Fourth Biannual Update – March 2021

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Final Assessment of the Queensland Fuel Price Reporting Trial

For the Department of Energy and Public Works

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Contents

Executive Summary

- This final review investigates the full impact of the (now permanent) two-year long Queensland Fuel Price Reporting Trial (QFPRT) on state-wide retail fuel prices that commenced on 3 December 2018. Specifically, it examines the effect of the now-scheme on retail fuel prices by considering trends in average daily retail fuel prices using the times-series based Auto Regressive Distributed Lag (ARDL) modelling, and as an additional robustness measure, panel modelling, which utilise average monthly data. It also studies the spread of fuel prices, highlighting the potential for savings at the bowser. Finally, it focuses on the role price surges and price leadership plays in setting retail fuel prices.
- Results from both models report a small but statistically significant decline in the average daily retail prices of regular unleaded (ULP91), premium unleaded (PULP) and ethanol (E10) petrol fuels in most regions across Southeast Queensland as well as Cairns, and less broadly, Bundaberg (E10 only). This is also the case for diesel prices in the panel model. These reductions are attributed to the impact of the scheme given the models also control for other potential variables that effect retail petrol pricing.
- There is evidence of a statistically significant increase in the spread of prices (price dispersion) in a majority of the Southeast Queensland LGAs in 2020. Examining differences between minimum and average ULP91 fortnightly prices, this report finds that motorists in Brisbane who fill up at the minimum can save up to $171.60 relative to filling up at the mean price for calendar year 2020. A lack of competition, plus higher cost structures for retail fuel stations reduce this opportunity outside of Southeast Queensland. For example, motorists in Rockhampton (Cairns) could save up to $37.21 ($48.59) per annum.
- Retail petrol price cycles are a well-documented phenomenon in the Southeast Queensland retail fuel market. The scheme allowed for a detailed analysis of these cycles with a focus on price leadership. Between December 2018 and December 2020, 24 price surges were identified, initiated by six different firms. Post-compliance (around May 2019), four different firms (who each own numerous petrol stations across the Greater Brisbane region) initiated 75% of all surges. This is suggestive of a certain degree of price leadership led by a select number of operators, pointing to a potential presence of a considered pricing strategy. This has previously been documented in Western Australia following the introduction of its Fuel Watch scheme.

- New to this final report is evidence of petrol pricing cycles in less urban/regional LGAs such as Toowoomba and Scenic Rim. These LGAs are seeing an increasing number of stations echo the surge cycles in Greater Brisbane since January 2020, by hiking their prices shortly after the initial spikes in the Greater Brisbane area. This potentially leads to greater potential savings at the bowser for motorists in these locations should they be able to source pricing information via the use of the relevant fuel price apps.

- A positive relationship between the price of petrol and fuel price app usage was found in Brisbane LGA, though the estimates are statistically unreliable and should be used cautiously. Delving further, we report that the cyclical price surges exhibited across Brisbane LGA are closely correlated with higher numbers of app users, indicating that price alone does not appear to be impacting the number of app user sessions. Instead, consumers seem to be more likely to check the app when they notice a price surge cycle is occurring. This indicates that users are sensitive not just to prices at any given point in time, but also to price variations, as they decide not just on which retail fuel station to use, but also when to fill up at the bowser.

- Relative to the average daily price of petrol variants prior to the introduction of the scheme, regular unleaded (ULP91) users in Brisbane can, on average, save $6.63 annually ($13.81 over the 25 months from December 2018 – December 2020) per passenger vehicle, and for Southeast Queensland the estimate is $6.85 ($14.27). For PULP, the figures are $7.86 ($16.38) in Brisbane and $7.75 ($16.15) in Southeast Queensland, and for E10 $12.36 ($25.75) in Brisbane and $7.53 ($15.69) in Southeast Queensland. The estimated gain in consumer surplus is $9,509,205.95 per annum ($19,810,845.73) in Brisbane and $12,322,102.72 per annum ($25,671,047.33) in Southeast Queensland.

- Outside Southeast Queensland, the annualised (25 months) savings in Cairns for the regular ULP91 user is averaged at $2.07 ($4.31), for PULP $3.63 ($7.56) and for E10, $6.86 ($14.29). Total annual (25 months) consumer surplus is $126,920.53 ($264,417.77). Regular E10 users in Bundaberg can, on average save $8.16 annually or $17 over the 25 months period. The consumer surplus accruing (from E10 only) in Bundaberg is $32,139.40 annually or $66,957.08 between December 2018 – December 2020.

1. Introduction

The scheme commenced on 3 December 2018, with full legal and enforceable compliance coming into force on 15 April 2019 (DNRME, 2018). It requires retail fuel stations to publish their fuel price within 30 minutes of making a price alteration. An aggregation system collates this information, which is then made accessible to motorists via established third party fuel price apps such as Motormouth, RACQ Fair Fuel, and Petrol Spy. This final (fourth) biannual update presents an in-depth quantitative and qualitative evaluation of the impact of the scheme on state-wide average daily retail fuel prices over a 25-month timeframe (December 2018 - December 2020). Its impact is assessed empirically by comparing fuel prices pre- and post-implementation, using both time-series (ARDL) and panel models, as well as by utilising other quantitative and qualitative methods to study opportunities for motorists to save at the bowser.

A number of conditions would have to be present for average retail fuel prices to fall, some of which are scheme specific. First, fuel prices would have to be disseminated to the public in a timely and accurate manner, a finding confirmed by RACQ's (2021a) study of third-party app usage. Second, a substantial proportion of consumers would need to utilise this information to identify which fuel stations offered the cheapest fuel in the region. Results from the latest app survey (RACQ, 2021a) suggests that this is indeed the case for a significant number of motorists in urban centres, though it is noteworthy that a sizeable number continue to fill up at their usual retailer, even if the pricing is unfavourable.[1] Third, a sufficient level of competition would need to exist amongst retail petrol stations to make it possible for motorists to identify cheaper petrol prices amongst local competitors. Finally, unanticipated and exogeneous events could matter, such as the COVID-19 disruptions and even lockdowns, which heavily impacted on fuel prices globally and sharply decreased the demand for fuel domestically (ACCC, 2020a, 2021; RACQ, 2020).

[1] This can occur for various reasons including convenience, habit, price insensitivity and access to other goods and services at the retail fuel station.

2. Update on the Queensland Fuel Market

Previous reports (Griffith University, 2019, 2020, 2020a) provided an overview of the key factors influencing retail fuel prices in Queensland. In the following we provide a brief update on new relevant information and trends that have since emerged:

- **Retail competition levels:** There has been an increase in the number of fuel stations participating in the trial. As of December 2020, there are approximately 1,627 retail fuel site reporting prices according to the trial data. It is notable that in the Brisbane area, the Australian Competition and Consumer Commission (ACCC) (2019) reported a 12% rise in retail sites between 1 January 2017 and 30 September 2019, which they note has likely increased competition and lowered prices.[2] The ACCC suggest the potential impact of the scheme (on top of likely greater competition due to the rise in retail sites) has contributed to the lowering of fuel prices in Brisbane. This lowering of fuel prices coincided with the rise in users of fuel price apps (RACQ, 2021a), which could have raised greater awareness of the competitive pricing strategies of independent fuel retailers.

- **International oil prices:** The fall in international oil prices in the first part of 2020 was due to a combination of falling global demand and rising oil inventories plus the inability of OPEC and Russia to agree to credible production cuts and was covered in the previous report (Griffith University, 2020a). This was followed by a stable recovery, where Brent crude prices ranged around the US$37-US$45 mark from June to mid-November 2020. This was a rise from the previous lows and reflected improved demand as COVID-19 lockdowns eased, bringing with it falling inventory. From late November onwards through to the new year prices ticked up considerably (US$51.22 by 31 December 2020) on the back of optimism that the COVID-19 vaccine progress trajectory was positive, cuts in shale oil production in North America, and general optimism about economic recovery (U.S. Energy Information Administration, 2021; Oilprice.com, 2021; The Balance, 2021).

[2] Data used in this report has also shown a 5% (11%) rise in retail sites in Brisbane (Southeast Queensland) between 1 January 2019 and 31 December 2020.

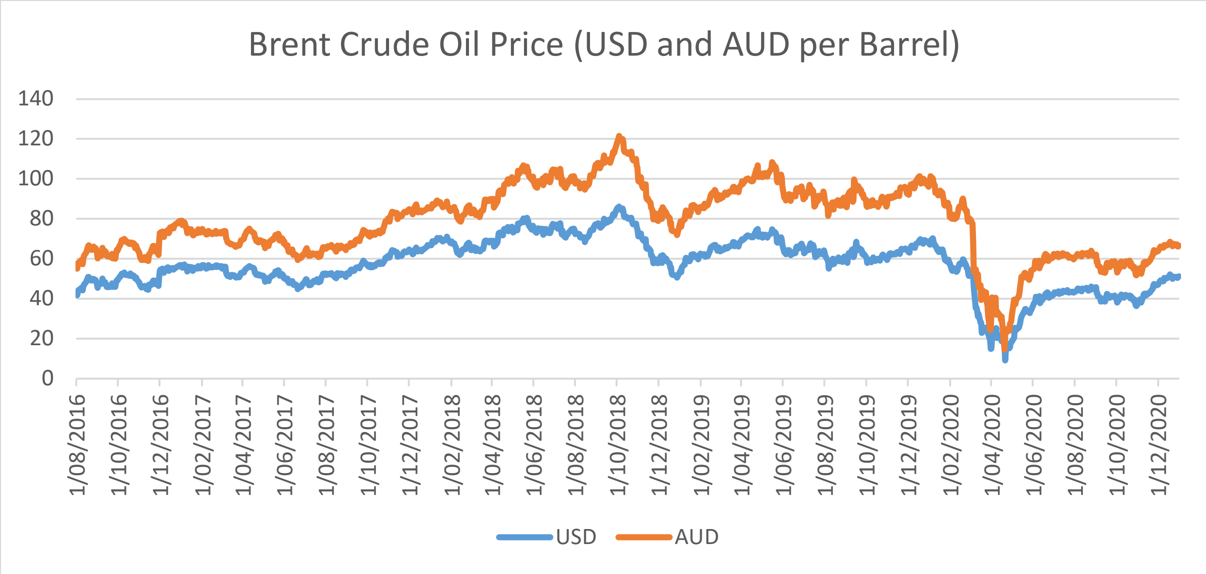

Figure 1: Brent crude oil prices in both USD and AUD from 1 August 2016 to 31 December 2020. AUD figures imputed from the daily USD-AUD exchange rate (source for both Brent crude oil process and the USD-AUD exchange rates: Macrotrends.net).

- **Refined Fuel Costs and Refinery Cost Margins.** As noted in the last report (Griffith University, 2020a), these account for a large share of retail fuel prices.[3] Figure 2 highlights how wholesale fuel prices (TGPs) move consistently with international refined fuel prices in the Asia-Pacific region, albeit with a short time lag.[4] Figures 3 and 4 highlight how regulatory charges such as fuel excise make up a substantial portion of wholesale prices and that refiner mark-ups appear to be relatively small. Refinery cost margins have remained relatively stable for a sustained period, and it was only around the period that international oil prices began to tumble sharply that we witnessed a sharp decline in margins (see Figure 4) (ACCC 2020b, 2020c). However, an upward trajectory in margins, consistent with rising international oil prices has been evident since then, albeit still below the average. However, we are unable to state with any certainty if this initial impact is transitory or permanent, and data from future points are required before more definitive statements can be made.

[3] These vary over time. They are partially accounted for by fluctuations in both international prices and exchange rates (which as previously noted have both been relatively stable in recent months), but have been estimated to average around 57% (AIP, 2018) of the final retail price.
[4] The AIP (2021, 2021a, 2021b) suggests a lag of between 1-2 weeks, though this period was briefly extended around the time domestic demand was depressed due to the COVID-19 lockdowns.

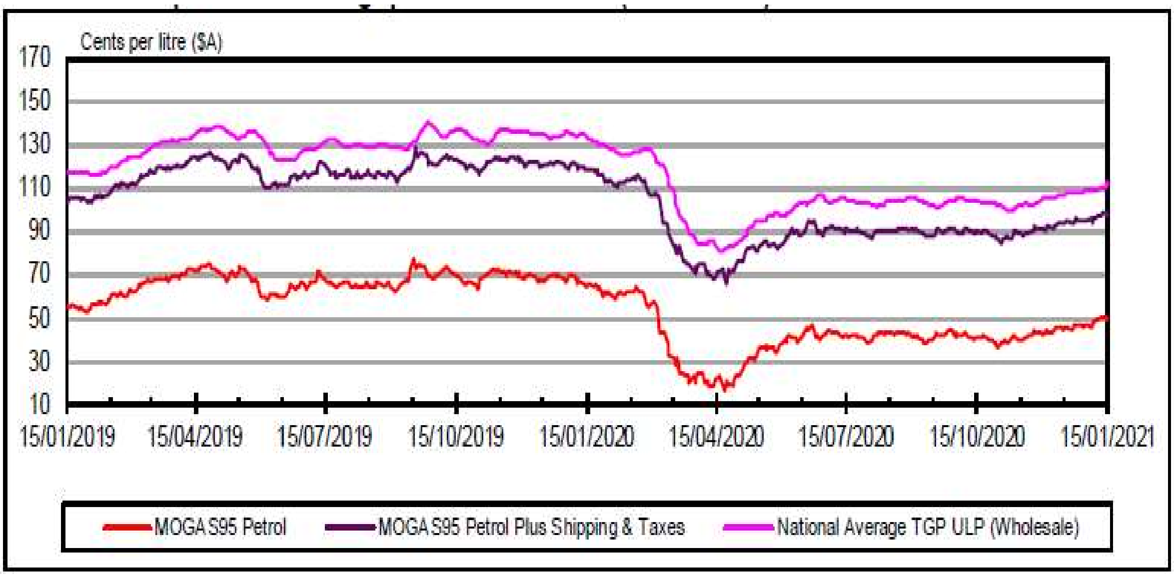

Figure 2: Comparison of Singapore Fuel Prices (MOPS95 Fuel) with Australian fuel TGP (source: AIP, 2021).

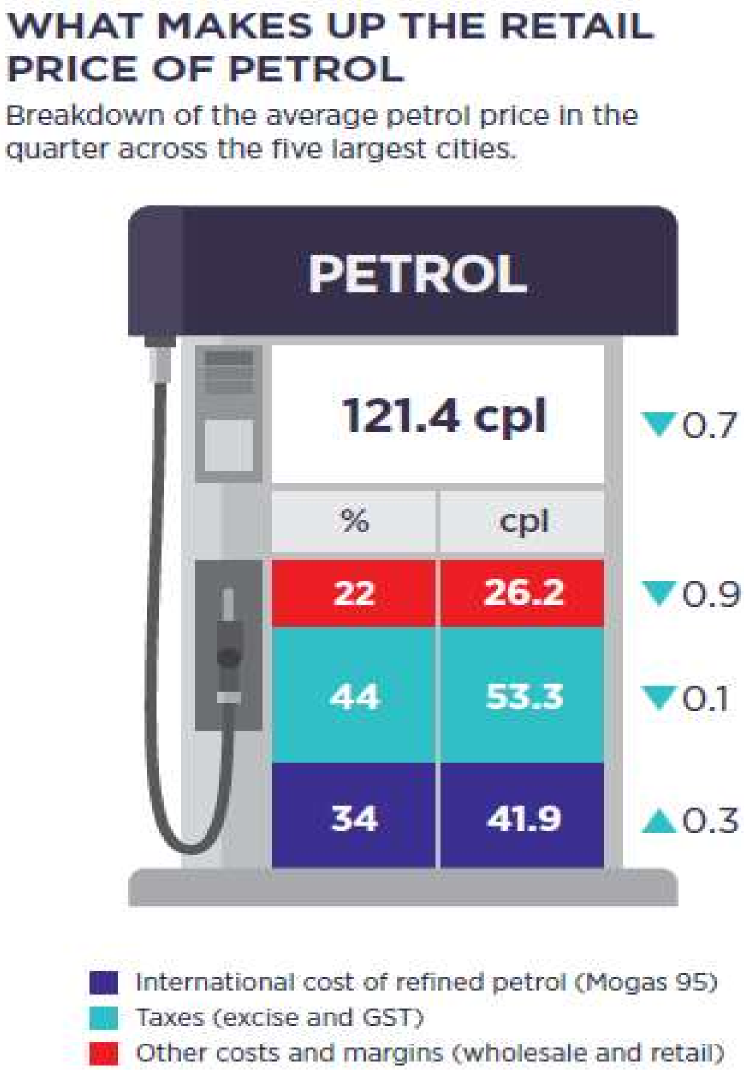

Figure 3: Breakdown of ULP91 costs based on the October – December 2020 average (ACCC, 2021).

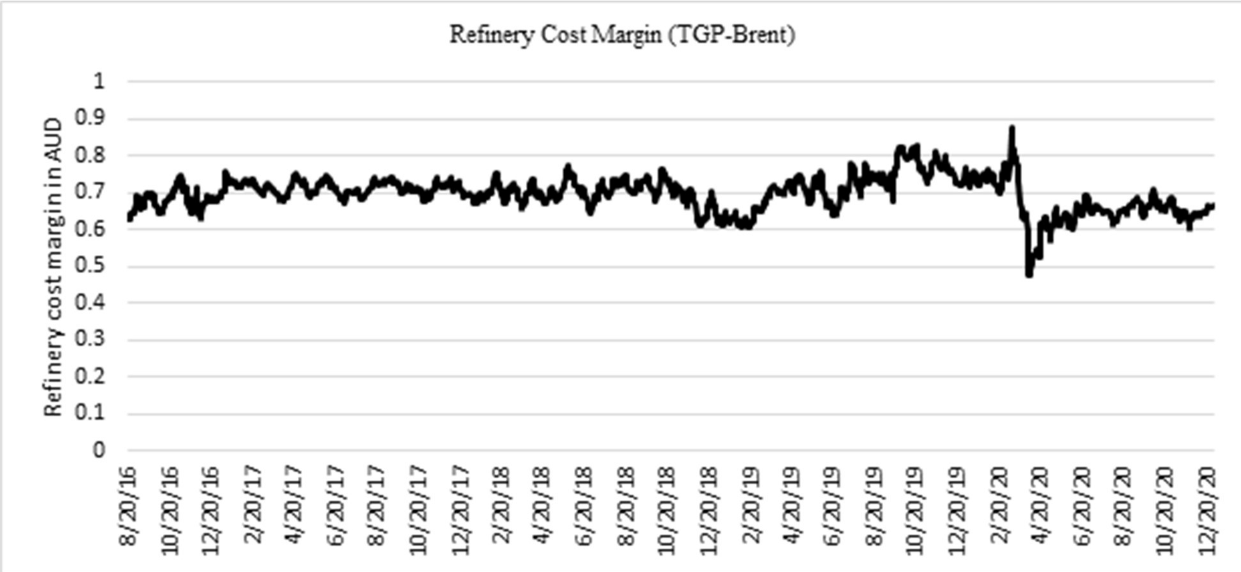

Figure 4: Refinery cost margins, August 2016 – December 2020.

- **Retail Gross Margins**[5] can vary substantially both across price cycles and between retailers, with market leaders being more likely to charge higher peak prices at the bowser relative to retail discounters (ACCC, 2020a, 2020b, 2020c; RACQ, 2020, 2021). Figure 5 highlights a rough approximation of retail gross margins in Brisbane by comparing the difference between ULP91 retail prices and the reported TGP. There is evidence of greater price spreads since the scheme began,[6] leading to greater scope for consumer savings should the near live app information be utilised by motorists.

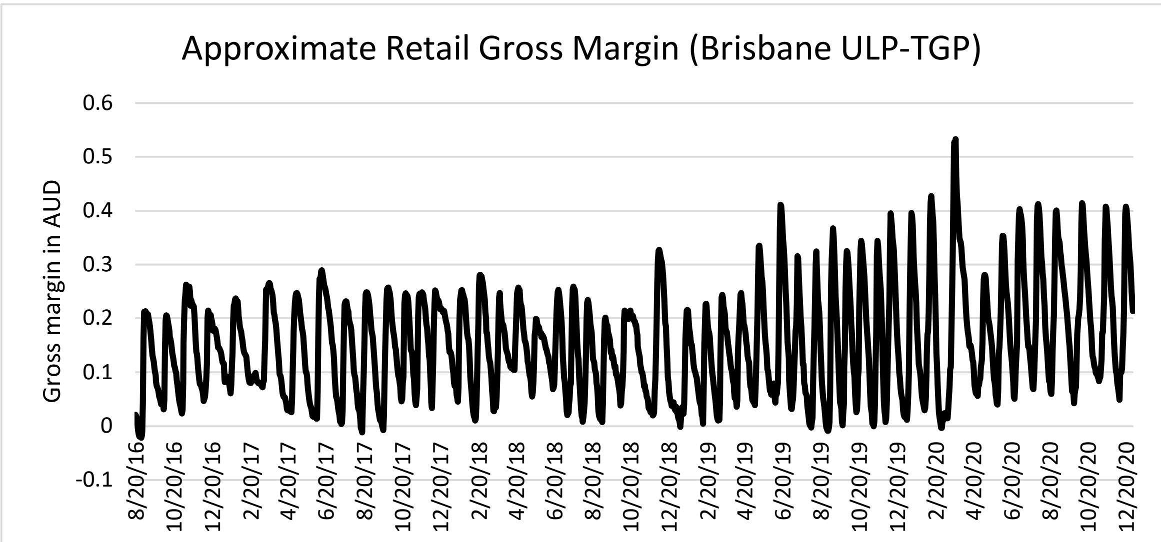

Figure 5: Approximate retail gross margins for ULP91 in Brisbane, December 2016 – December 2020.

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[5] This is the difference between the retail fuel price and the published TGP price.

[6] Prior to the scheme (20 August 2016 to the start of the scheme in early December 2018), the average retail gross margin was 13.94 cpl and thereafter 17.03 cpl.

- **Evidence on consumer use of retail apps.** The RACQ (2021a) survey on fuel price app usage reported a significant rise in the utilisation of such apps and websites, with usage increasing from 12.4% in 2017, to 30.6% in 2020. Those in Brisbane and Southeast Queensland are also more likely to fill up when prices are low relative to the rest of the state, and this does coincide with the fact that retail competition, and hence price dispersion is greatest in the southeast corner of the state. Brisbane LGA app usage data also exhibits a coinciding increase in users and sessions with some of the identified price surges (Griffith 2020a), which is discussed in greater detail in Section 3.

3. Data and Fuel Price Trends

3.1 The Dataset

To study retail fuel price trends pre- and post-implementation, three different data sources have been integrated:

- Baseline legacy data supplied by Informed Sources that reported fuel prices across all major grades of fuel from December 2017 to December 2018. This consisted of 398,531 observations across 857 fuel stations.

- Baseline data sourced from point-of-sale data provider, Oil Pricing Information Service (OPIS). These data also reported fuel prices across all major grades of fuel from December 2016 to end of March 2019 and consisted of 3,470,641 observations across 1,544 fuel stations.

- API Data from the Queensland Fuel Price Reporting Trial (www.fuelpricesqld.com.au) that covers the period of December 2018 to the end December 2020. This covers 1,627 stations; this number increased over the period of the trial.

In terms of the regional distribution of fuel stations, these remain highly concentrated in the Southeast Queensland regions as approximate half of all fuel stations in Queensland are in this region. 24.40% of retail stations are in the Brisbane and Gold Coast LGAs, while LGAs close to Brisbane, such as Ipswich, Logan, Moreton Bay, Redland and the Sunshine Coast account for a further 22.74% of retail stations. 33 of the 70 LGAs (47.14%) have (individually) only between 1 and 8 retail stations. Figure 6 provides an illustration for Southeast Queensland.

