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What Drives Petrol Price Dispersion across Australian Cities?

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Abstract: Petrol directly impacts the ability of and extent to which households can engage in day-to-day activities and ultimately directly influences the aggregate economic activity. Petrol price increases can lead to major economic disruption, especially among the most vulnerable, such as low-income families. In Australia, petrol prices differ substantially between metropolitan and regional areas, and regional drivers must pay more for purchasing petrol than those in capital cities. This research explored why retail petrol prices vary from one city to another within and between Australian regions. In this study, clustering methods and panel models will be used to identify factors that cause price differences. The findings revealed that a considerable part of the price differences arose from specific characteristics of cities that influence the demand and supply of petrol, thereby causing variations in price decisions. Petrol prices were substantially influenced by wholesale petrol prices, oil prices, petrol and diesel vehicles, population density, station density, and public transport accessibility. These factors are the main determinants that contribute significantly to price variations between Australian cities. The findings provide critical information for economic agents that interact in this market. From a social welfare perspective, government authorities can consider these factors to improve living standards and consumers' welfare under price pressure in regional cities.

Keywords: unleaded petrol; retail price; regional markets; clustering; Australia

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1. Introduction

Transport costs in Australia account for a significant proportion of household budgets and are also a critical cost for businesses. Given the strong dependency of Australians on roads and the essential role of petrol in the family budget and business profits, the demand for understanding petrol price behavior has increased over the last decade. According to the Australian Competition and Consumer Commission (ACCC), petrol prices vary significantly between cities, and some areas have higher prices than others [1]. The main questions that arise are, first, why do retail petrol prices differ from city to city, and second, why do consumers have to pay more for petrol in some areas? Despite the importance of these questions, they have not received much attention from researchers. In particular, no significant studies have explicitly investigated the factors that influence petrol prices in regional markets in Australia. Focusing on Western Australia (WA), the purpose of this study was to address the following questions:

- What determines the price variation between cities in WA?
- What is the correlation between petrol prices and city-specific characteristics?
- Which factors result in cross-sectional price variations?

According to the ACCC [2], petrol price differences result from less competition, high profiteering power, high distribution costs, and low petrol sales. Besides the factors already mentioned, other elements cause price variation that could be explained by demand-side factors, daily changes in purchasing patterns, and city characteristics. Researchers have primarily investigated the effects of station characteristics (such as brand) and upstream cost shocks (such as crude oil price) on retail petrol prices among stations, cities, regions, and even countries. However, fewer studies have examined the impact of local characteristics associated with different petrol price patterns. This study applied cluster analysis to find factors that drove the petrol price dispersion between different locations.

The contribution of this research is to provide the following novel results. The findings extend the understanding of the Australian regional petrol markets. It was one of the first studies to examine the effect of city-specific features on petrol prices in regional Western Australian cities. It was also the first study to use a novel dataset. The micro-level dataset used in this study determined the extent of price differences between cities in WA. By examining petrol prices alongside city-specific features, we were also able to distinguish critical factors associated with high petrol prices in some cities and also different price patterns between urban and rural areas. Moreover, the dataset contained city-level information, which helped to avoid possible biases that may result from considering specific cities or metropolitan areas. A particular feature of the database was that it provided a detailed picture of petrol prices across all rural and urban areas in WA, revealing significant explanatory variables that influence prices. Accordingly, this study shed light on the regional petrol markets accurately and transparently.

The practical implications of this study can be represented as follows. First, this study's findings help regional authorities to understand the retail petrol markets more accurately. To establish effective policies, they need comprehensive information on pricing behaviors. Second, given that price patterns make price comparisons between cities more complicated, the findings of this study help to identify those cities with the higher petrol prices on average after controlling for other influencing factors. It seems that there is collusion or monopoly power in the retail petrol markets in these cities, which push prices higher. Thus, these areas should come under closer scrutiny by authorities. Regional authorities can focus mainly on these cities to conduct the best policies to decrease prices and increase living standards for their citizens. Finally, this study contributes to the regional petrol markets by determining factors that influence prices. The findings provide critical information for economic agents and decision makers that interact in this market. From a social benefit perspective, economic agents can consider these factors to improve living standards and the welfare of consumers under price pressure in some regional cities. For instance, in those areas with significantly higher prices, strategies that will enhance public transport facilities would be more effective at increasing consumer welfare.

