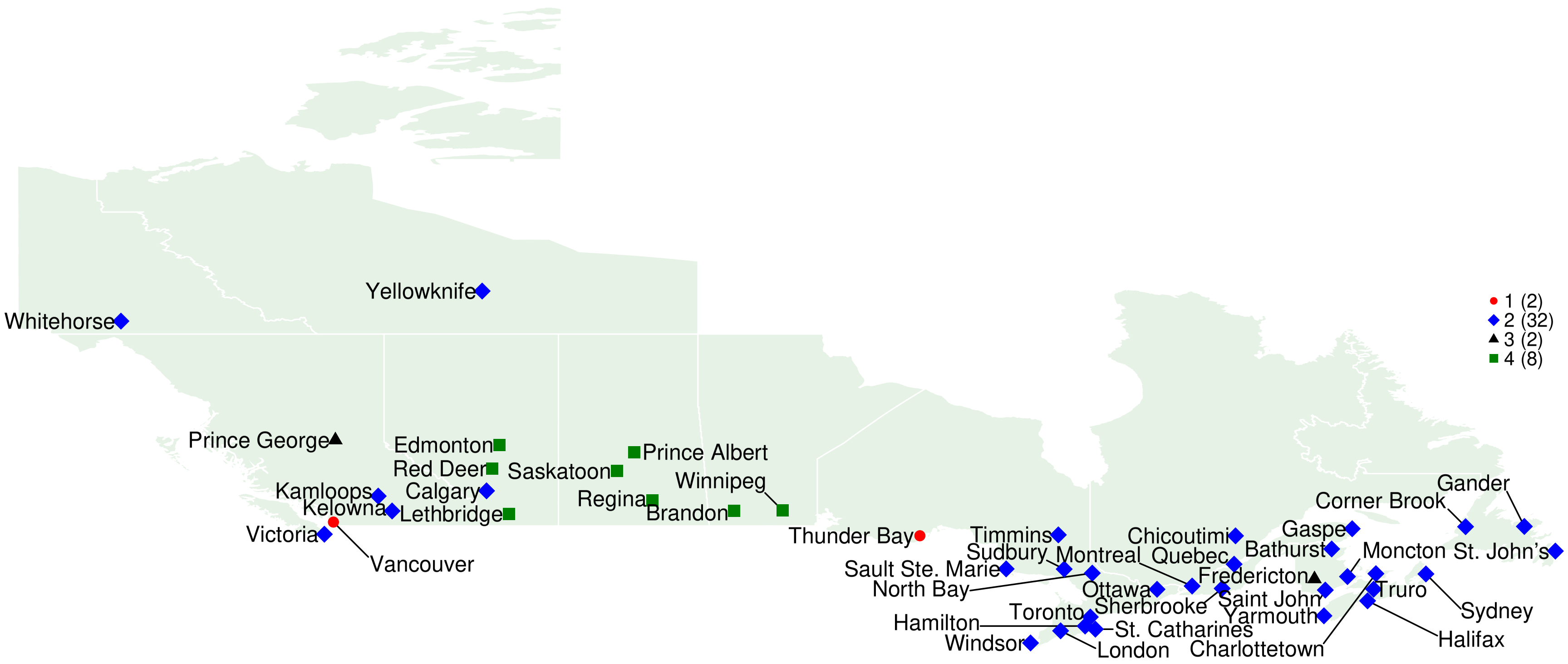


Figure 6: Convergence clubs medium-grade retail gasoline prices including taxes

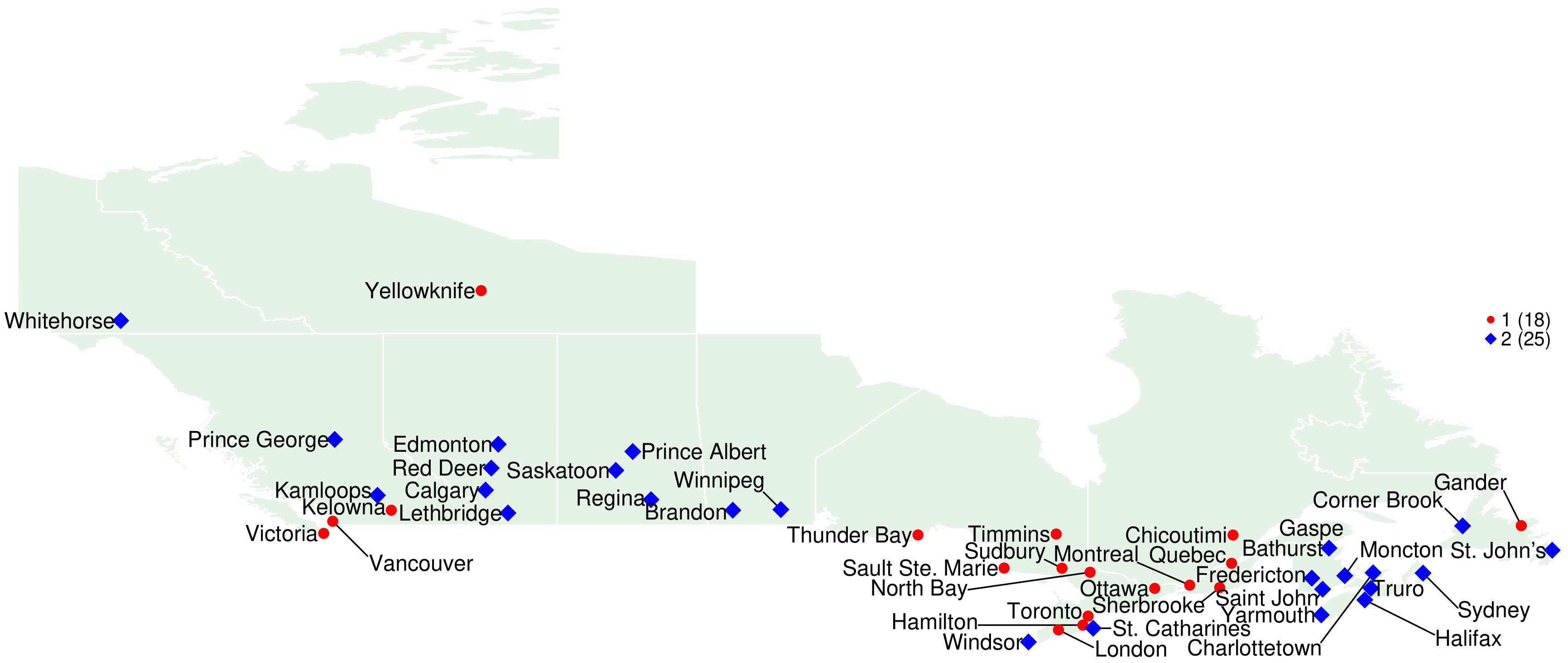