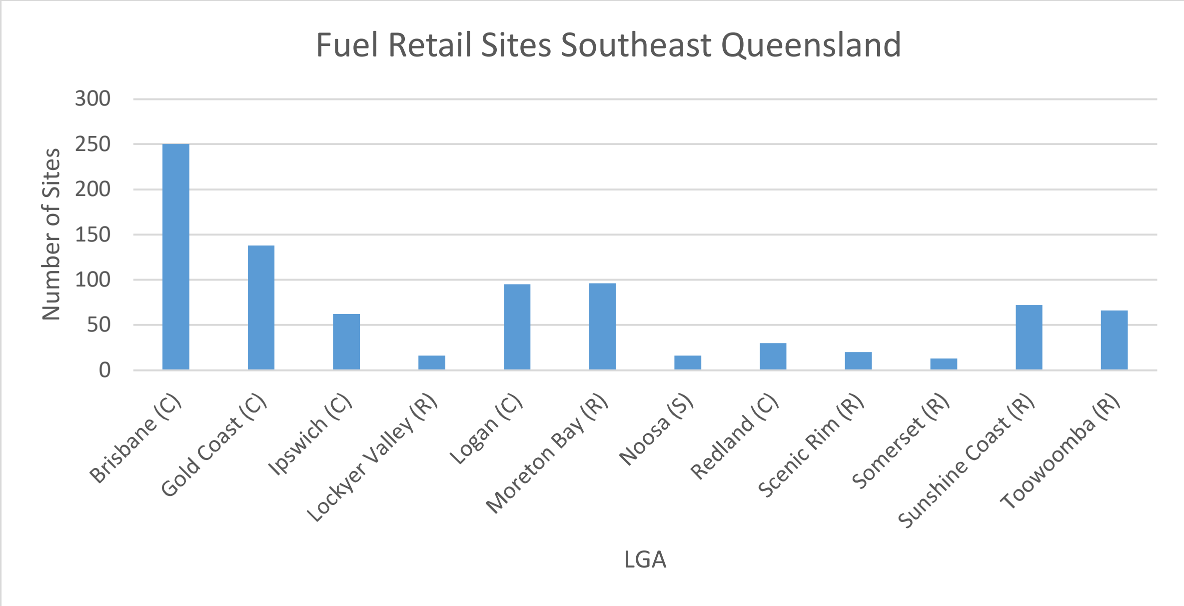


Figure 6: Southeast Queensland retail fuel sites by LGA.

3.2 Price Cycles, Price Surges and Price Leaders

This sub-section highlights a series of trends that can be observed at the most disaggregated fuel station level. Figure 7 provides a typical overview of fuel station level fuel price trends observable in Southeast Queensland between the second half of 2016 and the end of 2020.[7]

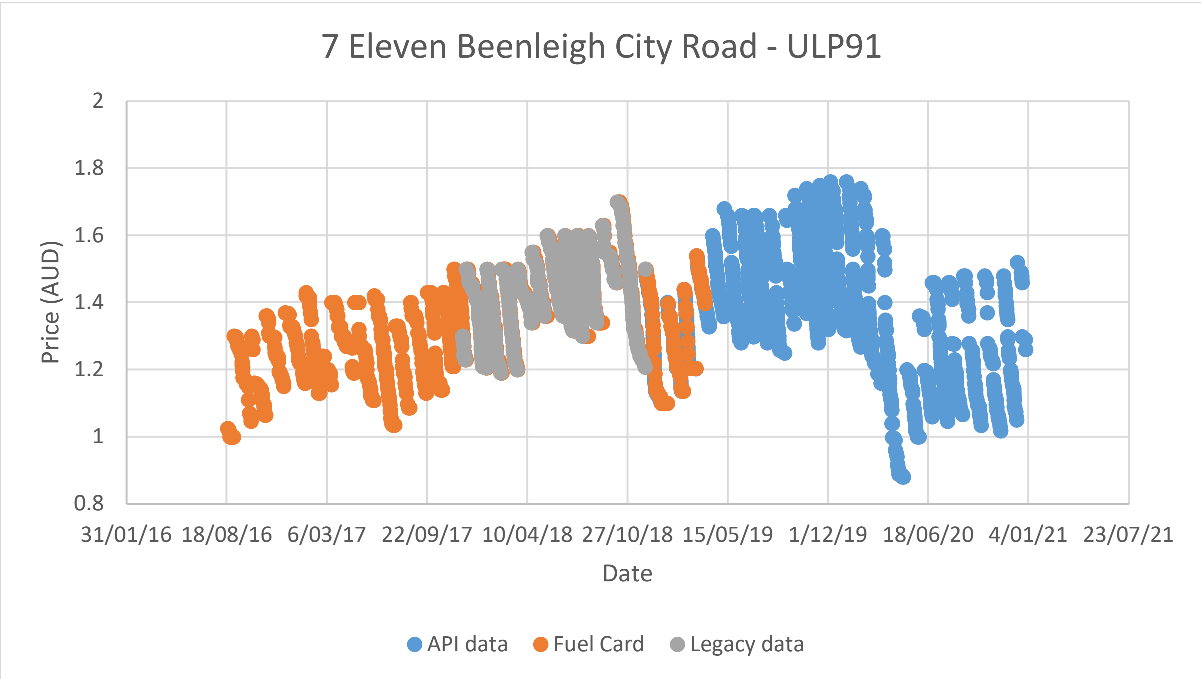


Figure 7: Average daily ULP 91 fuel prices (cents per litre) for one fuel station in Southeast Queensland.

[7] Appendix A provides LGA level price trends for selected LGAs.

It highlights the manner in which retail petrol prices can exhibit asymmetric price cycles: sudden, sharp increases in the price of unleaded petrol, followed by a gradual decline. These are a prominent, and longstanding, feature of retail petrol prices in urban areas across the country (ACCC, 2018). These cycles occur due to competitive pressures, which is why they are often observed in urban areas where retail competition is more pronounced. These competitive pressures encompass the need to capture market share whilst at the same time maintain retail margins. In fact, a known feature of these cycles is periods of negative retail margins, suggesting that the trade-off between market share and retail margins are a live feature of these cycles.

The rest of this sub-section focuses on data since the scheme came into effect. Figure 8 indicates a small rise in the difference between the peak and trough of price cycles since December 2018.[8] These stations were selected to compare price cycles across independent retailers and larger brands. However, it is unclear to what extent these changes are statistically significant. As such, the trends in price dispersion are empirically examined and discussed in Section 4.

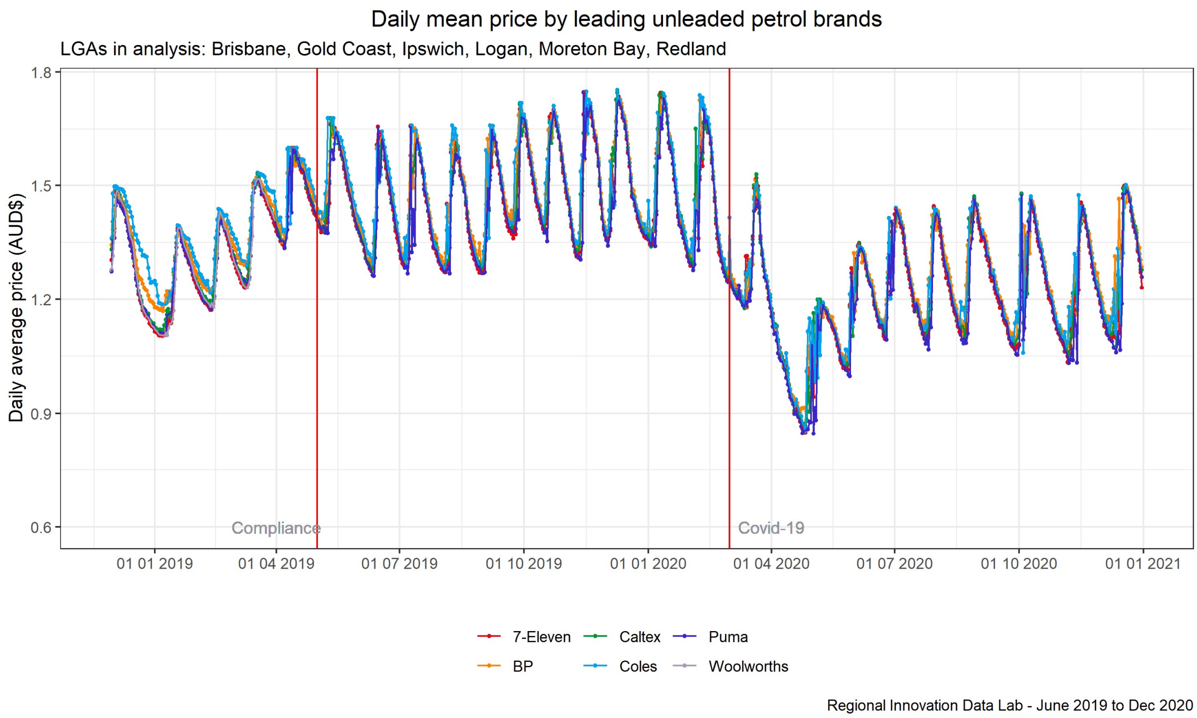


Figure 8: Average daily fuel price (cents per litre) over time (i.e., across surge and reset cycles) for selected brands, Dec 2018 – Dec 2020. The red vertical lines indicate key dates in the cycle: the compliance of the policy and the interruption caused by COVID – 19 related restrictions.

[8] See Appendix B for LGA level results.

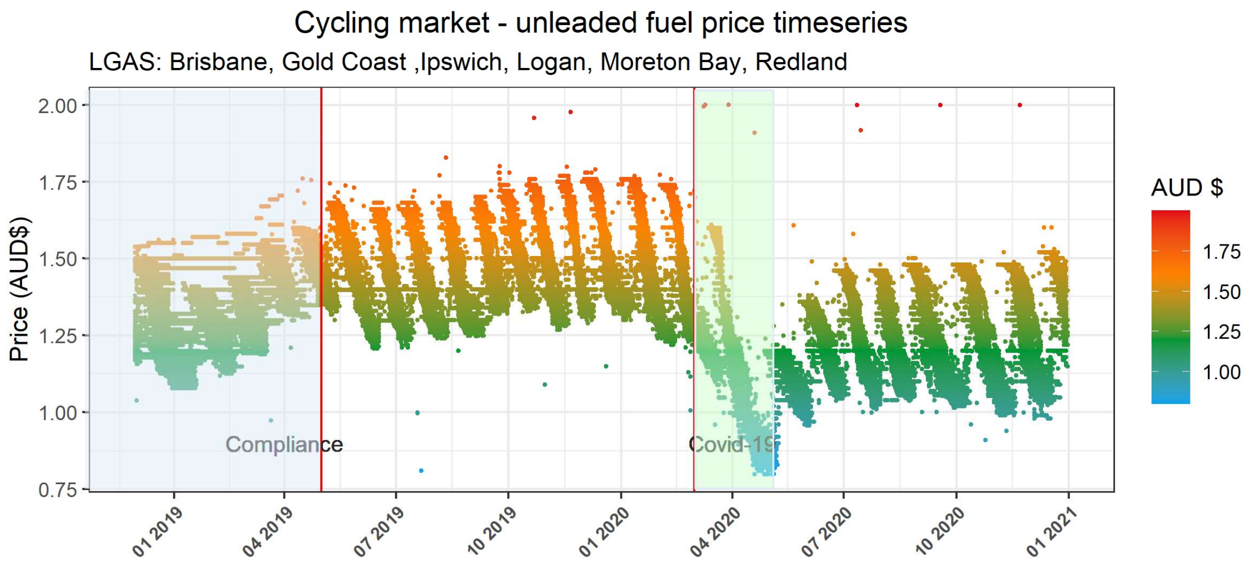


Figure 9: Individual unleaded fuel price points over time (i.e., price surge and reset cycles) in the Greater Brisbane LGAs: December 2018 - December 2020.

Figure 9 provides a timeseries view of per station unleaded fuel prices in the Greater Brisbane (i.e., Brisbane, Gold Coast, Ipswich, Logan, Moreton Bay and Redland LGAs) region. There are four periods within the time series worth noting, separated by shading on the graph. The two non-shaded sections are the periods during which the cyclical price surges and reset patterns are most consistently followed by over 90% of the market. The first period is the lead up period before compliance set in. During this period, price leadership is shared between four firms. As well, market norms are established, and the cyclical pattern is widely followed. Similar to analysis undertaken by de Byrne and de Roos (2019) in Perth, we find that two market norms or focal points are established, which enable market coordination across the cycles.

The first norm is the initial price hike (start of a surge), defined by a minimum price increase of $0.15 (mean increase is $0.36), and this increase becomes our first focal point. The surge is followed by the second norm, gradual price reductions. Our second focal point is a mean decrease of $0.015 (see Figure 10). Byrne and de Roos (2019) describe the incremental price decrease part of the cycle as *the "undercutting phase*". The undercutting phase continues until a baseline price is reached, at which point the cycle restarts with a price surge.

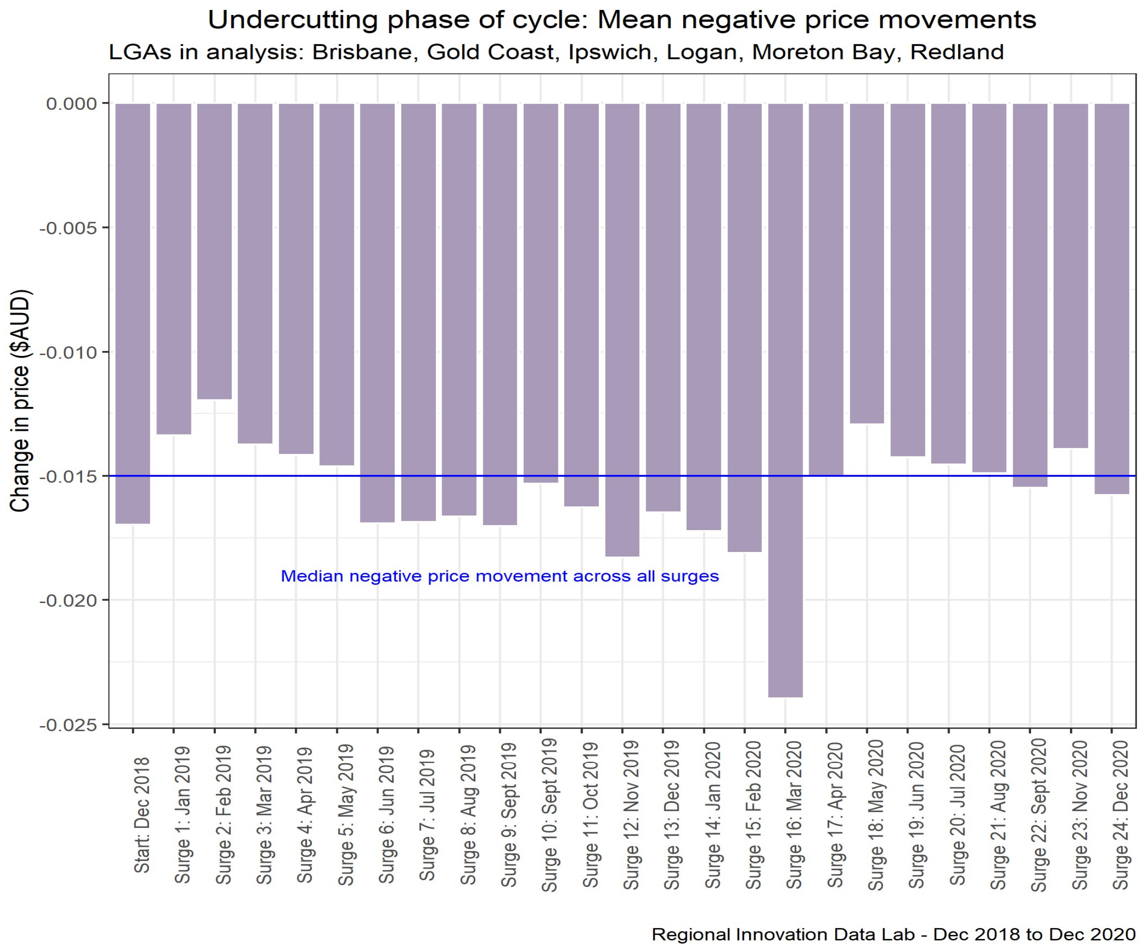


Figure 10: Average negative price movement during the undercutting phase of the surge and reset cycles. The median negative price movement across all 24 surges is -$0.015 cents.

During the second period (June 2019 - February 2020), mandatory reporting had been bedded in, and price cycles become more consistent and tightly coordinated, with roughly 94% participation across 630 stations, and a clear price leader emerges. Eight out of the 11 (73%) surges in this period are led by one firm. During the third period (March - May 2020), the cyclical pattern falters and prices reach new lows requiring large price hikes from a larger group of initiating stations to restart the price surge and reset cycles, (see Figure 11). This interruption is likely due to reduced demand resulting from Covid-19 movement restrictions.[9]

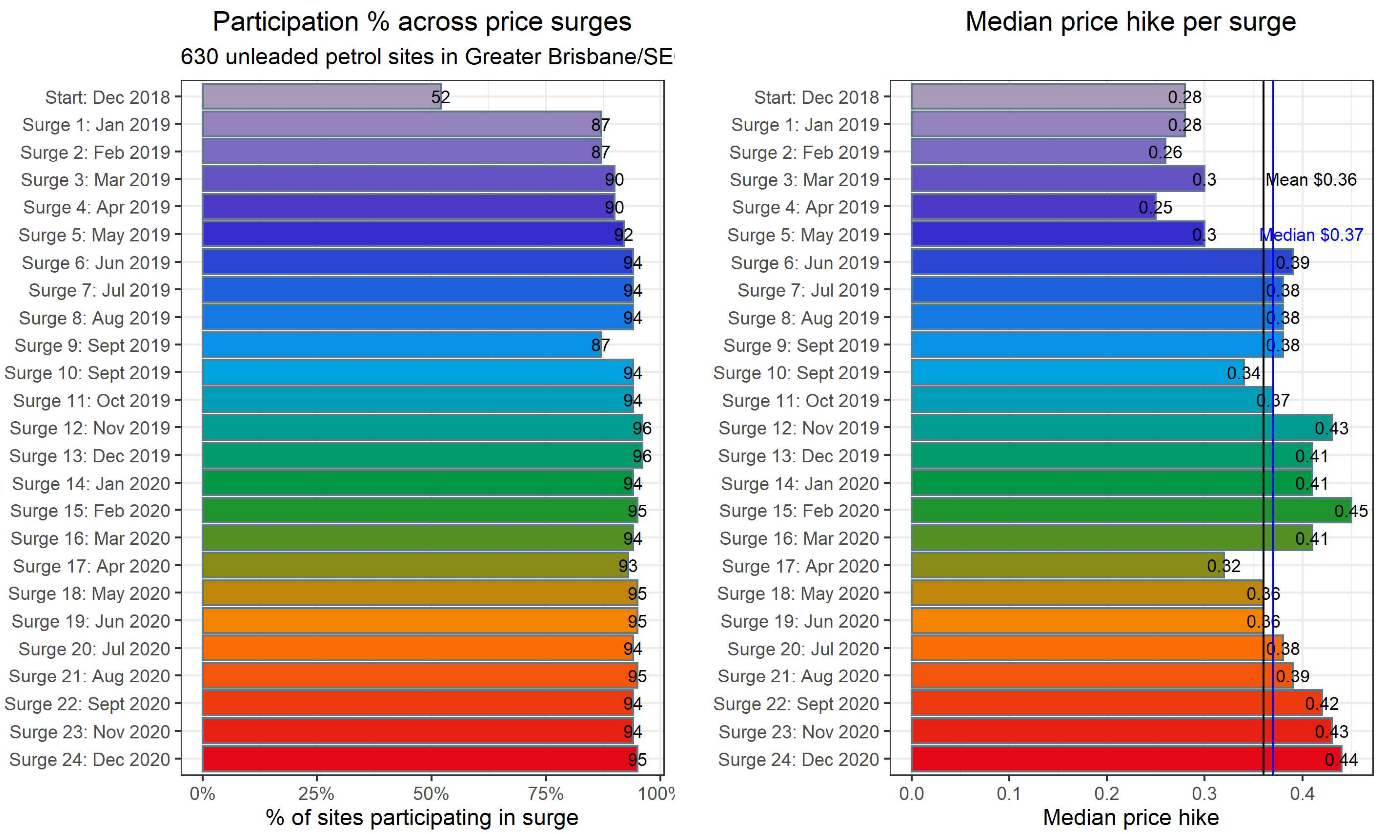
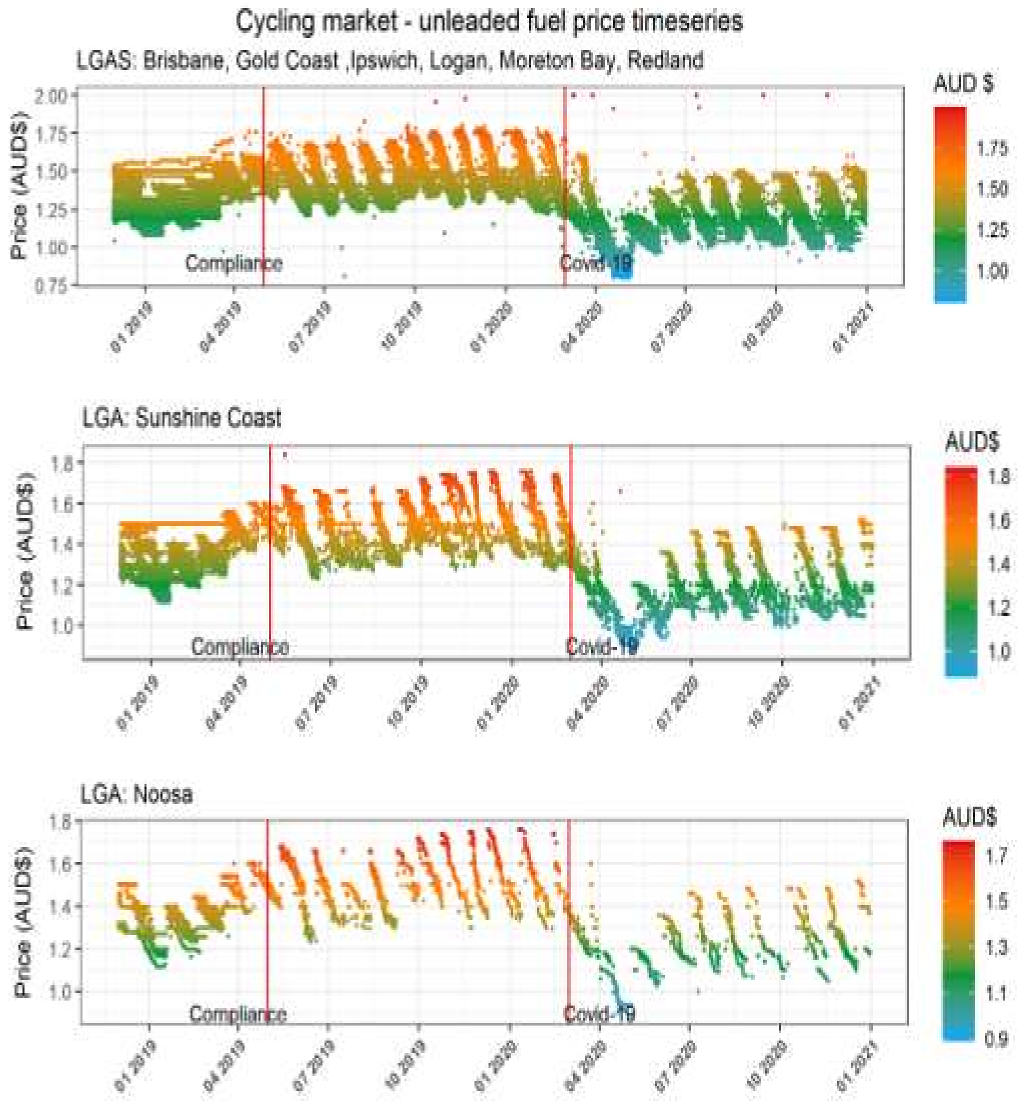


Figure 11: Percentage of sites participating in each surge remains consistently high and median positive price movements during the surge phase of the surge and reset cycles.