This paper is classified into several parts as follows. Section 2 provides an explanation of the relevant theoretical concepts and a review of the related literature. Section 3 presents the empirical framework of this study. In Section 4, the data are described, and the estimated results are presented in Section 5. Finally, Section 6 includes the conclusion of this paper.

2. Background and Literature

There are a few governmental reports and theoretical or empirical studies that examined the reasons for cross-sectional differences in the prices of petrol between geographical locations. As reported by the ACCC [3], there is geographic price discrimination in the Australian retail petrol market because "company data also shows that margins in regional areas are generally higher than in metropolitan cities. Higher margins in country areas have affected the strategy of some businesses such as United Petroleum, which states that it is looking to expand its business by focusing on regional rather than metropolitan sites because there is less competition, lower volumes, and higher margins in regional areas".

The ACCC reported that lower population and demand in regional areas lead to fewer petrol stations, causing less competition in the retail petrol market [4]. Therefore, we expect that less competition in Australian retail markets results in higher petrol prices in rural and regional areas. Previous literature also revealed a significant relationship between the petrol price and the market structure in different geographical locations, i.e., [5–8]. As mentioned by Tappata and Yan [9], in less-populated cities with lower station density, there is less competition, such as oligopolistic markets, resulting in higher petrol prices. Kvasnička et al. [10] examined the effect of station density on retail petrol prices in the Czech Republic and found that station density negatively affects petrol prices. Considering the impact of competition on price-setting decisions, Valadkhani et al. [11] examined the impact of upstream cost shocks on the retail petrol prices in Sydney. They found that passthrough is faster among stations with more intense local competition. Therefore, this study examined the impact of competition on retail petrol prices in different WA cities.

Moreover, the ACCC [12] suggested that high petrol prices in regional areas can stem from factors such as supply-side determinants (i.e., international oil price, wholesale price, the Australian/US dollar exchange rate, and higher distribution costs), demand-side factors (i.e., purchasing power, petrol demand, and lower sales of petrol), stations' locations (i.e., stations in busy highways with higher turnover), and city characteristics (i.e., population). This study examined the impact of all these factors on petrol prices.

The empirical literature chiefly analyzed the effect of station characteristics or international factors on petrol prices, i.e., [13–21]. For instance, Haucap et al. [22] found that station characteristics and cost shocks are the most critical factors that affect prices in Germany. Yilmazkuday [23] examined the price differences between stations in the USA using a dataset containing 38,245 price data points. They found that crude oil prices (51%), refinery-specific costs (33%), state taxes (12%), and spatial factors (i.e., land prices, 4%) had the most significant impact on the price disparity between states. However, these studies looked only at price variations at individual stations rather than analyzing price uniformity over a wide geographical area.

Another strand of literature was undertaken to examine the reasons for the petrol price disparity between states, regions, or cities. Most of these studies analyzed the effect of upstream costs, such as wholesale or oil prices, on retail petrol prices [24]. At the country level, Rietveld and van Woudenberg [25] examined the effect of fuel taxes on differences in fuel prices between countries. They used a dataset of diesel and petrol prices for 100 countries to find that tax differences caused significant variations in fuel prices. Burke and Nishitateno [26] also analyzed the price elasticity of petrol demand for 132 countries from 1995 to 2008. They found that differences in petrol consumption and the economy primarily caused different fuel prices.

At the state level, Chouinard and Perloff [27] used a panel dataset containing monthly observations of retail and wholesale petrol prices, oil prices, taxes, demographic factors, state characteristics, and environmental regulations to examine disparities at the state level in the USA from 1989 to 1997. Their focus was on understanding why prices increase and why petrol prices are higher in some states than others. Their findings show that crude oil price, demand variation, tax rates, environmental regulations, and market power are the essential elements that lead to price variances between states in the USA. At the regional level, Bello and Contín-Pilart [28] specified the effect of cost parameters, demographic factors, demand-side variables, and taxes that contribute to price formation in the Spanish markets. According to their findings, price differences were mainly caused by differences in taxation between regions.