Figure 7: Convergence clubs premium-grade retail gasoline prices including taxes

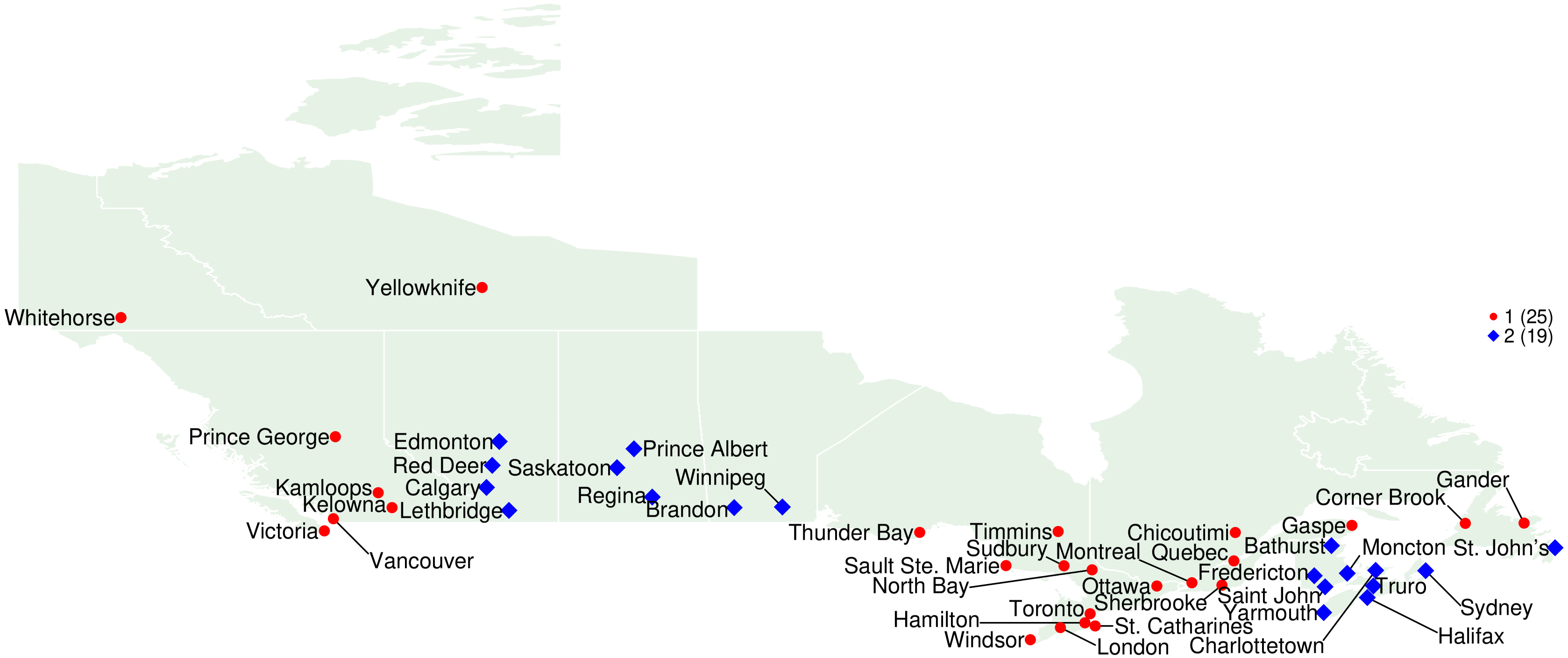
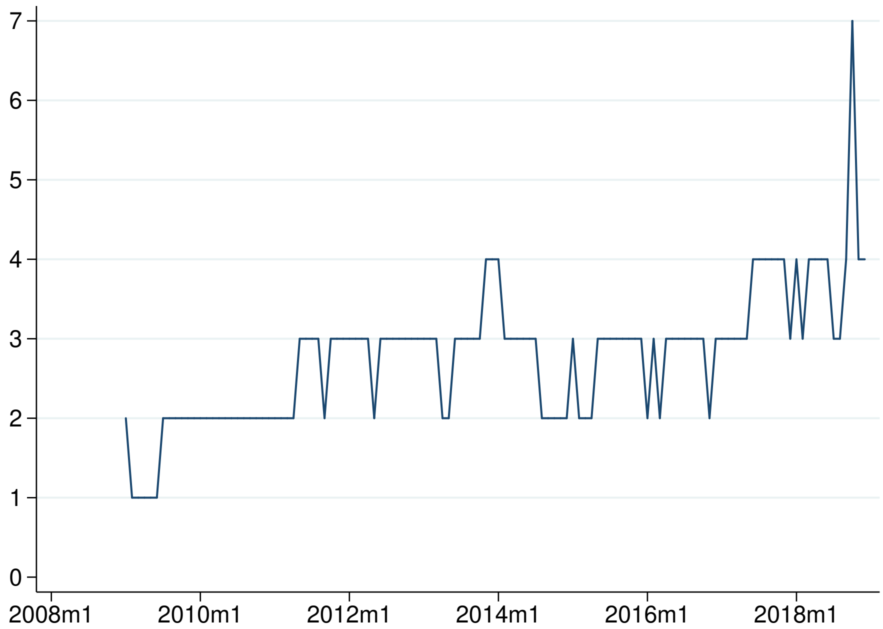