Between January and April 2020, the world started experiencing significant economic and social effects from Covid-19. This heavily impacted upon crude oil prices, leading to unprecedented events for the oil industry, further exacerbated in Australia with the COVID-19 lockdown that came into play in March 2020. During this period beginning January 2020, the regular surge leaders attempted to initiate a cycle in early February 2020 but corrected their prices when others did not follow suit. This is followed by two surges with prolonged undercutting phases in March (new leader) and April (back to regular surge leader). The amount by which prices are hiked at the beginning of the surge moderate, taking a few months to return to the pre-Covid-19 (May

[9] The change in fuel retailer behaviour during the COVID-19 period is only beginning to be investigated. Nevertheless, the ACCC (2021) has suggested that the price cycles during this period have not been marked by as much discounting relative to pre-COVID-19 times, and that retailers have attempted to increase their margins to offset the fall in sale volumes, which fell by 14% in 2020 relative to 2019. Thus, there is indicative evidence that retailers did attempt a new pricing strategy during this period of uncertainty.

2019 - January 2020) mean price hikes of +$0.39.[10] The fourth period (June - December 2020) sees cycles regain consistency, with participation rates and price hike amplitudes returning to pre-Covid-19 levels, although overall prices are lower than before. The price cycle and leadership analysis initially focussed on the Greater Brisbane LGAs because the asymmetric saw-tooth cyclical pattern dissipates in outer LGAs. For example, the cyclical pattern, which is still most pronounced in Brisbane, started to diminish around the Sunshine Coast, and was no longer evident in Toowoomba (Griffith University, 2020a). This is not the case in this report, and the pattern is being exhibited in some less urban/regional LGAs (see Figure 12 for a selection of LGAs).



[10] Note that discounting occurs differently. It occurs gradually (slowly and step-wise).

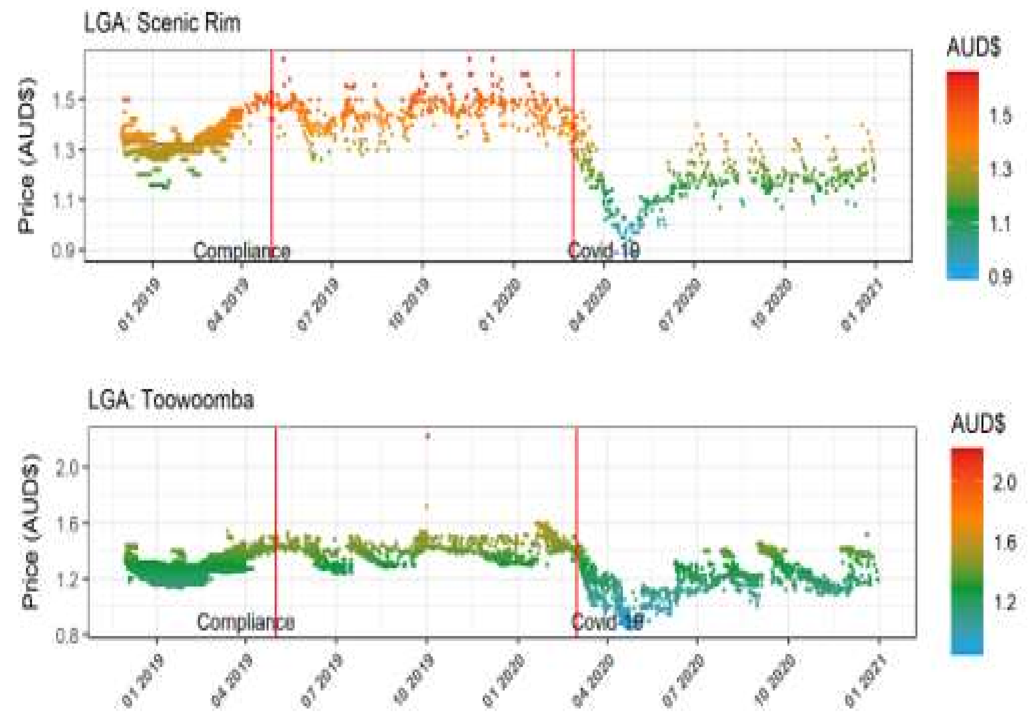


Figure 12: Indicative evidence of increasing participation in price cycles in less urban/regional LGAs.

Current analysis, while not exhaustive, shows that the previously metro-centric surge cycles are being exhibited, albeit in a delayed and muted sense in nearby less urban/regional areas. The dynamics around which markets adopt cycles in these areas is worth examining further. According to figures 12, 12a and 12b, we see that the market cycles initiated in the Greater Brisbane region are being echoed in neighbouring less urban/regional areas. The focal points (price increase of at least \$0.15 followed by an undercutting phase of -\$0.015) are present in these LGAs. The concentration of green and yellow points across all three LGAs in Figure 12a intimate that most reported price movements are negative, giving us the incremental undercutting phase. The blue horizontal lines across the plots indicate the cut off point for classifying whether a station participates in a surge. To participate, they need to increase their price by at least \$0.15. The threshold for meeting our surge definition is being increasingly met, for example, by a growing number of Toowoomba fuel stations.

Figure 12a: Individual unleaded fuel price changes over time (i.e., price surge and reset cycles) in selected LGAS neighbouring Greater Brisbane.

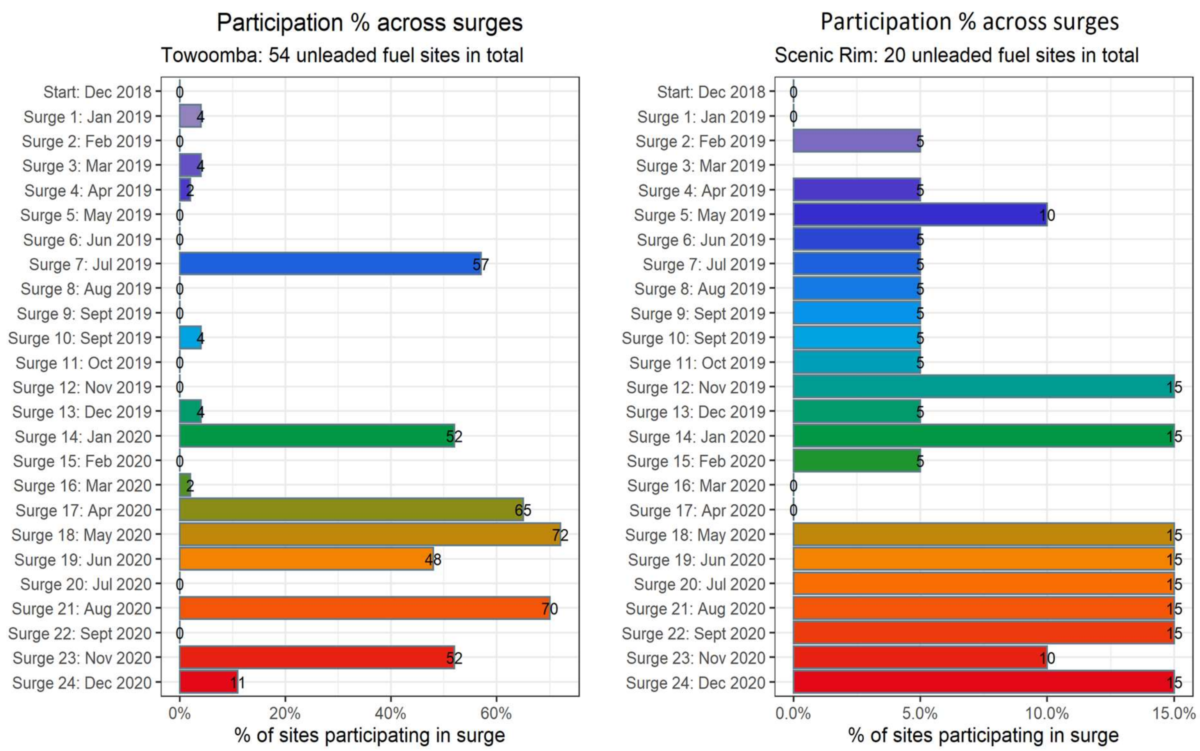


Figure 12b: Increased cycle participation rates (December 2018 - December 2020).

To ensure focus is maintained on the stations which are participating in and/or driving the price reset cycles, we classify a fuel station as 'participating' based on whether their price increased by $0.15 or more (this cut-off was determined based on the detailed analysis depicted in Figure 13). Based on this logic and by visualising changes in price, 24 clear price reset cycles were identified. There were 630 unleaded fuel stations in Greater Brisbane and practically all of them (626) participated in the reset cycles.[11] Of these 626, 543 or 90% of stations participated in all 24 of price cycles. [12]

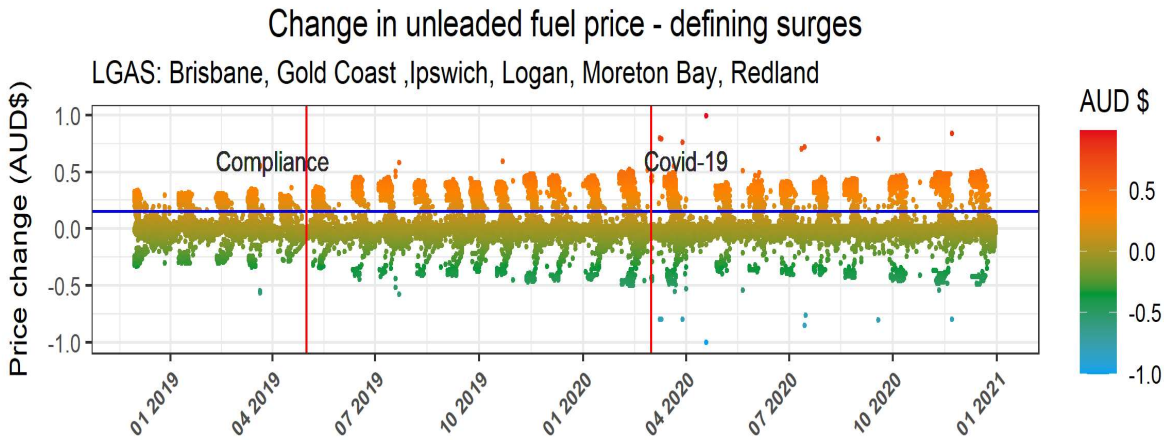


Figure 13: Price changes demonstrating the +$0.15 (focal point 1) cut off point for determining whether a site participates in a surge and reset cycle, and the concentration of negative price moves means a fall of -$0.015 (focal point 2) during the undercutting phase.

By applying a relative scoring mechanism to accurately capture how quickly retail stations adjust their price following an initial price hike, we were able to identify exactly which sites repeatedly drive the price reset cycles and how quickly other stations respond. In Greater Brisbane, a few firms own the majority of the stations, and interestingly, they do not apply a blanketed pricing strategy across all their stations, indicating the presence of well-thought out and considered pricing strategies. The analysis suggests that while only a few firms drive the majority of surges, one specific firm led 15 out of the 19 (79%) of the post-compliance surges. The first two surges of the second period (June - July 2019) are led by a repeated set of Caltex stations, whereas the August 2019 - 2020 surges are driven by a key set of Coles Express stations. After a failed attempt to get the market surging again in February 2020 by the Coles Express leader, the March 2020 surge is led by a group of 7 Eleven branded stations before the aforementioned Coles Express stations take back their lead (April -

[11] The non-participating stations are located in North Stradbroke island.

[12] We also identified a failed cycle or false start of a cycle during the initial Covid-19 restrictions in March 2020. The reason we excluded this cycle from our analysis is that only 13 stations participated in the cycle. What makes this failed attempt interesting is that the same key stations which drove the preceding surges also drove this failed attempt, but then quickly adjusted their prices when no other stations followed suit.

December 2020). Overall, five different firms, post-compliance use a collection of 70 stations spread out across Greater Brisbane to drive the price cycles.[13,14]

The firms driving the cycles do not use a single petrol station to initiate price hikes. Instead, a combination of three to 11 stations are used to repeatedly drive the surges, again indicating a considered pricing strategy at play. By pegging the retail margin higher during the surge/peak of the cycle and then very gradually reducing price by -$0.015 cents per movement, participating sites stand to benefit from the increased margins at the top of the cycle. Firms operating numerous stations respond to cycles by raising their prices quicker than those operating fewer or single stations. On average, a reset cycle occurs every 23 days. Between June 2019 and January 2020, cycle lengths reduced but in February and then again in August 2020, cycle lengths blew out to 38 and 40 days respectively. These prolonged undercutting phases interrupting the cycle may be due to Covid-19 related movement restrictions (see Figure 14).

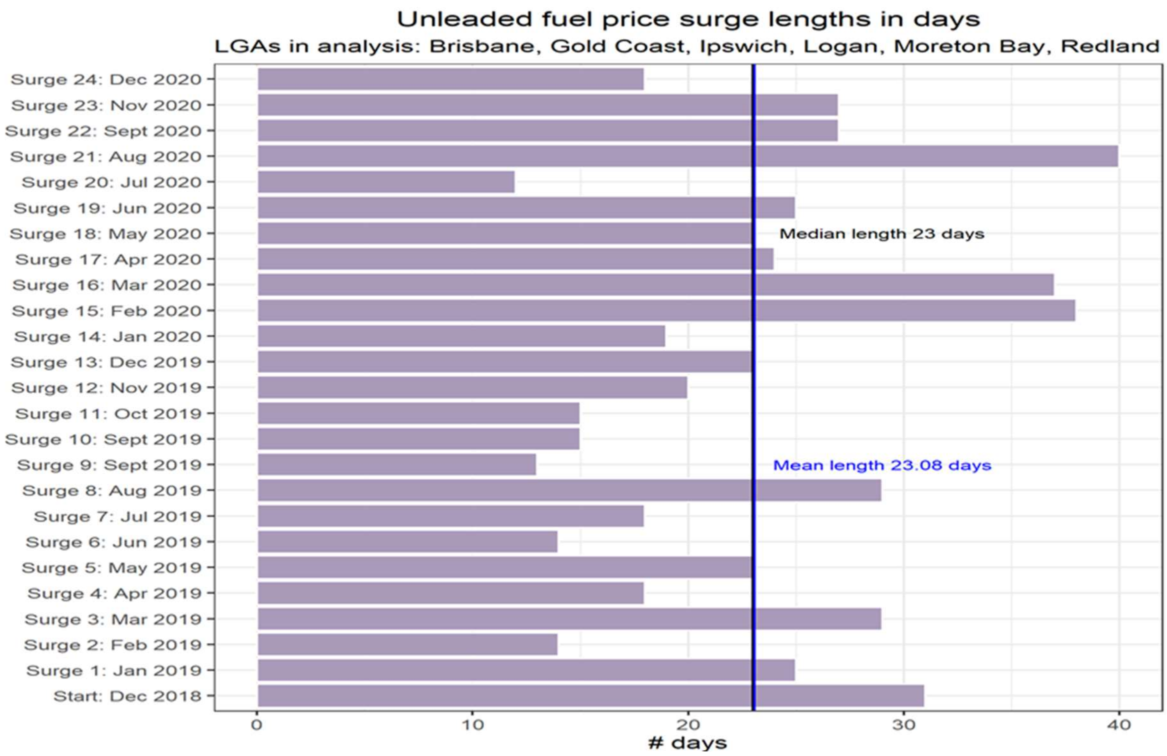


Figure 14: Cycle length (in days) for each of the 24 identified cycles

13 The 15th surge driven by the 7 Eleven branded stations is less characteristic of the overall pattern as it happened after the Covid-19 restrictions relaxed. If that surge was to be excluded, then an even fewer stations (19) are being used to drive the price cycles.
14 For a dynamic visualisation of these surges, see the attached animated illustrations sent alongside this report, which show the way the leading firms utilise selected stations to repeatedly drive the cycles.

3.2.1 Correlation between App Usage and Price Surges – An Examination of Brisbane LGA

A correlation analysis on the daily average price of unleaded (ULP91) petrol and the number of unique app users was run in order to test for a relationship between the price of petrol and app usage in the Brisbane LGA. A weak positive correlation was found,[15] indicating that app usage rises when fuel prices rise (see Figure 15). However, the relationship is statistically insignificant, and as such this finding is potentially unreliable. Thus, we cannot claim the finding to be robust and it should be used with an abundance of caution. Next, we investigated if the cyclical price surges exhibited across Brisbane LGA were more closely correlated with higher numbers of app users checking fuel prices, using a point-biserial correlation analysis (Pearson test for binary discrete and continuous values).

Three new variables are defined for this purpose. First, we calculated the daily median price change for all fuel stations in Brisbane. Next, we defined two binary variables to classify days that are part of a surge peak. Surge peaks are defined as days during the cycle on which the median or mean price change is greater than or equal to $0.15. This price change threshold for defining surge peaks allows us to determine days on which a market level surge is occurring, as the majority of stations raise their prices to participate in the peak of the cycle. These two surge peak variables are defined as follows, 1: daily mean price change was more than or equal to $0.15(1 = yes, 0 = no), and 2: daily median price change is more than or equal to $0.15 (1 = yes, 0 = no).

Results intimate that when consumers in Brisbane LGA notice bigger changes in price, they are more likely to start using the app and shop for cheaper fuel. This indicates that price alone does not appear to be impacting the number of app user sessions; instead consumers seem to be more likely to check the app when they notice a price surge cycle is occurring. This fits in well with the RACQ (2021a) app usage survey that indicate greater use and uptake in more urban settings where such surges are more commonplace.

[15] A positive (negative) correlation means that the two variables of interest move in the same (different) direction.

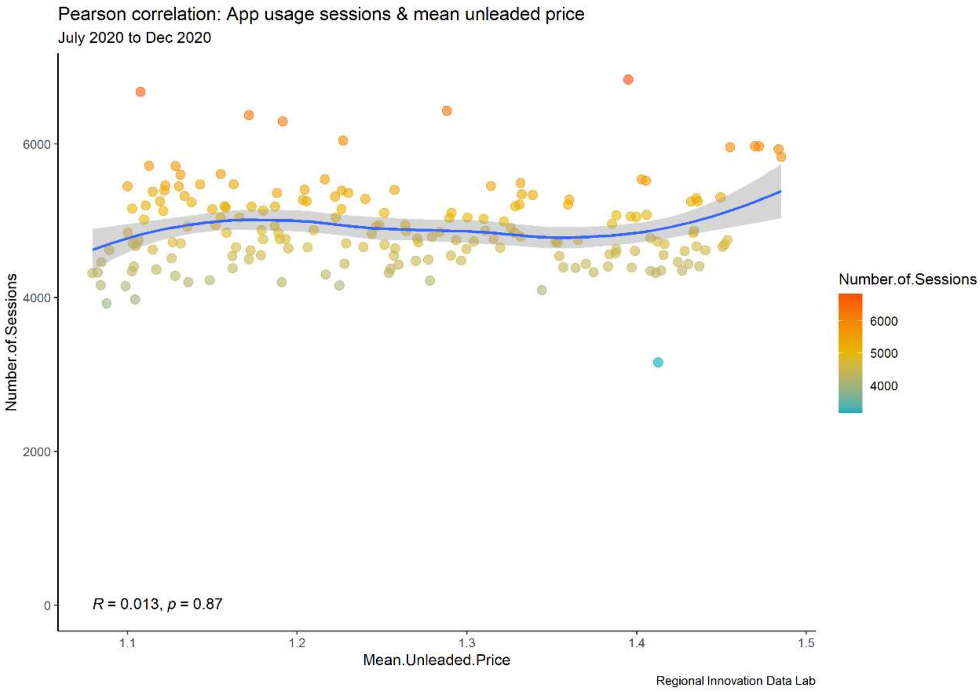


Figure 15: Pearson correlation test testing the strength and direction of the relationship between app usage and the average price for fuel in Brisbane.

3.3 Snapshot of Fuel Price Changes: Comparing Periods

Aggregated figures 16 and 16a provide a snapshot of the observed regular unleaded fuel price (i.e., ULP91) prior to and during the scheme period (1 December 2017 - 31 December 2020). While these show that average prices have generally declined, it is noting that the declining trend in international oil prices have been a significant contributing factor, though there is also evidence of the scheme leading to more competitive pressures in the Southeast Queensland region.[16] As well, there has been a fall in minimum prices alongside a rise in maximum prices since compliance was introduced. For example, in Ipswich LGA, the minimum price fell from $1.23 (pre-trial) to $0.88, but equally the maximum price was higher post-compliance ($1.72 as opposed to $1.67 pre-trial). Thus, there is a general trend showing greater volatility once the scheme came into being, as the standard deviation of retail fuel prices increased in that period relative to the pre-scheme period.

[16] More specifically, while the minimum prices noted in the figures have occurred during the period of the scheme, we caution against inferring that the scheme was the direct cause of the fall in prices. This is as local prices are influenced by international prices and also by a confluence of other factors such as the pandemic and exchange rate fluctuations, thus making it difficult to isolate the true effect of the scheme on fuel price trajectory.

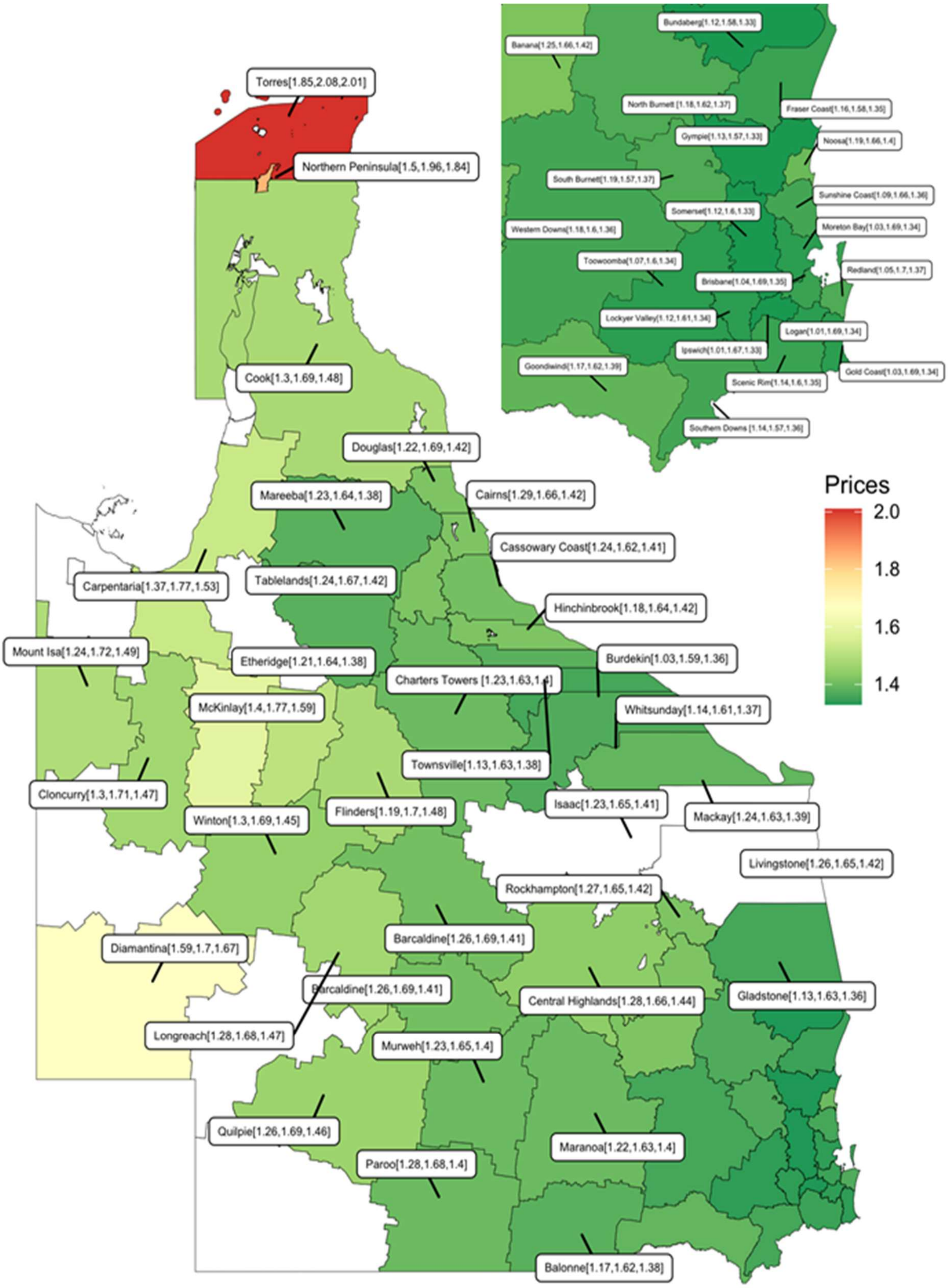


Figure 16. A snapshot of the observed regular unleaded fuel price across Queensland pre-policy (December 2017 – 2 December 2018) The set of numbers show the minimum, maximum and average (mean) prices of the period. The colours denote average prices (green indicates a low price, yellow medium, red high while white denote LGAs without data).

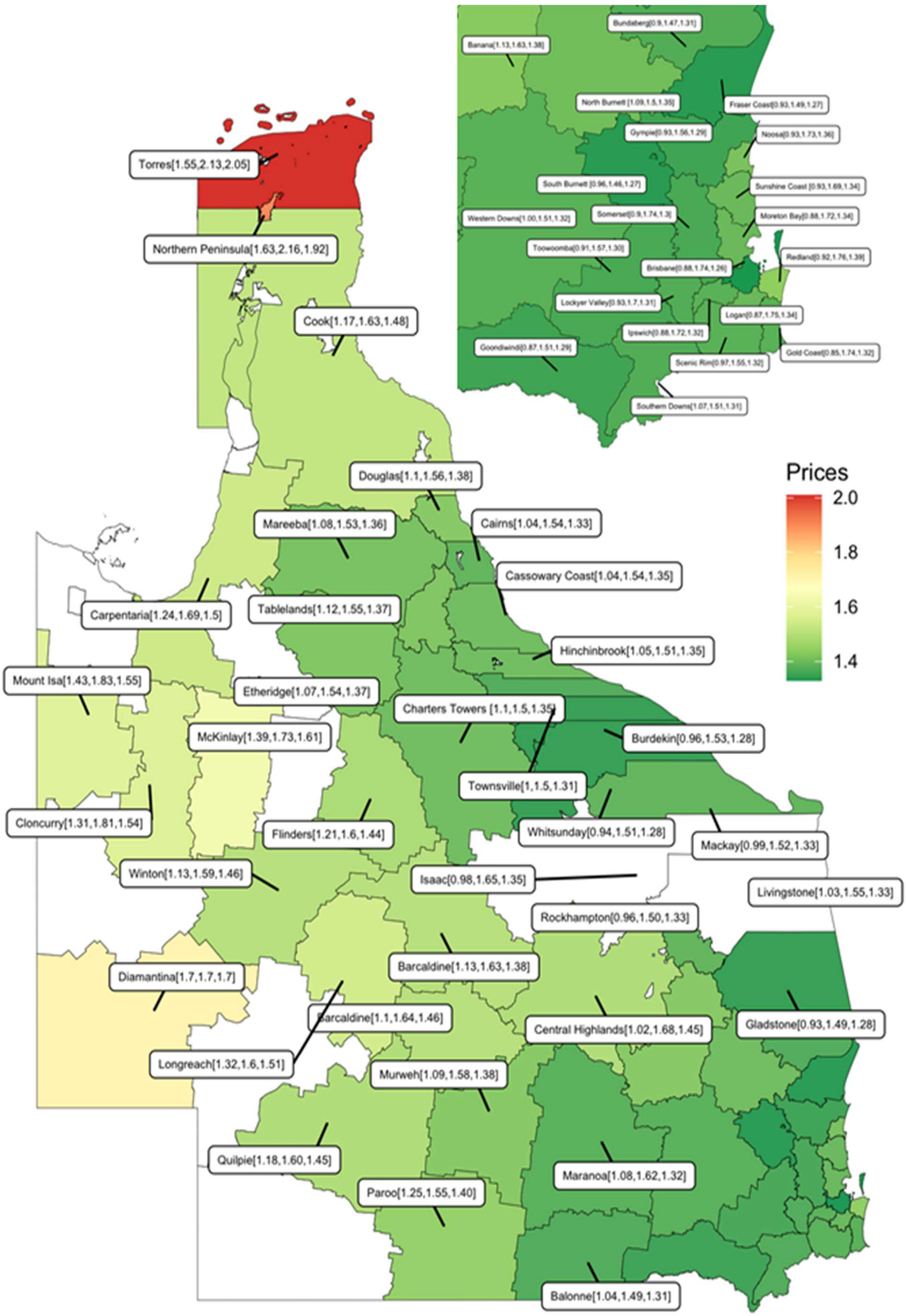


Figure 16a. As per previous figure but for the post-implementation period (3 December 2018 - December 2020.

4. Empirical Modelling and Results

4.1 Time-series (Auto Regressive Distributed Lag [ARDL]) Model

A time series model of the log average daily retail price[17] by LGA and fuel type is constructed in order to empirically verify the impact of the scheme on retail fuel prices using tests for structural breaks that coincide with the commencement of the scheme. It incorporates the main drivers of price fluctuations, including international oil prices, retail margins, demand conditions, changes in fuel excise[18] and exchange rates. The average daily petrol price for each fuel type and LGA is converted into natural-logged variables. As this analysis uses time series data, it is vital to investigate the presence of unit roots and/or co-integration relationships among variables. This is as we are interested in identifying whether the time series variables in the model are either stationary or non-stationary[19] as well as whether there are long run equilibrium relationships among variables. The preliminary analysis suggests that price variables in some LGAs are stationary, whereas the Australian dollar value of the international oil price is non-stationary (integrated of order 1). The dependent variable (retail fuel price) is regressed over its own past values (lagged values) as well as current and lagged values of other independent variables (in this case, the domestic currency value of international oil prices). The model is augmented via the incorporation of a further set of dummy variables that control and account for fuel excise imposed by the government that occur on a biannual basis.

Table 1 summarises the impact of the implementation of the scheme using the ARDL model (see Appendix C for detailed results). The model covers logged average daily prices per LGA and petrol type. The negative (minus) sign indicates that the model has detected a decline in retail fuel prices since the introduction of the scheme, with a positive (plus) sign indicating the reverse scenario.

[17] Transforming variables into natural logs helps to handle non-linear relationships within linear models. Similarly, logarithmic transformations help to convert highly skewed variables into more approximately normal variables.

[18] The fuel excise rise that was due on 3 August 2020 was not executed as CPI entered negative territory (RACQ, 2021).

[19] Stationarity means that the statistical properties of a process generating a time series do not change over time. A stationary time series tends to revert to a long run mean and has constant variance. When there is a mix of stationary and non-stationary variables as well as co-integration association among variables, the well-known ARDL model becomes a suitable modelling framework for the analysis.

	Independent Variable: Brent Price			
	ULP 91	PULP	E10	Diesel
Southeast Queensland LGAs				
Brisbane	−**	−**	−**	
Gold Coast	−**	−**	−**	
Ipswich	−**	−**	−**	
Logan	−*	−**	−**	
Moreton Bay	−**	−**	−**	
Lockyer Valley	−**	−**	−**	
Noosa	−**	−**		
Scenic Rim			−**	
Sunshine Coast		−*		
Redland	−**	−**	−**	
Average	−**	−**	−**	
Other LGAs				
Townsville				
Rockhampton				
Bundaberg			−**	
Cairns	−*	−**	−**	

Table 1: Impact of the scheme on retail fuel prices.
Note: ** refers to policy effect at 5% level of significance and * refers to policy effect at 10% level of significance.

Results show a statistically significant decline in retail petrol prices since the implementation of the scheme across most of Southeast Queensland. The impact of the scheme is largely confined to this region only, as, bar Cairns LGA, the other selected LGAs indicate no statistically significant decline in retail prices apart from E10 fuel in Bundaberg LGA. This suggests that the more competitive nature of the retail fuel market in Southeast Queensland relative to other regions, and the higher utilisation of fuel price apps (RACQ, 2021a) has enabled the implementation of the trial to generate consumer savings in Southeast Queensland, and to a lesser extent Cairns and Bundaberg.

The estimated magnitude of the impact on retail fuel prices is modest. The estimated fall in the ULP91 price due to its implementation in the Brisbane LGA is approximately 0.44%, relatively similar to the Southeast Queensland average (0.45%).[20] The greatest observed fall in average daily ULP91 price occurred in Ipswich (0.77%), and percentage falls were also sizeably greater than Brisbane's on the Gold Coast (0.57%), Logan (0.53%), Moreton Bay (0.61%), Lockyer Valley (0.57%) and Redland (0.70%). In Cairns, the percentage fall was 0.11%. In dollar terms, relative to the pre-implementation average ULP91 price, this equates to a fall of $0.0059 per litre in Brisbane, $0.0061 per litre for the Southeast Queensland and $0.0016 per litre in Cairns.[21] The non-effect on diesel

[20] Note that the average results for Southeast Queensland are weighted to account for the number of retail fuel stations in each LGA. Therefore, the Brisbane LGA results have a higher weighting than other LGAs, as Brisbane is part of Southeast Queensland.
[21] See Table 6 in Section 4.4 for PULP and E10 results.

pricing is expected, given that only approximately one quarter of diesel consumed is sold through retail outlets.

A further extension was undertaken whereby a COVID-19 dummy was incorporated in order to investigate its local impact. It was not utilised in the main model as (a) the main driver of prices at the bowser are international prices, which already demonstrate the impact of COVID-19 on global fuel prices, (b) it is not evident (at this stage) if the impact of COVID-19 is transitory or permanent, and (c) introducing COVID-19 controls potentially produces unreliable estimates as collinearity may be present between the COVID-19 controls and other controls like international oil prices. Nevertheless, results of the policy dummy (i.e., the initiation of the scheme) in Table 2 are largely consistent with the main model. Of interest is the impact of COVID-19 on retail fuel prices. Bar one instance the impact of COVID-19 was either negative or minute, lending support to statistical findings of falling retail fuel prices during the COVID-19 lockdown period.

	Independent Variable: Brent Price							
	Policy Dummy				**Covid-19 Dummy**			
	ULP 91	PULP	E10	Diesel	ULP 91	PULP	E10	Diesel
Southeast Queensland LGAs								
Brisbane	−**	−**	−**		−**	−**		
Gold Coast	−**	−**	−**		−**	−**	−**	
Ipswich	−**	−**	−**		−**	−**	−**	
Logan	−**	−**	−**		−**	−**	−**	
Moreton Bay	−**	−**	−**		−**	−**		
Lockyer Valley	−**	−**	−**		−**	−**	−**	+**
Noosa	−**	−**	−**		−**	−*	−**	−*
Scenic Rim	−**	−*	−**		−**		−**	
Sunshine Coast	−**	−**			−**	−**		
Redland	−**	−**		−*	−**	−*	−**	−**
Average	−**	−**	−**		−**	−**	−*	
Other LGAs								
Townsville								
Rockhampton					−**	−**		
Bundaberg			−**			−**	−**	
Cairns		−**	−**				−**	

Table 2: Impact of the scheme on retail fuel prices, with COVID-19 dummy.
Note: ** refers to policy effect at 5% level of significance and * refers to policy effect at 10% level of significance.

4.2 Panel Model

Panel models are estimated with longitudinal data, where observations span across both time and individuals/entities in a cross-section. The advantages include the capability of capturing unobservable or unmeasurable sources of diversity across individuals or entities and controlling omitted variable bias. In this study, the panel data model is estimated as a robustness check for the ARDL time series model outcomes. The same LGAs used in the ARDL time series models are considered as entities. However, instead of daily retail prices, monthly average retail prices are considered instead. Similar to the ARDL model, the average retail fuel prices are assumed to be driven by international oil prices, retail margins, demand conditions, changes in fuel excise and exchange rates. Further, in order to empirically verify the scheme's impact on retail fuel prices, a dummy variable is included to test for structural breaks that coincide with its commencement. The model is augmented via the incorporation of a further set of dummy variables that control and account for fuel excise. The average monthly retail price for each fuel type within LGA is converted into natural-logged variables.[22]

Results are consistent across fuel types. Retail prices are positively related to Brent prices, which means that retail prices move in line with Brent pricing. Given the established close relationship between Brent and MOGAS95 prices, and thus between MOGAS95 and TGP pricing in Australia, this reiterates the points made by both the AIP and the ACCC that international pricing is the main contributor to retail fuel prices in Australia. Next, we note the negative value of the policy dummy. This means that consistent with ARDL results, the introduction of the scheme led to a lowering of retail fuel prices in the fourteen LGAs noted in the ARDL study. However, in contrast to the ARDL results, the panel results highlight that the trial impacted upon diesel retail prices by reducing prices. This could be due to data aggregation. Unlike the ARDL time series model that utilise daily data, the panel model uses monthly data. As the number of data points in the panel model are limited, the interpretation of coefficients needs to be treated with caution.

[22] There are two techniques in analysing panel data: fixed and random effects models. With the former, we assume that some characteristics within the entities may impact the outcome variables, and thus, need to be controlled for. Another assumption is those time-invariant characteristics are unique to the entity. A Hausman test was run, and it identified the random effects model as the preferred model. Thus, we report the results only for the random effects model.

Variables	Random Effects Model	
	Estimate	**Std. Error**
ULP91		
(Intercept)	0.56952***	0.0143116
Brent	0.42072***	0.0148956
Policy Dummy	-0.08296 ***	0.0123153
Adj. R^2	0.82275	
PULP		
(Intercept)	0.644148***	0.0125038
Brent	0.371048***	0.0130684
Policy Dummy	-0.07318***	0.0108047
Adj. R^2	0.82424	
E10		
(Intercept)	0.541715***	0.0155888
Brent	0.429750***	0.0164728
Policy Dummy	-0.084753***	0.0136194
Adj. R^2	0.80159	
Diesel		
(Intercept)	0.40498 ***	0.0138982
Brent	0.230755***	0.0149281
Policy Dummy	-0.072096***	0.0123423
Adj. R^2	0.82738	

Table 3: Panel results
Note: ***, ** and * refer to effects at 1%, 5% and 10% levels of significance respectively.

4.3 Estimated Potential Savings

Beyond changes in average retail prices, Section 3 noted visible increases in price dispersion (price spread) in some regions. Increases in the spread of prices suggests that informed consumers have a greater potential to save if they are able to locate the cheapest available prices in their area for a given fuel cycle. To find evidence for statistically significant changes in price dispersion, Table 4 summarises results of an ANOVA test[23] with unequal sample sizes that check if price dispersions (for ULP91) between daily minimums and maximums have increased in a statistically significant fashion over time. Three time periods are identified. The pre-scheme period (Segment 1, $\bar{\sigma}_{s1}$) from 20 August 2016 to early December 2018, the scheme commencement period prior to full enforcement (Segment 2, $\bar{\sigma}_{s2}$) (early December 2018 to April 2019) and the period thereafter (Segment 3, $\bar{\sigma}_{s3}$).

The main timeframe of interest would be between the pre-trial (S1) and the period when the scheme was fully up and running (S3). Results indicate a significant increase in the spread of prices across almost all Southeast Queensland LGAs, denoting potential for savings at the bowser. This is also consistent with the evidence that regions with more competition could benefit from a greater spread of fuel pricing information. However, for Cairns and Townsville, dispersion narrows instead, which is indicative of less potential for savings at the bowser. Nevertheless, it is important to note that this does not necessarily mean that there are savings (or otherwise in the case of Townsville and Cairns LGAs) to be had as the ANOVA test does not account for any other factors or determinants that may influence price dispersion such as retail competition, transport costs and regulatory charges.

There is also some evidence that price dispersion increased between the intermediate (S2) and full enforcement (S3) periods. This occurred in a majority (seven of ten) of Southeast Queensland LGAs and one of the four non-Southeast Queensland LGAs. While a separate and focussed study is required to better understand these regional differences, we note that regional areas typically have smaller numbers of retail outlets and thus price changes at any given station could wield a greater effect on overall price trends relative to LGAs with larger number of retail stations. Changes in prices pre- and early-implementation periods (S1 and S2) are, as expected, less apparent given the trial was being bedded in.

[23] Analysis of variance (*ANOVA*) is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyse the differences among group means in a sample.

	ANOVA pair-wise comparison		
Periods	**S1 and S2**	**S1 and S3**	**S2 and S3**
Southeast Queensland LGAs			
Brisbane		Higher (S3>S1)	Higher (S3>S2)
Gold Coast		Higher (S3>S1)	
Ipswich		Higher (S3>S1)	Higher (S3>S2)
Logan		Higher (S3>S1)	Higher (S3>S2)
Moreton Bay	Higher (S2>S1)	Higher (S3>S1)	Higher (S3>S2)
Lockyer Valley	Higher (S2>S1)	Higher (S3>S1)	Higher (S3>S2)
Noosa	Higher (S2>S1)	Higher (S3>S1)	
Scenic Rim		Higher (S3>S1)	Higher (S3>S2)
Sunshine Coast		Higher (S3>S1)	Higher (S3>S2)
Redland			
Other LGAs			
Townsville	Higher (S2>S1)	Lower (S3<S1)	Lower (S3<>S2)
Rockhampton	Higher (S2>S1)		Lower (S3<>S2)
Bundaberg			Higher (S3>S2)
Cairns	Higher (S2>S1)	Lower (S3<S1)	Lower (S3<>S2)

Table 4: ANOVA results for price dispersion. A 'higher' ('lower') spread means that price dispersion has increased (decreased) in a statistically significant manner in the later period relative to the earlier period. An empty cell denotes no statistically significant change in daily minimums and maximums price dispersion between selected periods.

Potential to save: An increase in the spread of fuel prices can grow the potential savings that can be made by motorists using fuel price apps to identify cheaper prices available in their local area. A rough indication of the annual potential savings can be derived from measuring the difference between the minimum fortnightly petrol price and the mean petrol price observed in the same period. Using LGA wide ULP91 price cycles between January to December 2020, we estimate annualised savings based on comparing minimum and mean prices (see Table 5). Savings potential is higher in the more competitive LGAs in Southeast Queensland, whereas we estimate a lower level of savings potential in the less competitive LGAs outside Southeast Queensland. Appendix D discusses the method in greater detail.

LGA	Potential Savings (January – December 2020)
Brisbane	$171.60
Ipswich	$156.15
Lockyer Valley	$93.15
Rockhampton	$37.21
Gold Coast	$145.48
Cairns	$48.59
Mt. Isa	$7.56

Table 5: Estimated potential savings accruing to motorists derived from refuelling at the minimum fortnightly observed ULP91 prices in their LGA, relative to refuelling at the mean fortnightly observed ULP91 price.

4.4 Estimated consumer savings

Consumer surplus arising out of the fall in prices since the implementation of the trial was calculated using both information derived from this study and that provided by the Australian Bureau of Statistics (ABS) 2019 Cat. No. 9208.0 (Survey of Motor Vehicle Use, Australia, 12 months ended 30 June 2018).[24] Analysis is conducted on the use of passenger vehicles. Using data from appendix tables C1-C3, we estimate average savings (on a per litre basis) at the bowser since the introduction of the scheme (see Table 6).[25]

	Average Savings (Per Litre)		
	ULP91	PULP	E10
Brisbane	$0.0059	$0.0070	$0.011
Southeast Queensland	$0.0061	$0.0069	$0.0067
Cairns	$0.0016	$0.0028	$0.0053
Bundaberg	-	-	$0.0063

Table 6: Average savings (per litre) for regular users

Brisbane LGA: According to ABS data, the average rate of petrol consumption in Queensland is 10.7 litres per 100 kilometres (0.107 litres per kilometre), though we note that more urban settings tend to see higher levels of fuel consumption per litre. The average kilometres travelled within Brisbane (passenger vehicles) is 10,500 kilometres per year. Thus, annual petrol consumption would be 1,123.5 litres (10,500 x 0.107). Users of ULP91 could save, on an annual (25-month period) basis $6.63 ($13.81) per passenger vehicle from the scheme relative to the pre-implementation period. For PULP, this would be $7.86 ($16.38) and for

[24] The ABS released an update (ABS, 2020a) for the 12 months ended 30 June 2020. However, the data for this release is unreliable for this study for two reasons; first the massive bushfires that occurred in summer 2019-20, and the impact of the COVID-19 lockdown (March - June 2020). Both are one-off factors that impacted upon driving patterns. For example, the data states (for passenger vehicles in Brisbane) that 9,200 kilometres was driven annually, when in the previous report it was 10,500 kilometres. Given it is unlikely for driving patterns to systematically change significantly over a short period of time (i.e. 2018 to 2020), data from the previous release (ABS, 2019) is more reliable, and is used instead.

[25] Note that ARDL results suggested no significant change in diesel retail prices pre- and post-implementation. Thus, consumer savings is only calculated for the three petrol variants.

E10, $12.36 ($25.75). Total annual consumer surplus is $9,509,205.95 or $19,810,845.73 over the 25-month December 2018 – December 2020 period.[26]

Variations to Consumer Surplus:[27] Changes in the figure for total kilometres travelled will alter consumer surplus, and there is no *a priori* reasoning to use only the 'within Brisbane' average annual kilometre estimate (10,500 kilometres). If we include trips not just within Brisbane but also those between Brisbane and other parts of Queensland as well as between Brisbane and other capital cities, then 15,692,955,000 kilometres are covered annually. This yields a total annual consumer surplus of $11,630,673.22, or $24,230,569.21 over the 25-month period of study. Nevertheless, this report opines that the 'within Brisbane' definition is a more accurate depiction of the use of passenger vehicles within the Brisbane LGA, and the presentation of a broader measure is used to indicate that aggregated savings can expand if we also incorporate a wider driving range that will better represent a minority of drivers.

Southeast Queensland LGAs:[28] With minimal alterations, the same methodology is used to calculate consumer savings for Southeast Queensland (including Brisbane). Regular users of ULP91 could save annually (25-month period) $6.85 ($14.27) per passenger vehicle from the scheme. For PULP, the figure is $7.75 ($16.15) and for E10, $7.53 ($15.69). Total annual consumer surplus is $12,322,102.72, or $25,671,047.33 over the extended period.

Cairns and Bundaberg LGA: A similar (but not identical) methodology is used to calculate consumer savings for these LGAs.[29] For Cairns, regular users of ULP91 could save annually (25-month period) $2.07 ($4.31) per passenger vehicle. For PULP, this yields $3.63 ($7.56), and for E10, $6.86 ($14.29). Consumer surplus totals $126,920.53 ($264,417.77). For Bundaberg, regular E10 users, can, on average, save $8.16 ($17.00). Consumer surplus totals $32,139.40 ($66,957.08).

5. Conclusion and Discussion

This report empirically examined the impact of the now permanent fuel price reporting scheme on retail fuel prices across Queensland from its inception in December 2018 through to the end of 2020. According to the ARDL model, the scheme generated a small but statistically significant decline in the average daily retail prices of ULP91, PULP and E10 petrol in most regions of Southeast Queensland resulting in annualised consumer surpluses both at the Brisbane

[26] See Explanation 1 in Appendix E.
[27] See Explanation 2 in Appendix E.
[28] See Explanation 3 in Appendix E.
[29] See Explanation 4 (Cairns LGA) and Explanation 5 (Bundaberg LGA) in Appendix E.