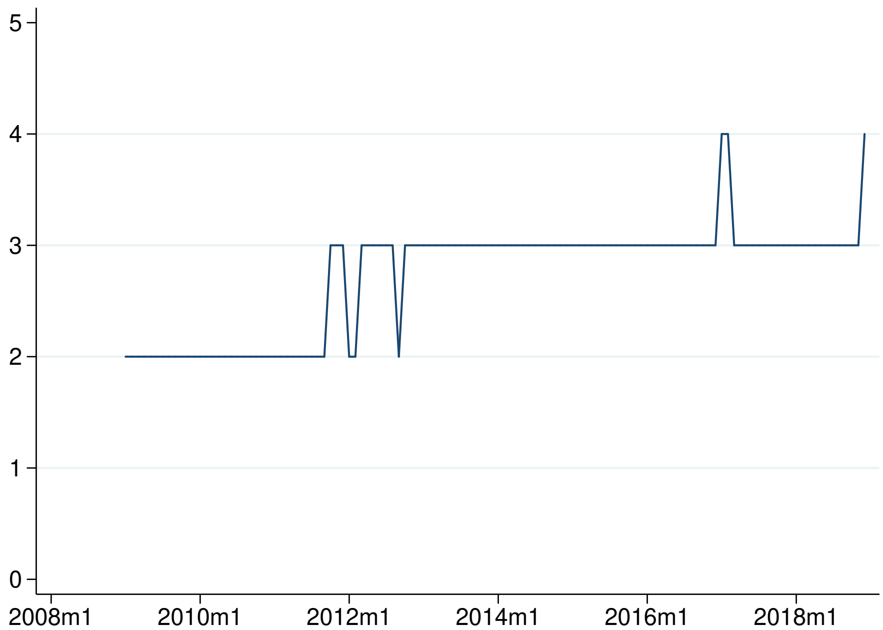


Figure 8: Recursive analysis of convergence clubs in retail prices



(a) Excluding taxes



(b) Including taxes