LGA ($9,509,205.95) and Southeast Queensland ($12,322,102.72) levels. The corresponding figures for the 25-month period under investigation is $19,810,845.73 and $25,671,047.33 respectively. Savings outside this region are minimal and found only for Cairns LGA and for the E10 petrol variant in Bundaberg LGA. Key to the effective working of the scheme include the need to increase the uptake of consumer utilisation of fuel price information via fuel price apps and to ensure greater competition in the retail fuel market outside of the Southeast Queensland region.

This study also investigated price surges and price leaders in the Greater Brisbane region and recently, the echoing of this phenomenon in other, less urban/regional LGAs. Results intimate that price surges are set by a minimum number of firms who utilise a select few retail stations in what can potentially be characterised as being a well thought-out and considered pricing strategy. Nevertheless, as volume and sales data are unavailable, the impact of price changes on sales (i.e., volumes) remain unknown.

Further research is required in order to enhance our understanding and knowledge of the impact of the scheme on consumer savings, specifically with respect to how the scheme motivates both the timing and volume of fuel purchases. Such studies would require the use of both additional qualitative and quantitative data. The app usage data commissioned by the RACQ is an example of such qualitative data, but other types of surveys, such as those that help to uncover the factors underlying the use of in-house retail services (e.g., convenience stores) would equally be useful. Quantitative data on fuel volumes purchased as well as time of entry to fuel retail stations in relation to peak and off-peak hours traffic flows, and their impact on purchase decisions would also be beneficial. Additional studies that seek to uncover the mechanisms underlying retail fuel price strategies (which create both price surges and price cycles) since the advent of the scheme would also increase awareness with respect to retail behaviour. Finally, the efficacy of the scheme should be consistently re-evaluated whenever new information and data become available, and as such policymakers would need to consider tweaks and alterations to the scheme to maintain its role in ensuring consumers continue to receive savings at the bowser.

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APPENDIX A: Average daily ULP prices for selected LGA regions

Note: Vertical (Y) axis refers to AU$. Red dashed vertical line represents the trial commencement, and the non-broken red vertical line represents the full compliance date.

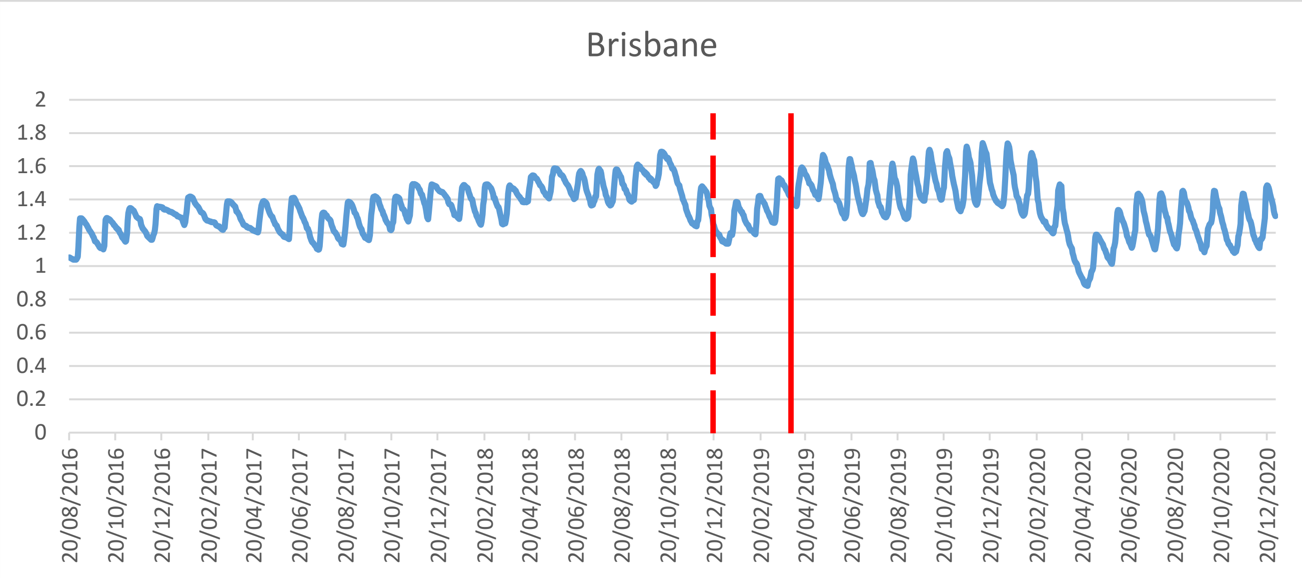

Figure A1: ULP 91 prices for Brisbane LGA.

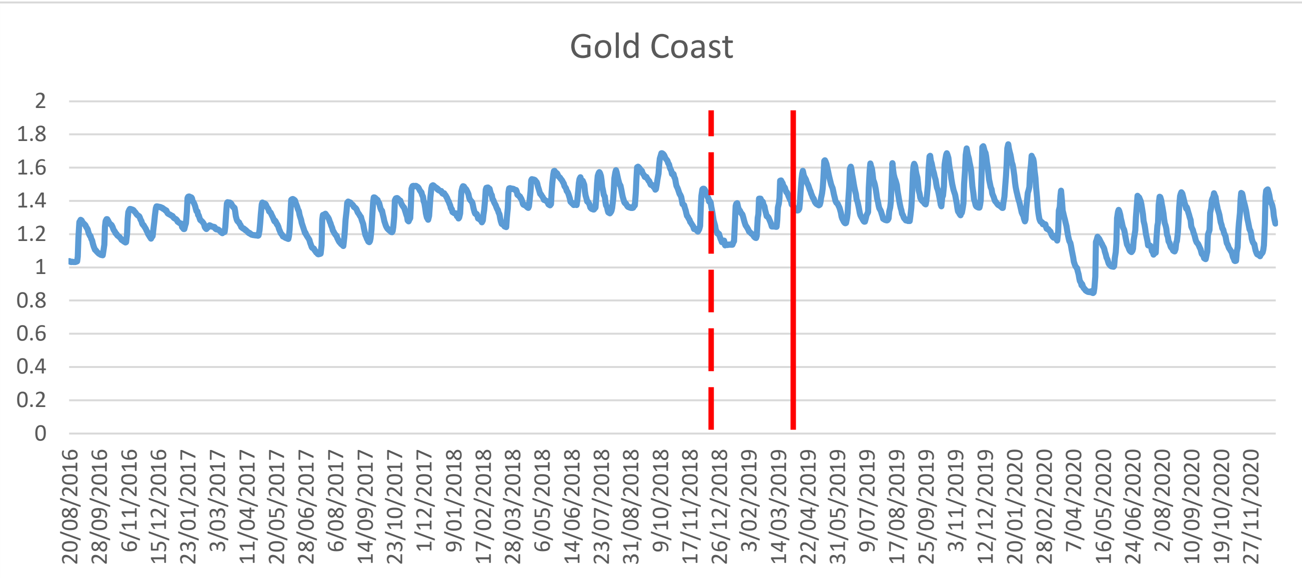

Figure A2: ULP 91 prices for Gold Coast LGA.

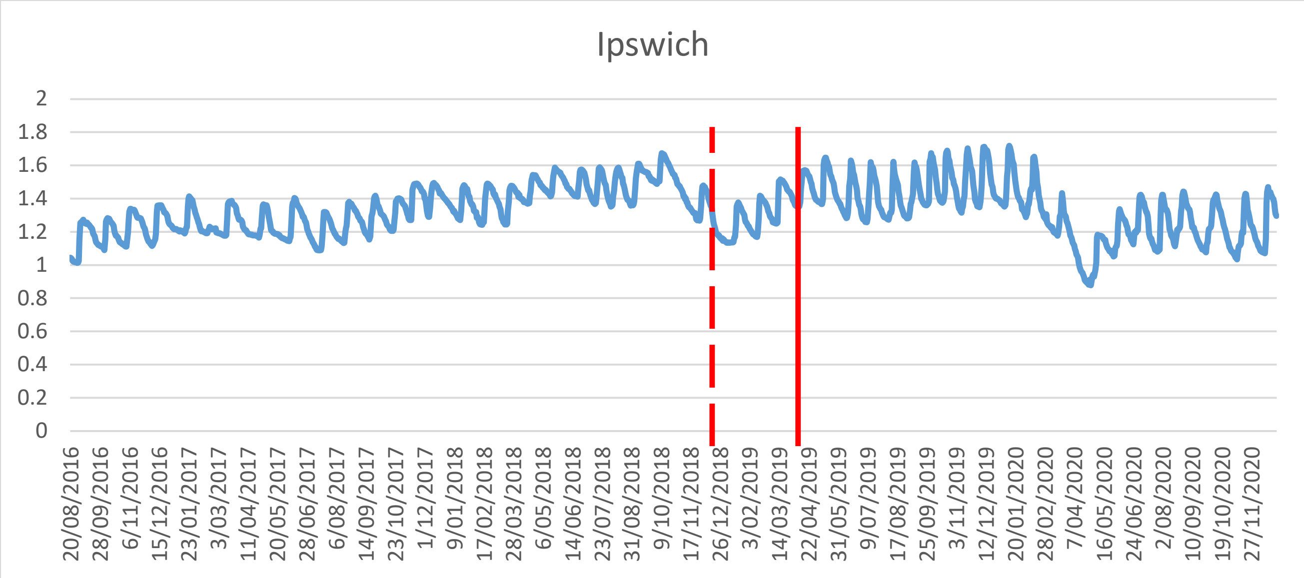

Figure A3: ULP 91 prices for Ipswich LGA.

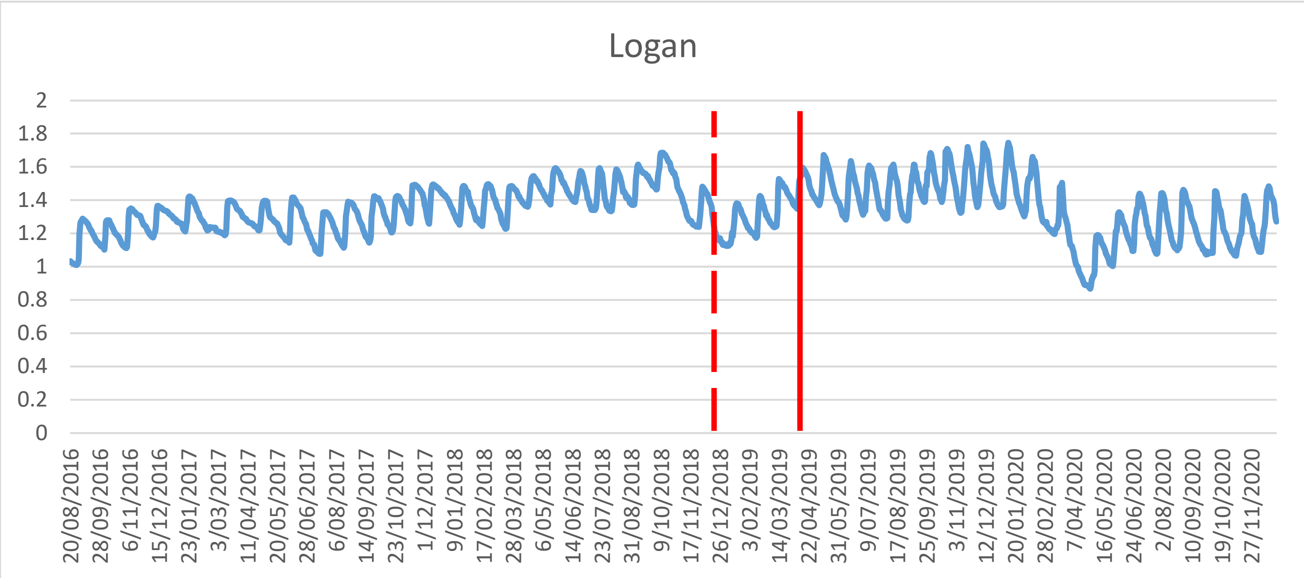

Figure A4: ULP 91 prices for Logan LGA.

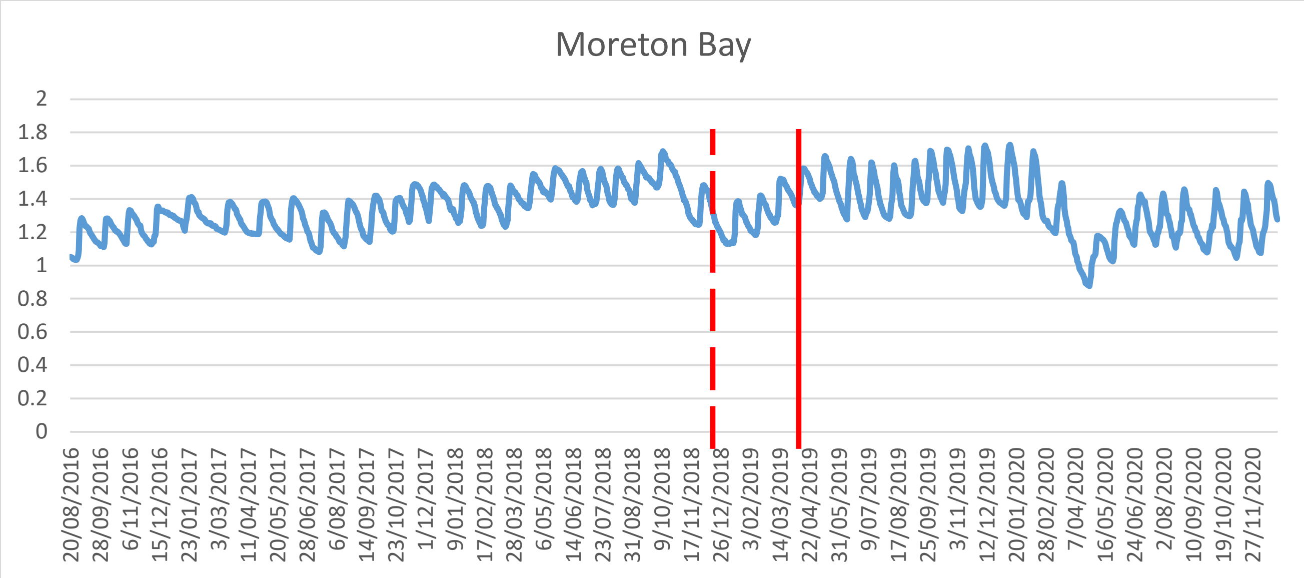

Figure A5: ULP 91 prices for Moreton Bay LGA.

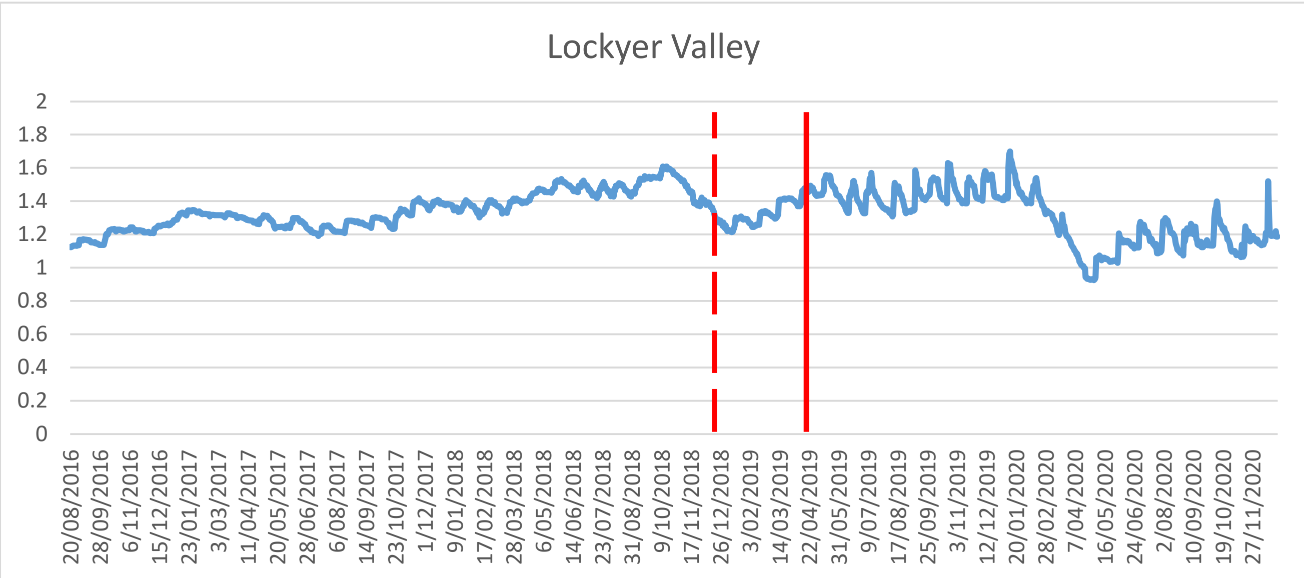

Figure A6: ULP 91 prices for Lockyer Valley LGA.

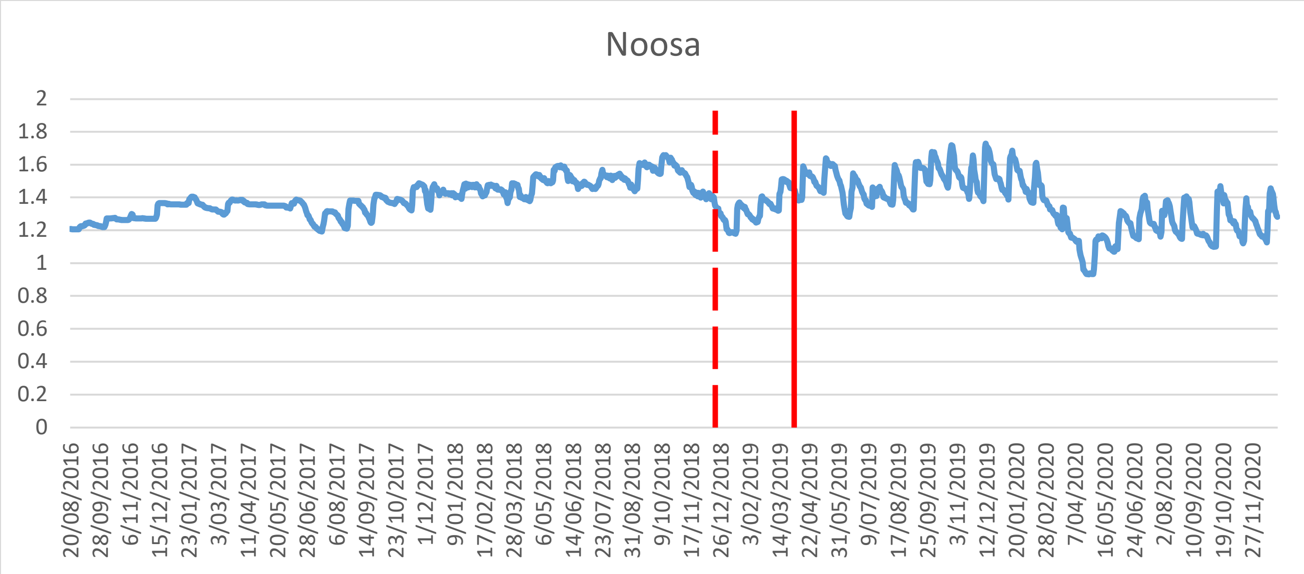

Figure A7: ULP 91 prices for Noosa LGA.

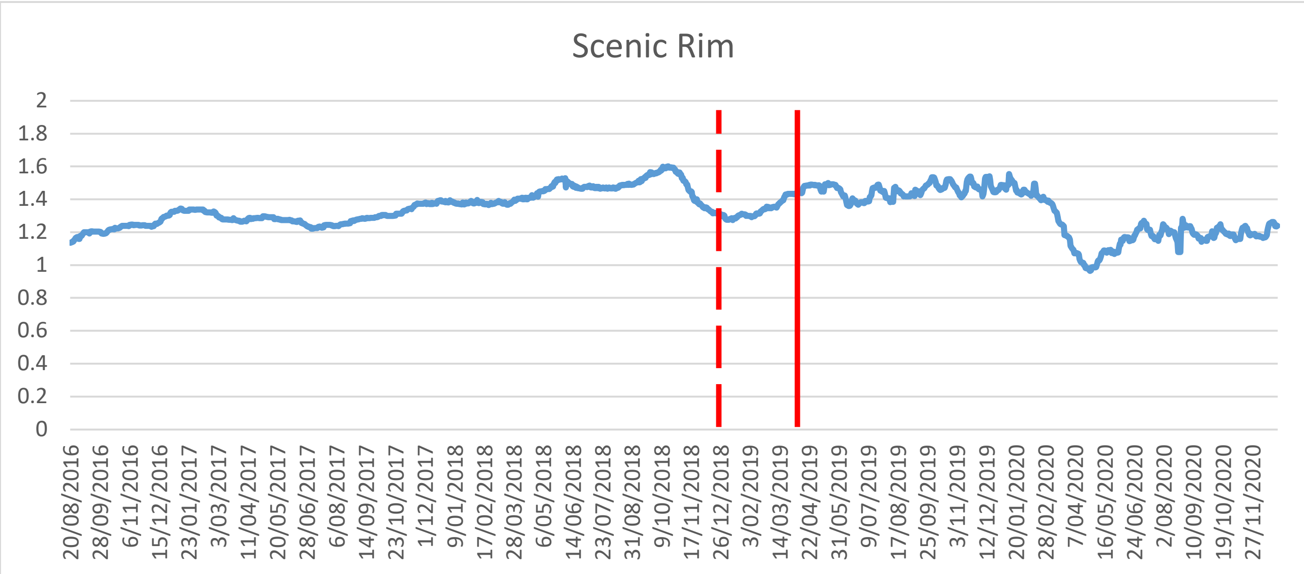

Figure A8: ULP 91 prices for Scenic Rim LGA.

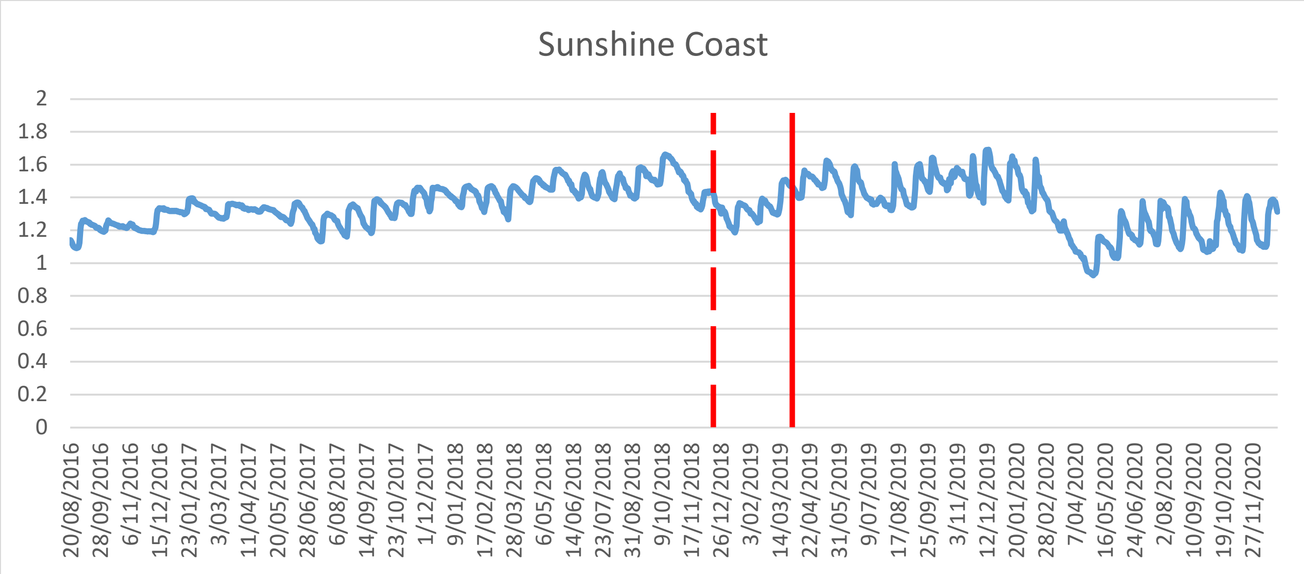

Figure A9: ULP 91 prices for Sunshine Coast LGA.

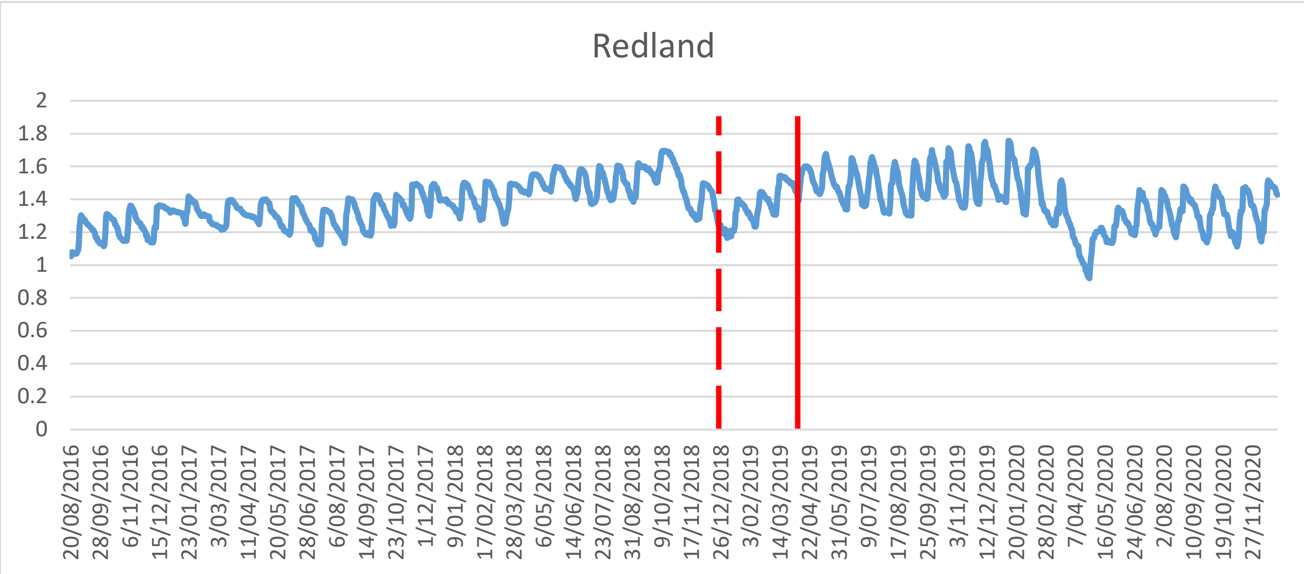

Figure A10: ULP 91 prices for Redland LGA.

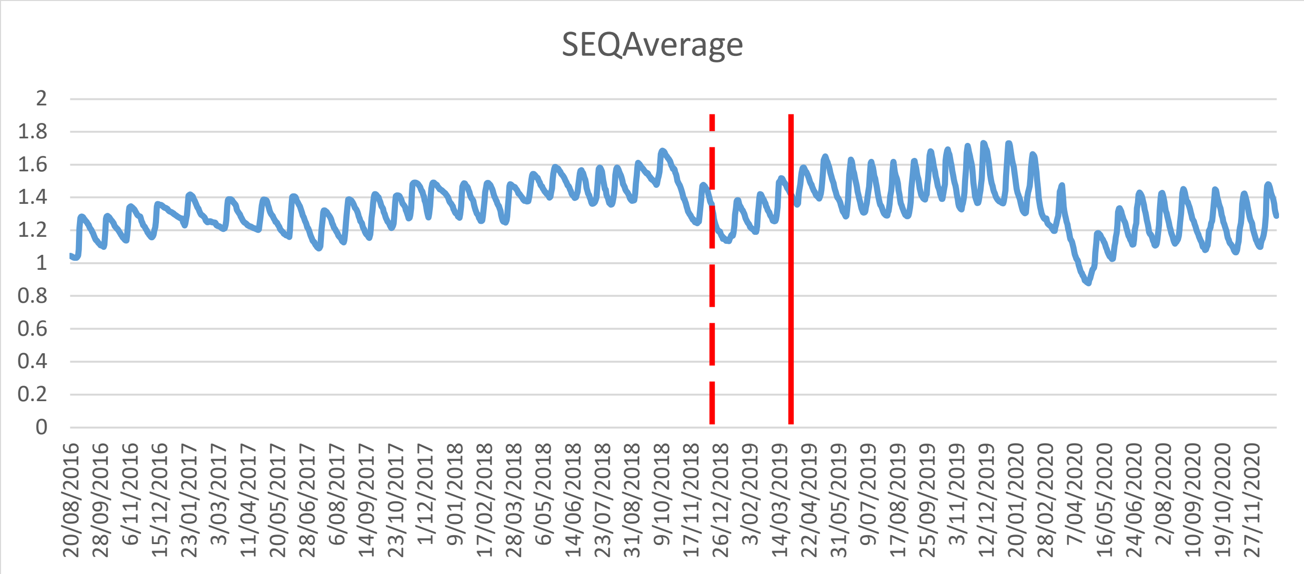

Figure A11: ULP 91 prices for Southeast Queensland LGAs (weighted average).

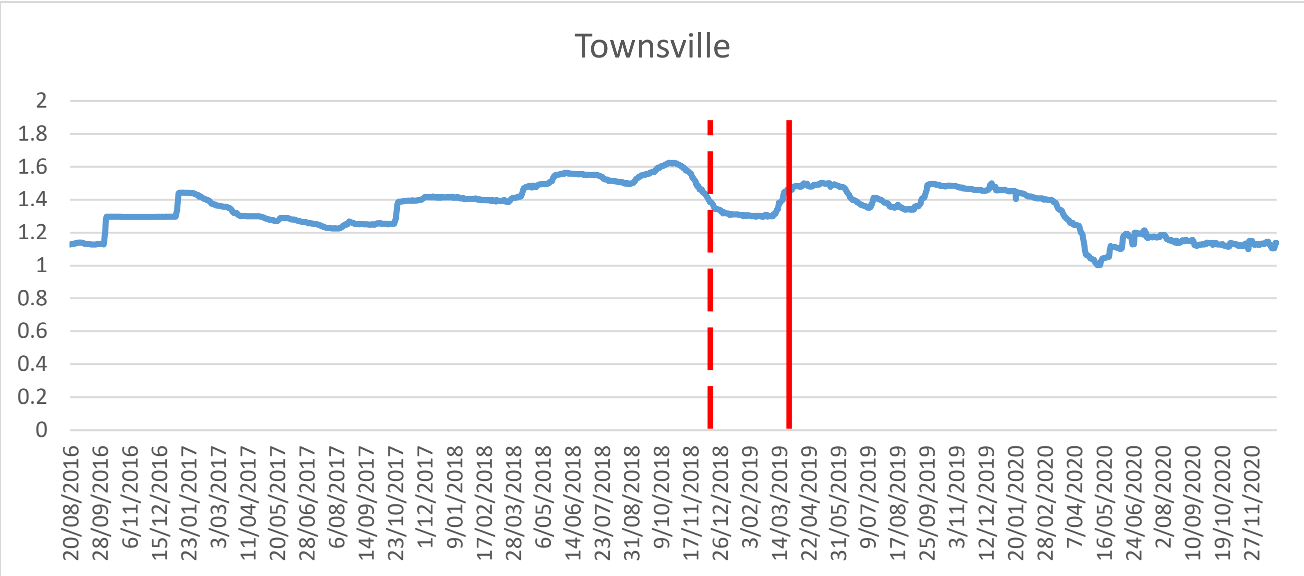

Figure A12: ULP 91 prices for Townsville LGA.

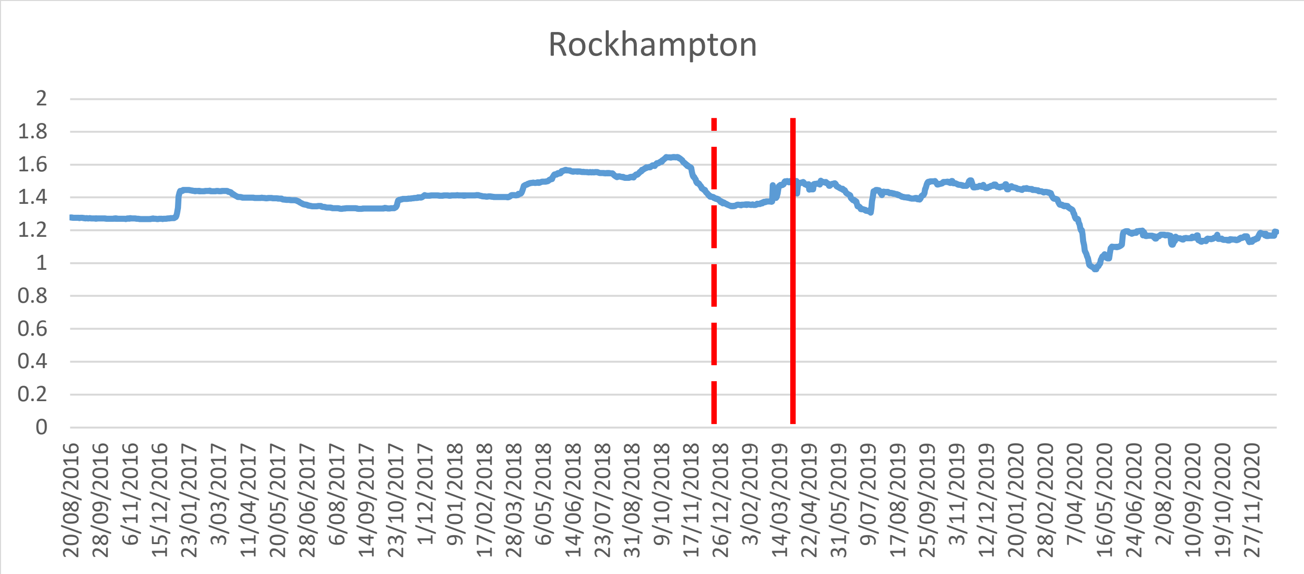

Figure A13: ULP 91 prices for Rockhampton LGA.

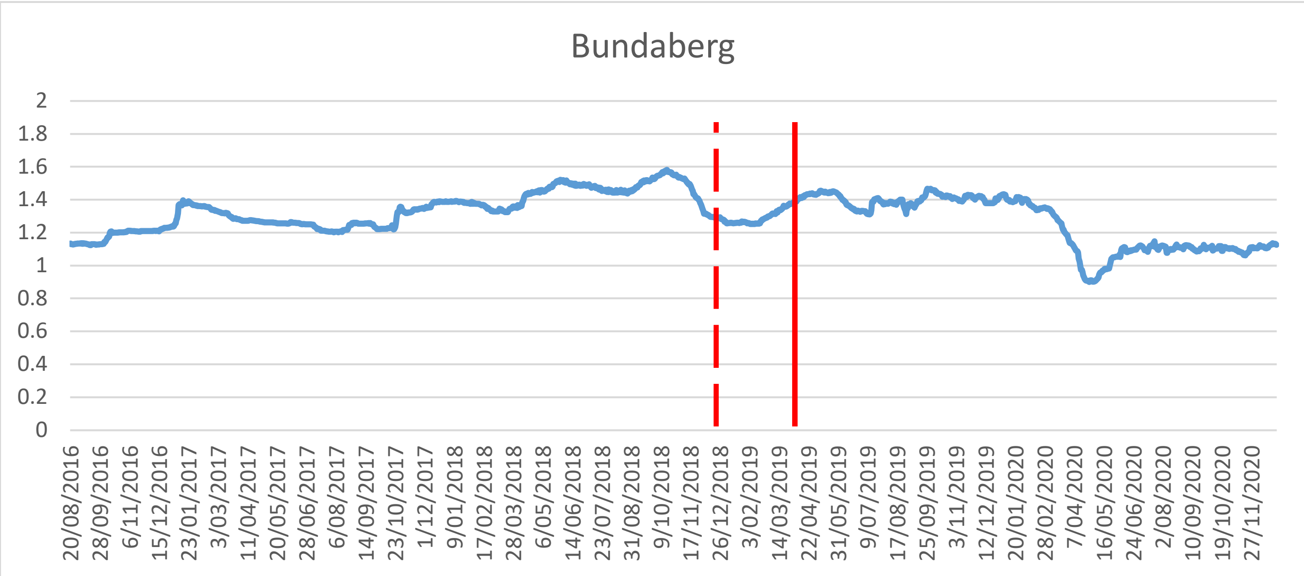

Figure A14: ULP 91 prices for Bundaberg LGA.

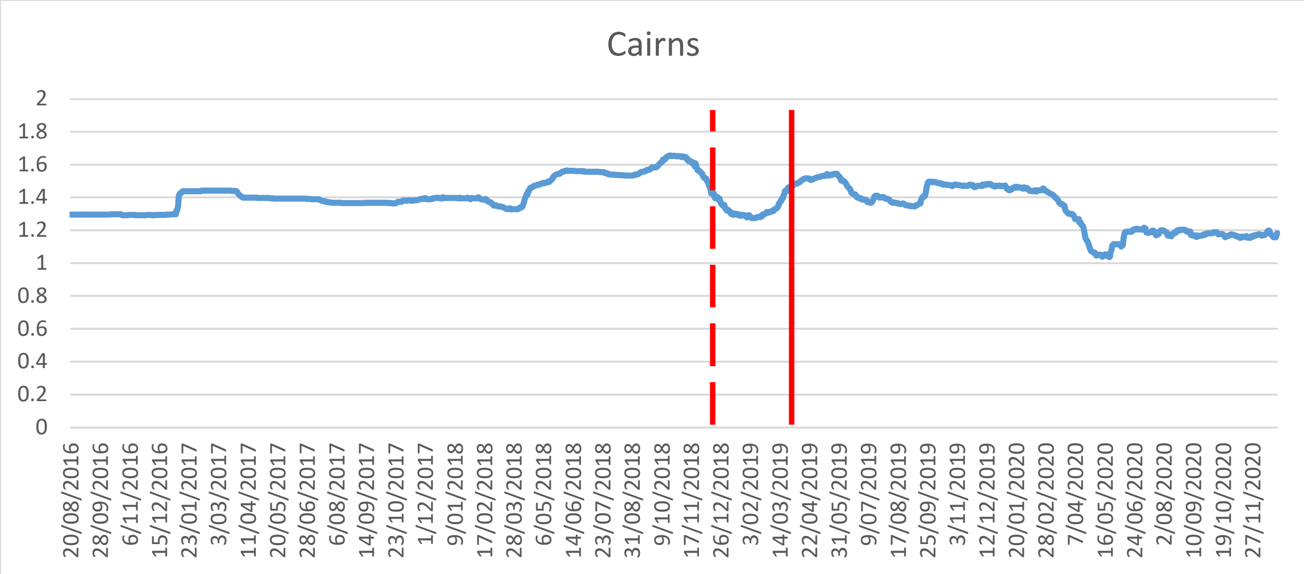

Figure A15: ULP 91 prices for Cairns LGA.

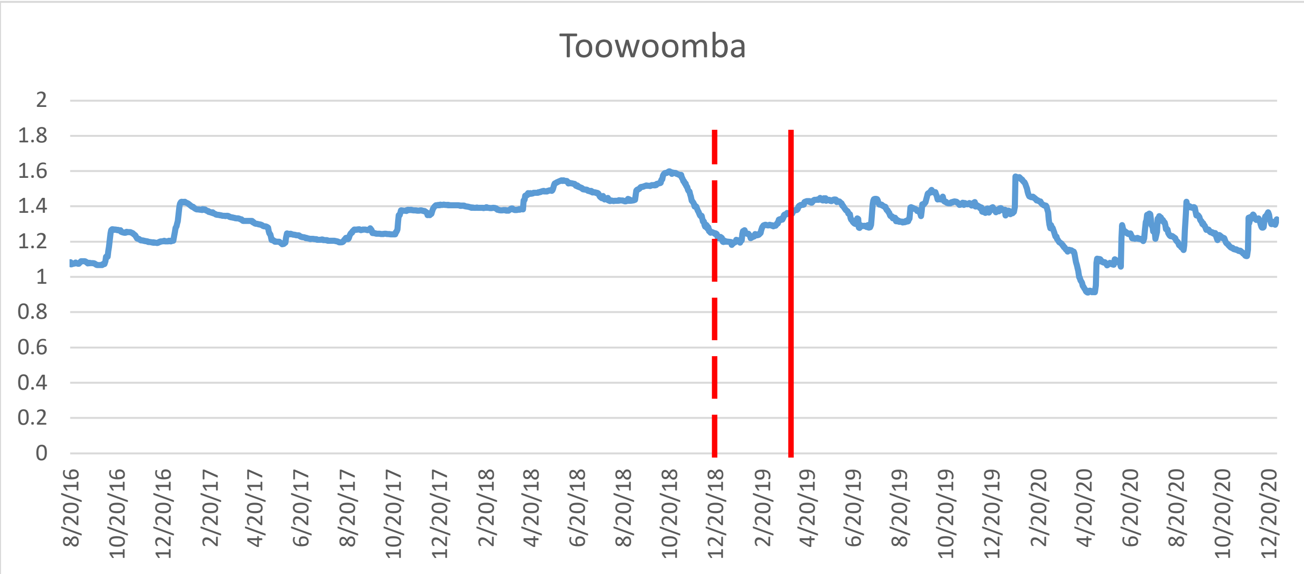

Figure A16: ULP 91 prices for Toowoomba LGA.

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APPENDIX B: Trends in Price Dispersion across selected regions.

LGA level figures for ULP 91. Vertical (Y) axis refers to daily standard deviation in ULP 91 prices per region.

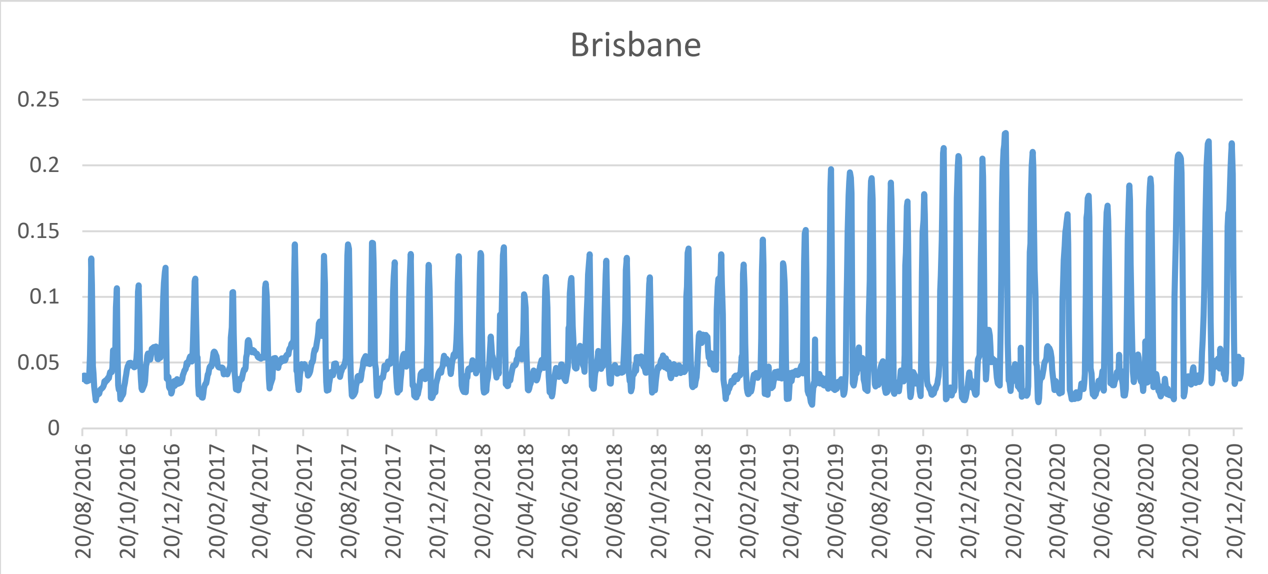

Figure B1: Standard deviation of daily prices for Brisbane LGA

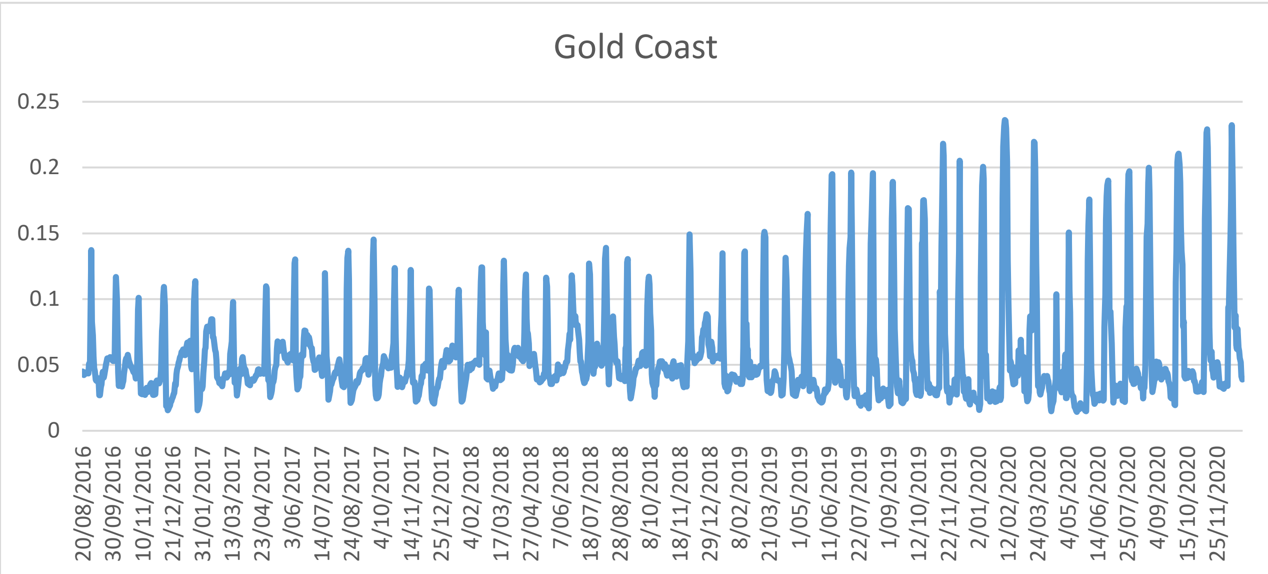

Figure B2: Standard deviation of daily prices for Gold Coast LGA

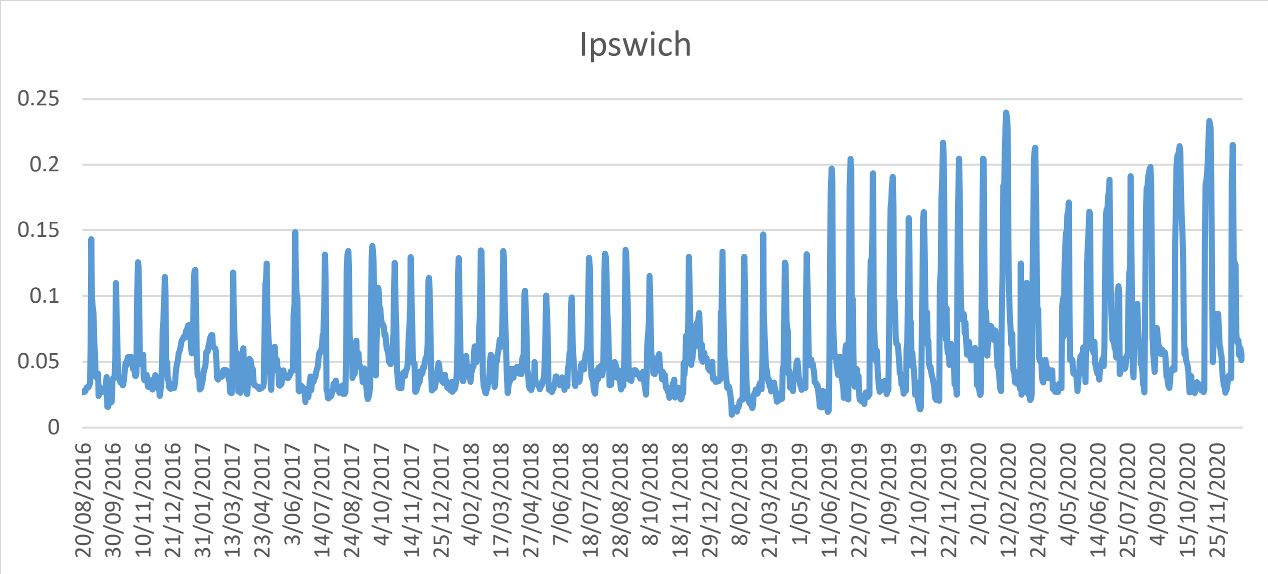

Figure B3: Standard deviation of daily prices for Ipswich LGA

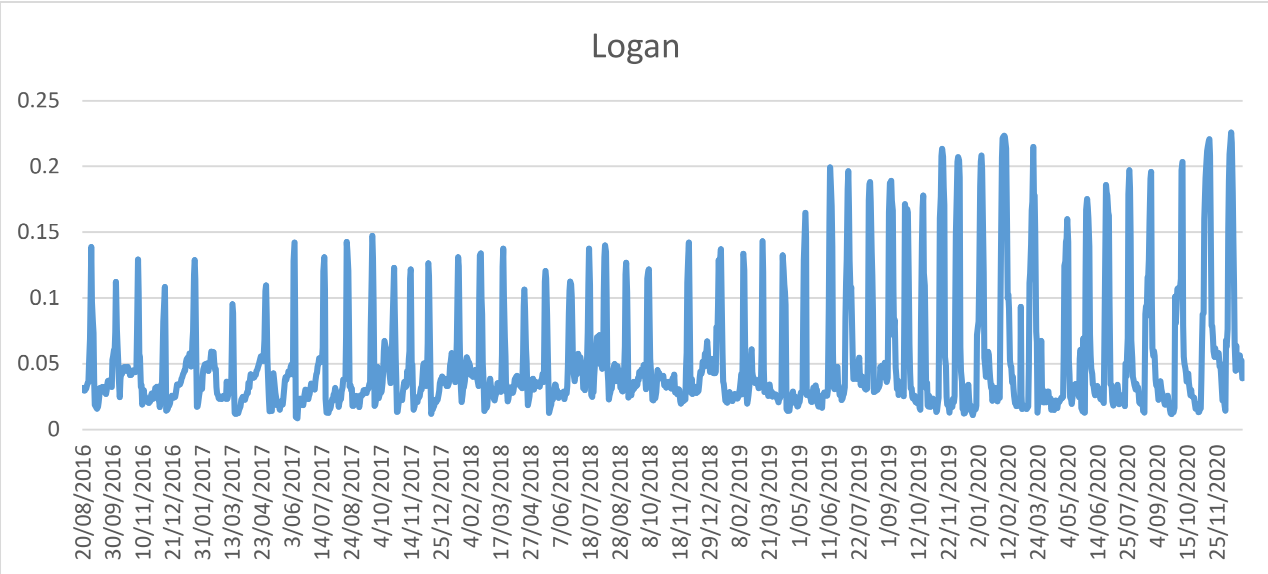

Figure B4: Standard deviation of daily prices for Logan LGA

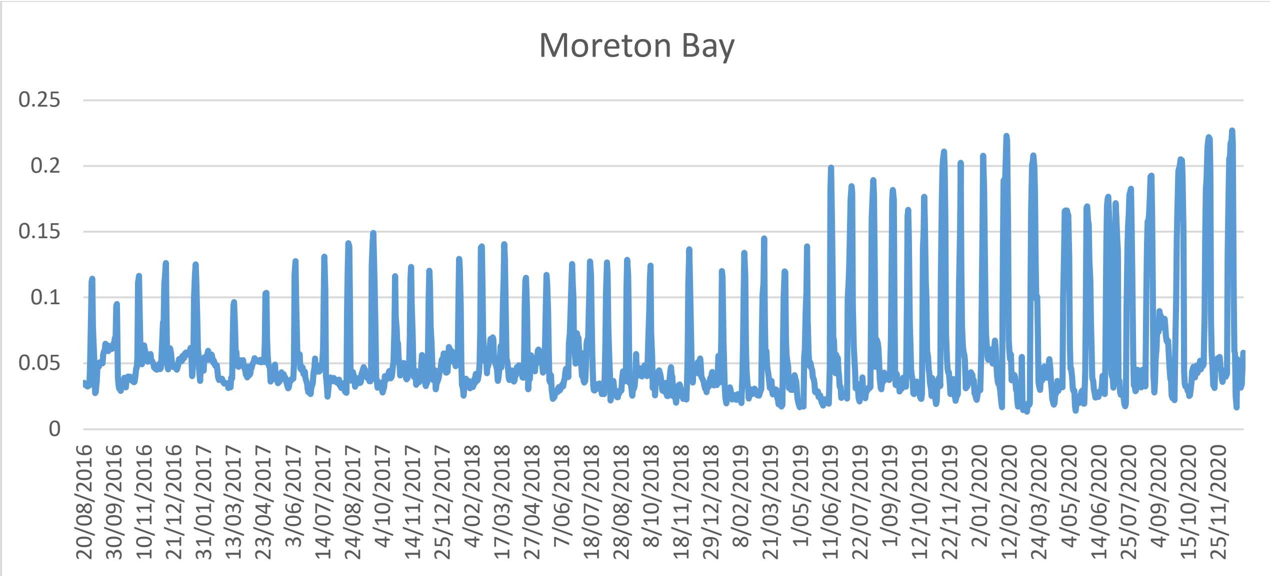

Figure B5: Standard deviation of daily prices for Moreton Bay LGA

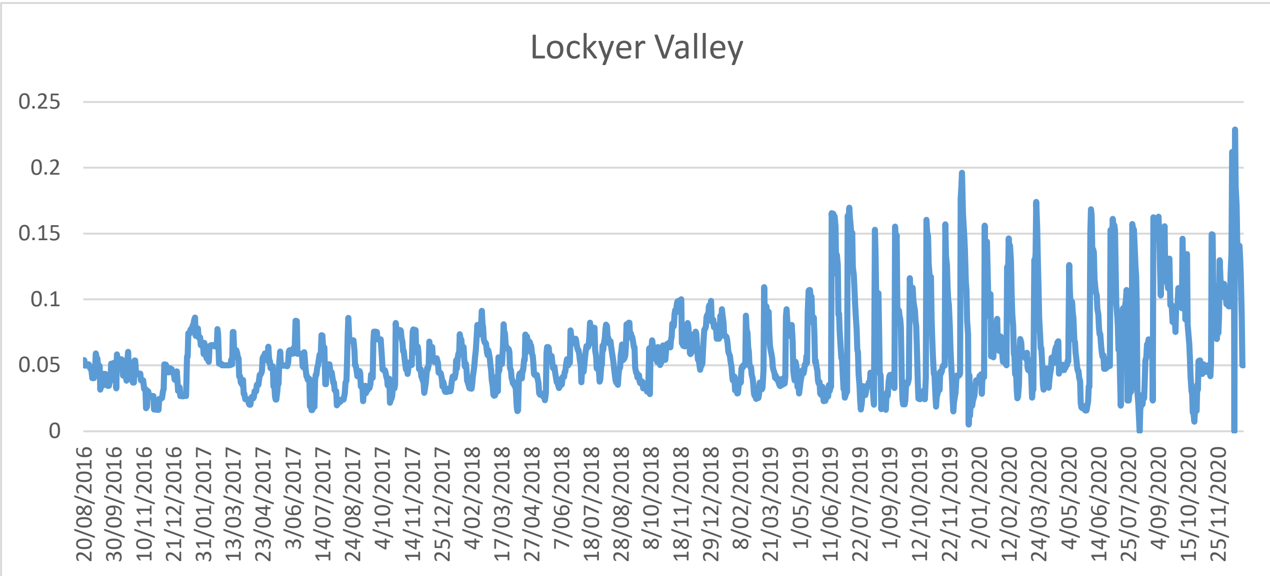

Figure B6: Standard deviation of daily prices for Lockyer Valley LGA

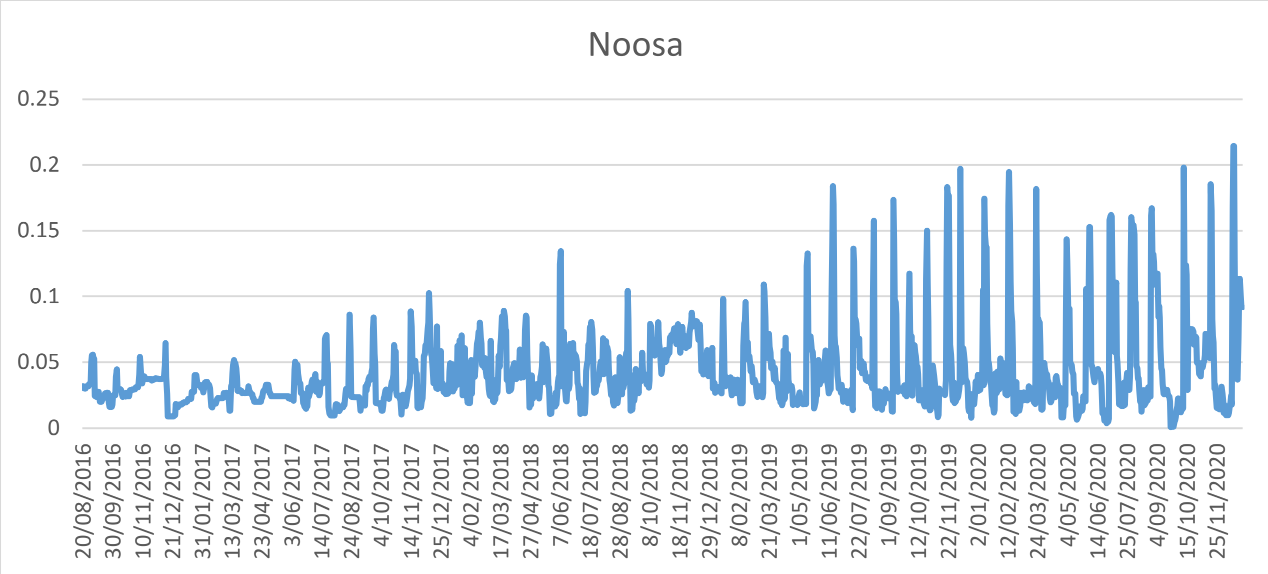

Figure B7: Standard deviation of daily prices for Noosa LGA

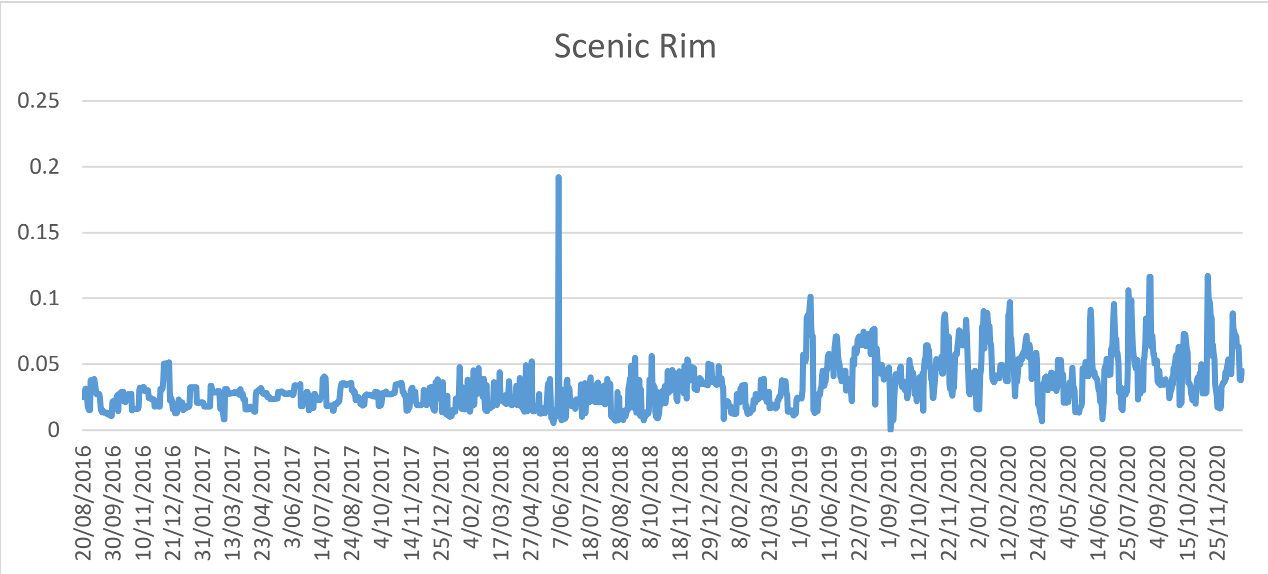

Figure B8: Standard deviation of daily prices for Scenic Rim LGA

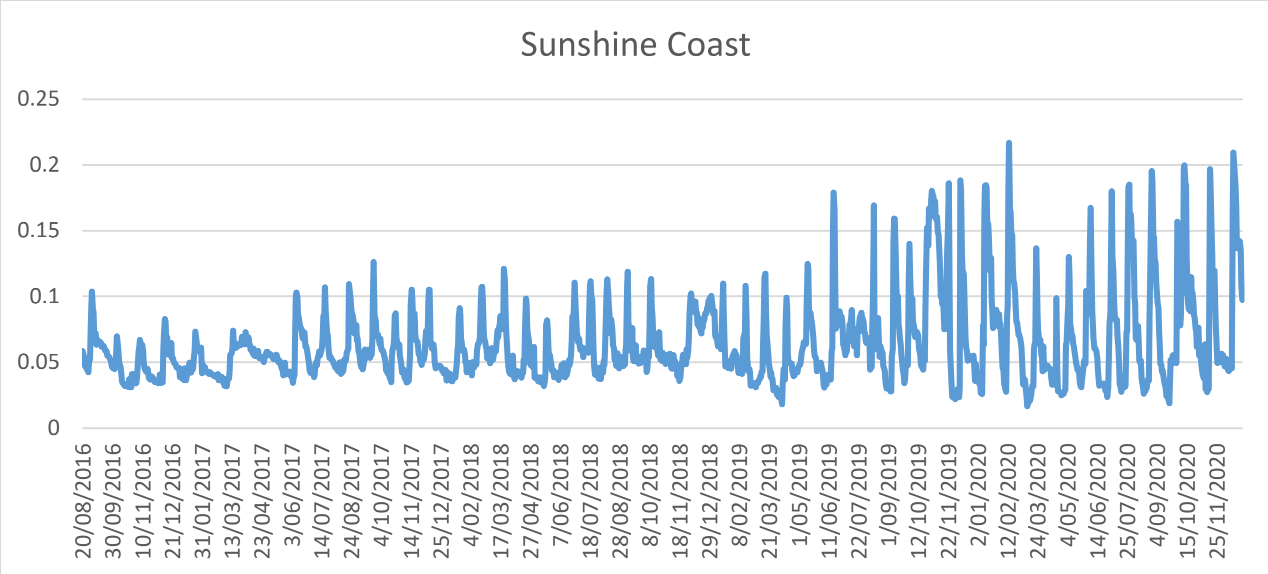

Figure B9: Standard deviation of daily prices for Sunshine Coast LGA

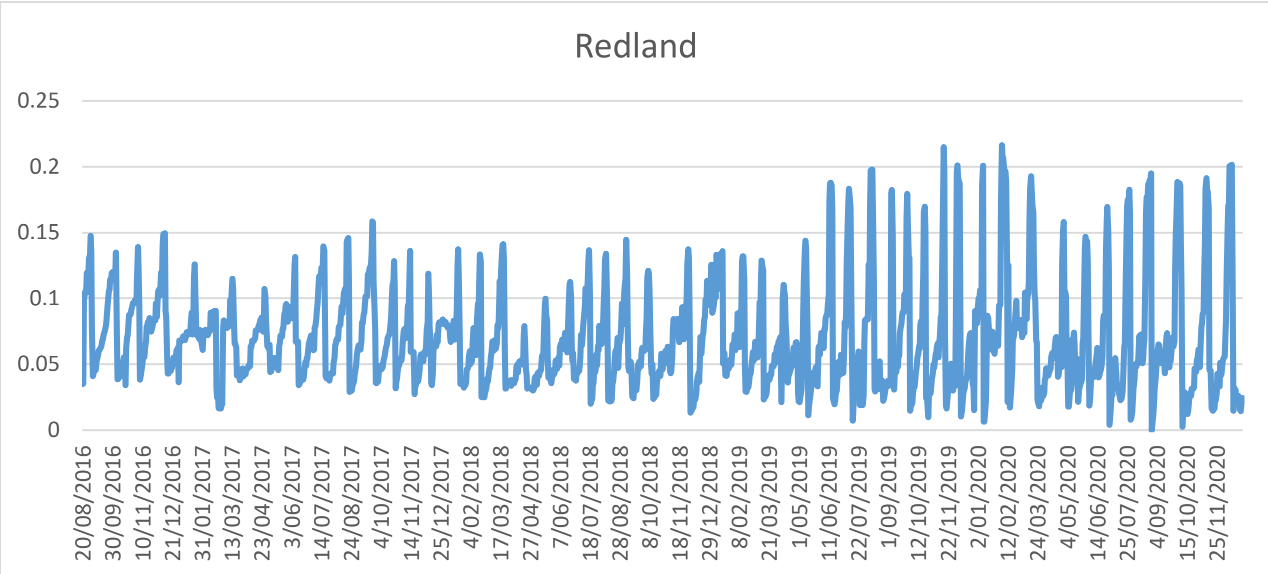

Figure B10: Standard deviation of daily prices for Redland LGA

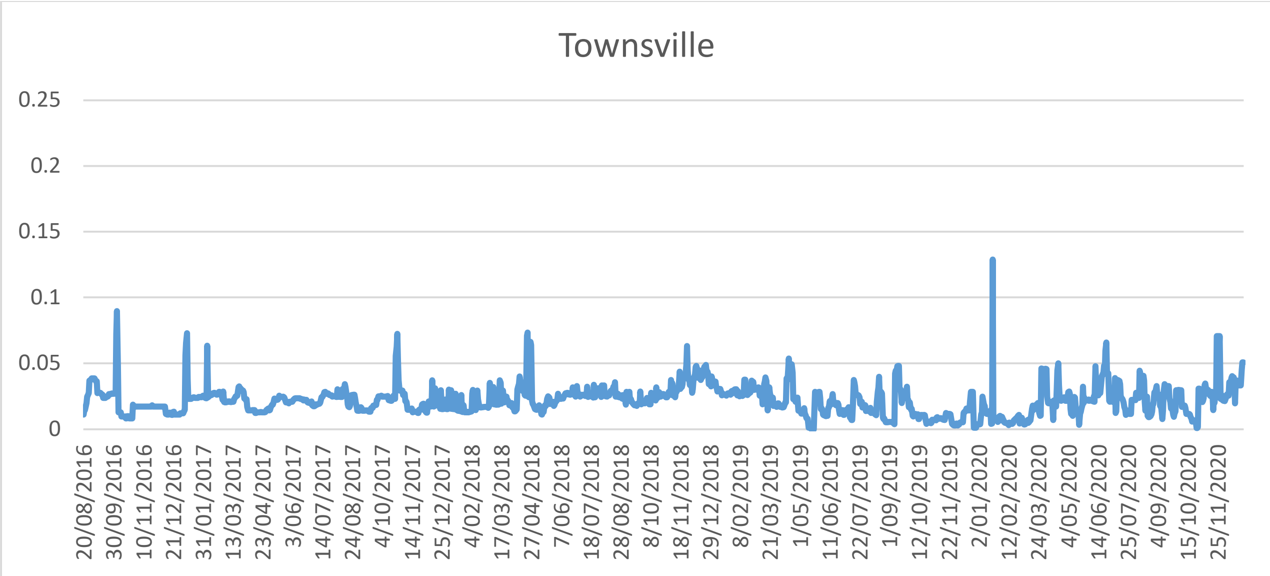

Figure B11: Standard deviation of daily prices for Townsville LGA

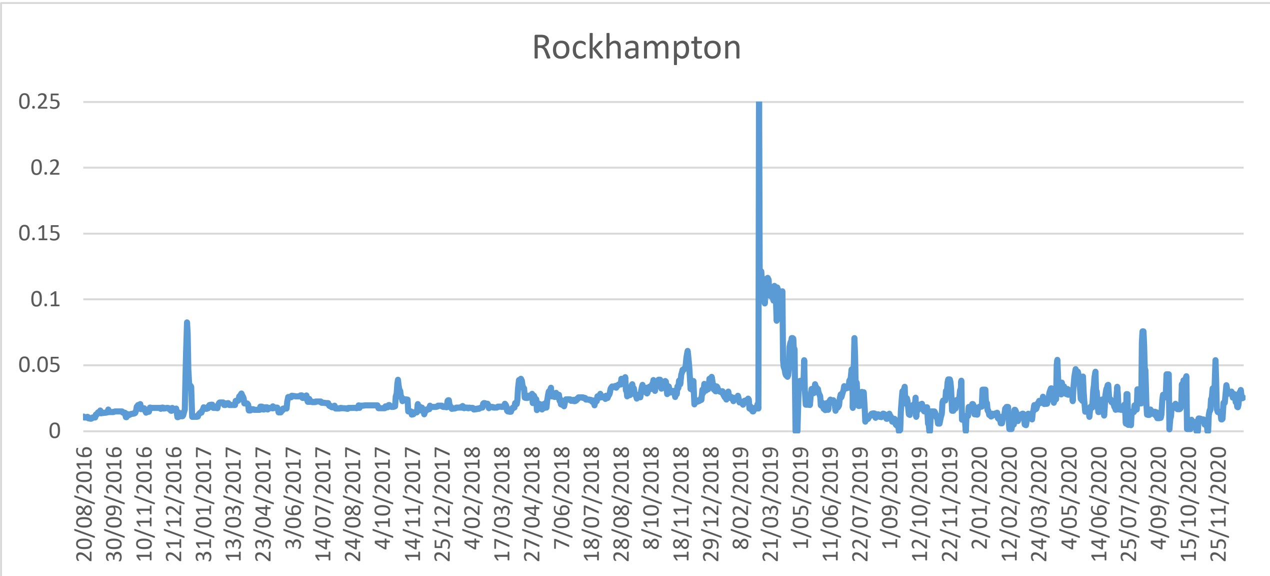

Figure B12: Standard deviation of daily prices for Rockhampton LGA

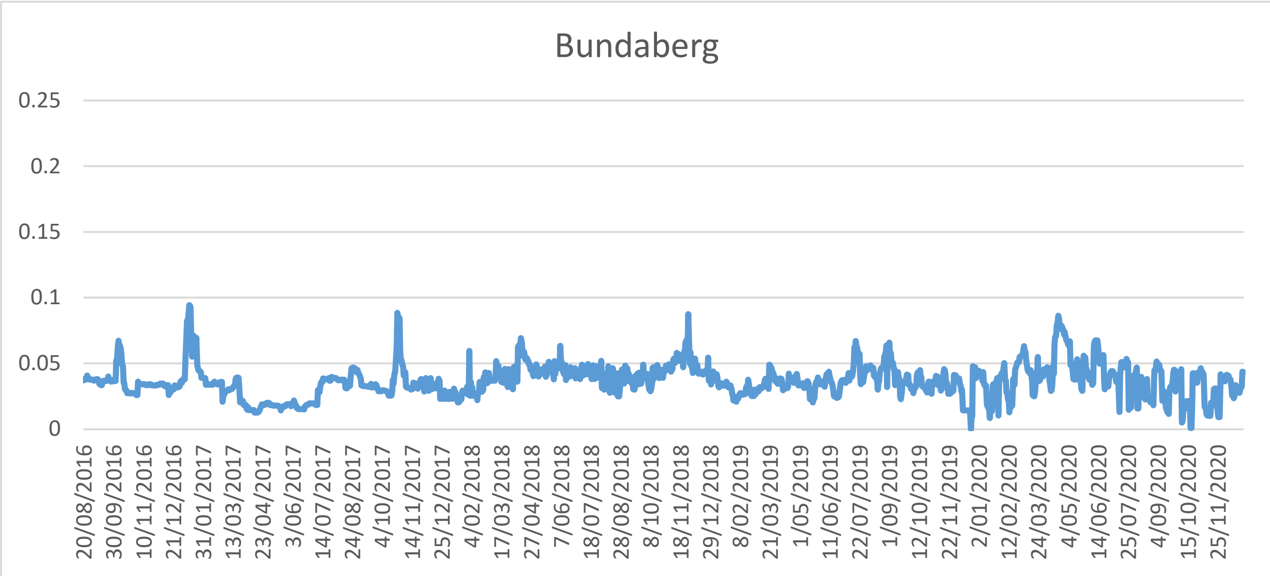

Figure B13: Standard deviation of daily prices for Bundaberg LGA

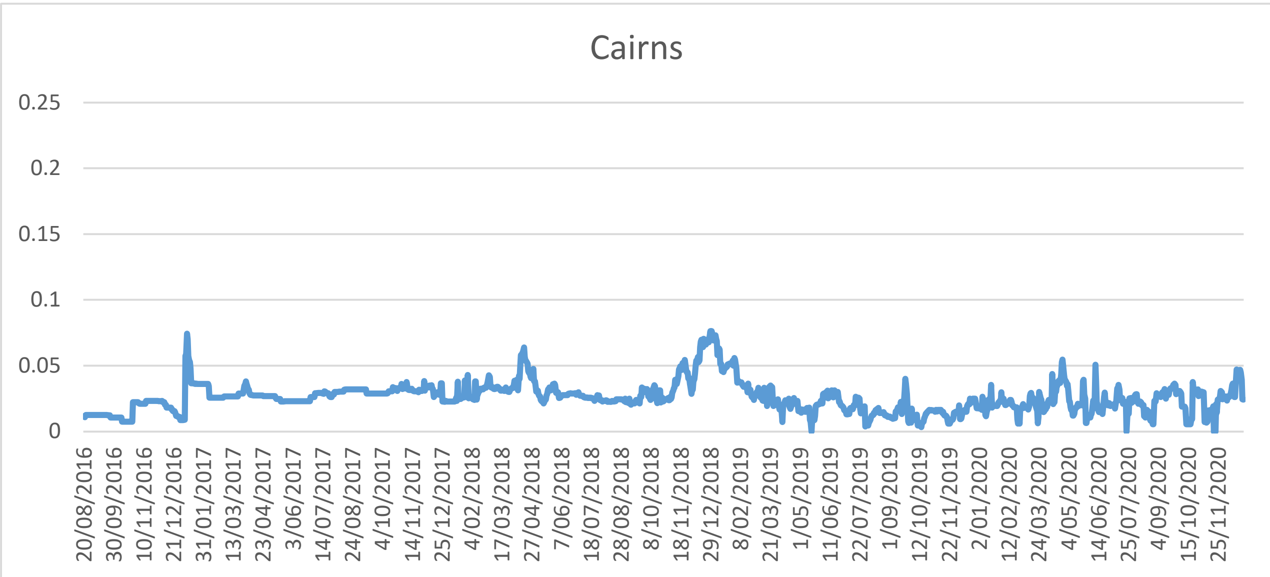

Figure B14: Standard deviation of daily prices for Cairns LGA

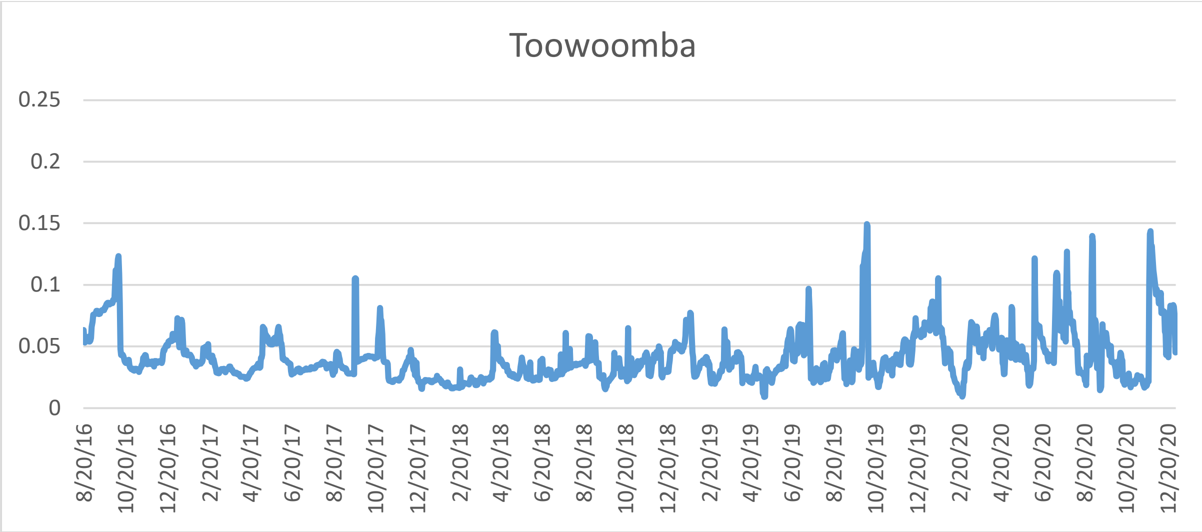

Figure B15: Standard deviation of daily prices for Toowoomba LGA

APPENDIX C: ARDL Model Results

Table C1: ULP 91 Results. ** and * refer to 5% and 10% levels of significance respectively.

LGA	Independent variable: Brent Price (with dummies)			
	Selected ARDL model using BIC	Existence of co-integration F statistic [95% interval]	Coefficient of dummy variable [P-value]	Policy effect
SEQ LGAs				
Brisbane	ARDL (2,0)	86.0176 [14.6254, 15.1320]	-.0044004** [.046]	Significant reduction in prices at 5% l.o.s
Gold Coast	ARDL (3,0)	79.6612 [14.6254, 15.1320]	-.0057085** [.047]	Significant reduction in prices at 5% l.o.s
Ipswich	ARDL (3,0)	68.2709 [14.6254, 15.1320]	-.007764** [.020]	Significant reduction in prices at 5% l.o.s
Logan	ARDL (2,0)	75.5014 [14.6254, 15.1320]	-.0052660* [.063]	Significant reduction in prices at 10% l.o.s
Moreton Bay	ARDL (2,0)	74.6909 [14.6254, 15.1320]	-.0060927** [.022]	Significant reduction in prices at 5% l.o.s
Lockyer Valley	ARDL (2,0)	46.8384 [14.6254, 15.1320]	-.0056674* [.074]	Significant reduction in prices at 10% l.o.s
Noosa	ARDL (2,0)	60.3190 [14.6254, 15.1320]	-.0019558** [.008]	Significant reduction in prices at 5% l.o.s
Scenic Rim	ARDL (3,0)	48.6944 [14.6254, 15.1320]	-.0010655 [.160]	
Sunshine Coast	ARDL (2,0)	72.0829 [14.6254, 15.1320]	-.0038527 [.136]	
Redland	ARDL (3,1)	66.3414 [14.6254, 15.1320]	-.0070212** [.025]	Significant reduction in prices at 5% l.o.s
Average	ARDL (2,0)	102.8583 [14.6254, 15.1320]	-.0045447** [.018]	Significant reduction in prices at 5% l.o.s
Other LGAs				
Townsville	ARDL (3,0)	35.5456 [14.6254, 15.1320]	-.2209E-3 [.814]	
Rockhampton	ARDL (3,0)	38.4134 [14.6254, 15.1320]	.1067E-3 [.913]	
Bundaberg	ARDL (3,0)	47.7564 [14.6254, 15.1320]	-.4633E-3 [.630]	
Cairns	ARDL (3,0)	38.5347 [14.6254, 15.1320]	-.0011321* [.095]	Significant reduction in prices at 10 % l.o.s

Table C2: PULP Results. ** and * refer to 5% and 10% levels of significance respectively.

LGA	Independent variable: Brent Price (with dummies)			
	Selected ARDL model using BIC	Existence of co-integration F statistic [95% interval]	Coefficient of dummy variable [P-value]	Policy effect
SEQ LGAs				
Brisbane	ARDL (3,0)	85.8957 [14.6254, 15.1320]	-.0045994** [.036]	Significant reduction in prices at 5% l.o.s
Gold Coast	ARDL (3,0)	79.6823 [14.6254, 15.1320]	-.0056728** [.042]	Significant reduction in prices at 5% l.o.s
Ipswich	ARDL (3,0)	71.2221 [14.6254, 15.1320]	-.0077891** [.013]	Significant reduction in prices at 5% l.o.s
Logan	ARDL (3,0)	74.4577 [14.6254, 15.1320]	-.0051823* [.069]	Significant reduction in prices at 10% l.o.s
Moreton Bay	ARDL (3,0)	72.5023 [14.6254, 15.1320]	-.0061819** [.020]	Significant reduction in prices at 5% l.o.s
Lockyer Valley	ARDL (1,0)	44.9013 [14.6254, 15.1320]	-.0065250* [.065]	Significant reduction in prices at 10% l.o.s
Noosa	ARDL (3,0)	60.0578 [14.6254, 15.1320]	-.0081230** [.004]	Significant reduction in prices at 5% l.o.s
Scenic Rim	ARDL (2,1)	49.9459 [14.6254, 15.1320]	-.0023338 [.153]	
Sunshine Coast	ARDL (3,0)	71.2916 [14.6254, 15.1320]	-.0042923* [.090]	Significant reduction in prices at 10% l.o.s
Redland	ARDL (3,0)	61.3801 [14.6254, 15.1320]	-.0061309** [.044]	Significant reduction in prices at 5% l.o.s.
Average	ARDL(3,0)	89.4752 [14.6254, 15.1320]	-.0045602** [.018]	Significant reduction in prices at 5% l.o.s
Other LGAs				
Townsville	ARDL (3,0)	35.1425 [14.6254, 15.1320]	-.4433E-3 [.660]	
Rockhampton	ARDL (3,0)	35.0264 [14.6254, 15.1320]	-.7967E-4 [.949]	
Bundaberg	ARDL (1,0)	35.9523 [14.6254, 15.1320]	-.0013558 [.394]	
Cairns	ARDL (3,0)	40.9435 [14.6254, 15.1320]	-.0018124** [.051]	Significant reduction in prices at 5% l.o.s.

Table C3: E10 Results. ** and * refer to 5% and 10% levels of significance respectively.

LGA	Independent variable: Brent Price (with dummies)			
	Selected ARDL model using BIC	Existence of co-integration F statistic [95% interval]	Coefficient of dummy variable [P-value]	Policy effect
SEQ LGAs				
Brisbane	ARDL (3,0)	67.3025 [14.6254, 15.1320]	-.0082718 ** [.019]	Significant reduction in prices at 5% l.o.s
Gold Coast	ARDL (3,0)	76.9117 [14.6254, 15.1320]	-.0058164 * [.055]	Significant reduction in prices at 10% l.o.s
Ipswich	ARDL (3,0)	71.7901 [14.6254, 15.1320]	-.0066926** [.022]	Significant reduction in prices at 5% l.o.s
Logan	ARDL (3,0)	52.8129 [14.6254, 15.1320]	-.0078798** [.049]	Significant reduction in prices at 5% l.o.s
Moreton Bay	ARDL (2,0)	57.7770 [14.6254, 15.1320]	-.011247** [.006]	Significant reduction in prices at 5% l.o.s
Lockyer Valley	ARDL (2,0)	49.6283 [14.6254, 15.1320]	-.0059230 * [.054]	Significant reduction in prices at 10% l.o.s
Noosa	ARDL (2,0)	70.5040 [14.6254, 15.1320]	-.0043985 [0.138]	
Scenic Rim	ARDL (3,1)	71.8653 [14.6254, 15.1320]	-.0077550** [0.018]	Significant reduction in prices at 5% l.o.s
Sunshine Coast	ARDL (3,0)	29.8739 [14.6254, 15.1320]	-.1932E-3 [.878]	
Redland	ARDL (2,0)	38.8075 [14.6254, 15.1320]	.2617E-3 [.817]	Significant reduction in prices at 5% l.o.s
Average	ARDL (3,0)	83.3226 [14.6254, 15.1320]	-.0050349** [.036]	Significant reduction in prices at 5% l.o.s
Other LGAs				
Townsville	ARDL (2,0)	37.3435 [14.6254, 15.1320]	-.6245E-3 [.633]	
Rockhampton	ARDL (3,0)	36.3310 [14.6254, 15.1320]	-.0013843 [.176]	
Bundaberg	ARDL (2,0)	96.7680 [14.6254, 15.1320]	-.0047719 ** [.020]	Significant reduction in prices at 5% l.o.s
Cairns	ARDL (2,0)	82.8098 [14.6254, 15.1320]	-.0038480 ** [.020]	Significant reduction in prices at 5% l.o.s

Table C4: Diesel Results. ** and * refer to 5% and 10% levels of significance respectively.

LGA	Independent variable: Brent Price (with dummies)			
	Selected ARDL model using BIC	Existence of co-integration F statistic [95% interval]	Coefficient of dummy variable [P-value]	Policy effect
SEQ LGAs				
Brisbane	ARDL (3,0)	58.7880 [13.8688, 14.4201]	.1881E-3 [.723]	
Gold Coast	ARDL (1,0)	55.0404 [13.8688, 14.4201]	.4941E-3 [.450]	
Ipswich	ARDL (3,0)	42.9851 [13.8688, 14.4201]	.8393E-3 [.329]	
Logan	ARDL (1,0)	48.5212 [13.8688, 14.4201]	.7155E-4 [.922]	
Moreton Bay	ARDL (2,0)	48.2950 [13.8688, 14.4201]	.2707E-3 [.697]	
Lockyer Valley	ARDL (2,0)	50.4557 [13.8688, 14.4201]	.4680E-5 [.995]	
Noosa	ARDL (2,0)	62.0415 [13.8688, 14.4201]	-.3107E-3 [.676]	
Scenic Rim	ARDL (2,0)	55.3010 [13.8688, 14.4201]	-.3968E-3 [.623]	
Sunshine Coast	ARDL (2,0)	52.4949 [13.8688, 14.4201]	-.4955E-3 [.495]	
Redland	ARDL (3,0)	28.0338 [13.8688, 14.4201]	-.0016640 [.481]	
Average	ARDL (3,0)	63.5617 [12.5407, 13.0825]	.3126E-3 [.507]	
Other LGAs				
Townsville	ARDL (2,0)	39.2838 [13.8688, 14.4201]	.8787E-3 [.291]	
Rockhampton	ARDL (3,0)	47.8788 [13.8688, 14.4201]	.0010310 [.260]	
Bundaberg	ARDL (2,0)	49.7401 [13.8688, 14.4201]	.3866E-3 [.609]	
Cairns	ARDL (2,0)	34.0200 [13.8688, 14.4201]	-.8134E-3 [.360]	

APPENDIX D: Savings from Greater Price Dispersion: Method

Daily price minimums and maximums per area of interest was identified and the mean was subsequently estimated. A visual inspection of minimum and maximum curves allowed for the removal of unrealistic low and high price points (outliers) that could have arisen out of input errors. In the case of missing observations, an assumption was made that in time periods where no price changes were reported, the price remained unchanged from the last reported price change. These removals were validated by investigating the length of time these prices remained unchanged, and in all cases, they occurred within a 2-hour window. This resulted in the removal of 15 price points.

An average unleaded petrol passenger vehicle in Southeast Queensland uses 1123.5 litres per annum (see Section 4.4 on the sourcing of this figure). For 2020 (with 366 days) that results in 3.07 litres being used per day. Daily simulations were executed using this amount of fuel at minimal, mean and maximal price point.

Realistic savings was calculated by subtracting this average mean yearly fuel expenditure with average minimums yearly fuel expenditure. If we would subtract the minimums from the maximums the potential savings are roughly double of the realistic savings.

APPENDIX E: Consumer Surplus Calculations and Explanations

Explanation 1

The ABS (2019) reports total distance travelled within Brisbane using passenger vehicles at 15,490,000,000 kilometres. Approximately 80.75% of passenger vehicles in Queensland use petrol as opposed to diesel, LNG and hybrid fuels (information obtained from Table 5 of Cat. No. 9208.0). Thus, total kilometres for petrol driven passenger vehicles in Brisbane is 15,490,000,000*0.8075 = 12,508,175,000 kilometres.

Given this information and the volume breakdown of petrol types provided by the DEPW[30] we estimate total kilometres travelled for ULP users to be 12,508,175,000*0.5536 = 6,924,525,680. For PULP, this would be 12,508,175,000*0.2679 = 3,350,940,082.5 kilometres and 12,508,175,000*0.1785 = 2,232,709,237.5 for E10 users.

This would yield a total consumer surplus of $9,509,205.95, consisting of 6,924,525,680*0.107*0.0059 = $4,371,453.06 for ULP users, 3,350,940,082.5 *0.107*0.0070 = $2,509,854.12 for PULP users and 2,232,709,237.5 *0.107*0.011 = $2,627,898.77 for E10 users.

Over the period of the study covering 25 months this works out as follows:

ULP = $9,107,193.90

PULP = $5,228,862.80

E10 = $5,474,789.10

Total = $19,810,845.73

Explanation 2

19,434,000,000*0.8075 = 15,692,955,000 kilometres for petrol. Delineated by petrol type, this is 15,692,955,000*0.5536 = 8,687,619,888 kilometres for ULP, 15,692,955,000*0.2679 = 4,204,142,644.5 kilometres for PULP users and 15,692,955,000*0.1785 = 2,801,192,467.5 kilometres for E10 users.

The consumer surplus figure is aggregated from the following:

ULP: 8,687,619,888 *0.107*0.0059 = $5,484,494.44

[30] ULP 55.36%, PULP 26.79% and for E10, 17.85%. This is the average volume share from quarterly volume data beginning Quarter 1 2017 and ending Quarter 3 2020.

PULP: 4,204,142,644.5 *0.107*0.0070 = $3,148,902.84

E10: 2,801,192,467.5 *0.107*0.011 = $2,997,275.94

Thus, adding up to $11,630,673.22.

Over the extended 25-month period this works out as follows:

ULP = $11,426,030.00

PULP = $6,560,214.30

E10 = $6,244,324.90

Total = $24,230,569.21

Explanation 3

To calculate total consumer surplus, we need to estimate the average (per annum) kilometres covered by passenger vehicles in Southeast Queensland. However, only information for Brisbane is available. While not ideal, the ABS Cat. No. 9208.0 also incorporates total kilometres travelled outside the capital city (within a 100 kilometres of base) using passenger vehicles (11,388,000,000 kilometres*0.8075 = 9,195,810,000).

Using ABS population data from Table 3 of Cat. No. 3218.0 (ABS, 2020), we weigh this latter figure to encapsulate the share of the non-Brisbane Southeast Queensland population relative to the rest of Queensland. Given our non-Brisbane Southeast Queensland population is 2,274,618 and the rest of Queensland is 1,565,910, this gives non-Brisbane Southeast Queensland a weighting of 0.59. Multiplying this (i.e., 0.59) by 9,195,810,000 yields 5,425,527,900 kilometres. Thus, the total kilometres travelled in Southeast Queensland (including Brisbane's 12,508,175,000 obtained in Explanation 1) is estimated at 17,933,702,900 kilometres.

We estimate total kilometres travelled for ULP users to be 17,933,702,900*0.5536 = 9,928,097,925.44. For PULP, this would be 17,933,702,900*0.2679 = 4,804,439,006.91 and 17,933,702,900*0.1785 = 3,201,165,967.65 for E10 users.

This would yield a total consumer surplus of $12,322,102.72 consisting of:

ULP users: 9,928,097,925.44*0.107*0.0061 =$6,480,069.52

PULP users: 4,804,439,006.91 *0.107*0.0069 = $3,547,117.32, and

E10 users: 3,201,165,967.65 *0.107*0.0067 = $2,294,915.88.

Over the period of the study, this works out as follows:

ULP = $13,500,144.83

PULP = $7,389,827.75

E10 = $4,781,074.75

Total = $25,671,047.33

<u>Explanation 4</u>

Following ABS (2019) Cat. No. 9208.0 data, we assume the average kilometres driven annually in Cairns LGA to be 12,100kms, using the category 'other urban areas'. Given fuel consumption of 10.7 litres per 100kms, this gives total fuel consumption of 12,100*0.107 = 1,294.70 litres per annum.

Savings for regular user of ULP91 would be 0.0016*1,294.70 = $2.07 a year or $4.31 for the 25-month period under consideration. The corresponding figures for PULP are 0.0028*1,294.70 = $3.63 a year or $7.56 over 25 months. The savings for the regular user of E10 would be 0.0053*1,294.70 = $6.86 a year or $14.29 for the 25-month period.

To get total consumer surplus we need to estimate the average per annum kilometres covered by passenger vehicles (see Table 27 of Cat. No. 9208.0). We use annual total kilometres travelled all outside the capital city (within 100 kilometres of base; 13,231,000,000 kilometres) using passenger vehicles. As stated earlier, we assume that 80.75% of passenger vehicles in Queensland use petrol (ULP91, PULP and/or E10). This gives a figure of:

13,231,000,000 kilometres*0.8075 = 10,684,032,500 kilometres a year.

Using ABS (2020) population data (Table 3 of Cat. No. 3218.0), we find the share of the Cairns LGA population (166,862) as at 30 June 2019 relative to the rest of Queensland excluding Brisbane LGA (3,840,528),[31] And obtain a weighting of 0.043. Multiplying 0.043 by 10,684,032,500 yields 459,413,397.50 kilometres travelled annually.

The volume breakdown is as follows: we estimate total kilometres travelled for ULP users to be 459,413,397.50*0.5536 = 254,331,256.86. For PULP, this would be 459,413,397.50*0.2679 = 123,076,849.19 kilometres and 459,413,397.50*0.1785 = 82,005,291.45 for E10 users.

This provides a total consumer surplus of $126,920.53, consisting of 254,331,256.86*0.107*0.0016 = $43,541.51 for ULP users,

[31] As the ABS data provides different figures for capital cities (Brisbane: 15,490,000,000 kilometres as shown in Explanation 1).

123,076,849.19*0.107*0.0028 = $36,873.82 for PULP users and 82,005,291.45*0.107*0.0053 = $46,505.20 for E10 users.

Over the period of the study covering December 2018 to December 2020, this works out as noted below:

ULP = $90,711.48

PULP = $76,820.46

E10 = $96,885.83

Total = $264,417.77

Explanation 5

The same methodology in Explanation 4 is utilised to calculate savings in Bundaberg LGA, but only for E10. Savings for the regular user of E10 would be 0.0063*1,294.70 = $8.16 a year or $17.00 for the 25-month period under consideration.

The population as at 30 June 2019 is 95,856 giving Bundaberg LGA a weighting of 0.025. Multiplying 0.025 by 10,684,032,500 yields 267,100,812.50 kilometres travelled annually. Total annual kilometres travelled for E10 users in Bundaberg LGA works out to 267,100,812.50*0.1785 = 47,677,495.03.

This generates an annual consumer surplus from using E10 of 47,677,495.03*0.107*0.0063 = $32,139.40. Over the extended period the figure is $66,957.08.