However, these studies had some limitations. These studies focused on the variations in petrol prices between broader geographical divisions, such as between states, countries, or regions. There are apparent dissimilarities between countries, states, or regions, resulting in price differences, such as regulations or taxation. A question that remains unanswered is why cities within a particular state and a specific region have substantially different petrol prices. Second, previous studies focused mainly on the impact of taxes, costs, or supply-side factors on price variations. However, it is expected that the specific characteristics of cities can influence the prices of petrol, which was scrutinized in this analysis. Third, these studies focused only on regional petrol markets in European countries or the USA while omitting the Australian market. In this study, we investigated why petrol prices differ between cities in Australia, which is a question that has so far been overlooked. It must be noted that Australians are highly dependent on petrol, especially in regional areas. Additionally, petrol prices have a considerable impact on family budgets and business profits and play a crucial role in the financial decisions of businesses and the quality of life and welfare of households. For this reason, understanding why petrol prices differ between locations in Australia is essential, especially for people who live in cities with high petrol prices. By reviewing government reports, as well as theoretical and empirical literature, the following primary hypotheses were examined:

Hypothesis 1. *The price of petrol is influenced by city-specific characteristics.*

Hypothesis 2. *Petrol prices and competition are negatively correlated.*

Hypothesis 3. *An increase in the demand for petrol leads to an increase in its price.*

Hypothesis 4. *An increase in the initial costs of petrol (such as upstream costs, exchange rate, and distribution costs) results in an increase in the petrol price.*

The empirical verification of these hypotheses was undertaken using the methodological framework explained in the next section.

3. Empirical Framework

3.1. Cluster Analysis

This study's main objective was to determine factors that influence retail petrol prices. To find determinants, first, we needed to classify cities based on their characteristics and then find out how petrol prices correlated with the cities' characteristics. To achieve this, the study used cluster analysis as the best method for grouping cities by their characteristics. Cluster analysis is mostly applied to market segmentation [29]. It lets us create clusters of cities with similar geographic, economic, and demographic features, as well as the same petrol prices [30]. The clustering method was used by a few energy scholars in their analysis, such as Gillingham [31] and Liu et al. [32]. In this study, both hierarchical and non-hierarchical methods were applied.

3.1.1. K-Means Clustering Method

The K-means method was applied to classify cities into groups with similar features. This approach is a well-known partitioning method for clustering that was developed by Steinhaus [33], Ball and Hall [34], and Lloyd [35] in different streams [36]. The K-means method is a simple, powerful, and efficient technique with some advantages compared with other clustering techniques. First, this method is relatively simple to apply and comparatively faster than non-hierarchical clustering methods. The hierarchical clustering method cannot handle an extensive dataset easily, while the K-means method can computationally cluster a large dataset quickly. This is because the time complexity of the K-means model is linear while the hierarchical model is quadratic. Second, compared with other clustering models, such as principal component analysis (PCA), which aims to cluster by similarities between the variables (columns) of a dataset, K-means analysis clusters observations according to similarities between rows. Third, the K-means method can easily create clusters of different sizes and shapes, such as elliptical clusters. Fourth, the non-hierarchical clustering methods, such as K-means, are more stable than hierarchical clustering. Considering all these advantages, the K-means method was the more appropriate method for clustering cities for this study, and thus, it was applied in the analysis. There are three stages involved in using the K-means clustering algorithm, as follows:

Stage 1:

The first stage of performing the K-means model is selecting the optimal number of clusters (the value of k). It must be noted that k indicates the number of groups or categories that we want the dataset to be divided into. Accordingly, we could classify the data into distinct groups with very similar features and characteristics. There exist different approaches to finding the optimal number of clusters. This study applied the elbow criterion, the gap statistic, the silhouette, the sum of squares, the Calinski criterion, NbClust, and a modified BIC criterion to identify the optimal number of clusters. We used different methods for checking the robustness to find the best value for k.

Stage 2:

After determining the optimal number of clusters (k), it is necessary to find the clusters' centroids, which are computed based on the means of the data points in each cluster. The Euclidean distance is applied to capture the cluster centroids. The Euclidean distance calculates the distance between two given points (i.e., p and q) in two dimensions (($p = (p_1, p_2)$ and $q = (q_1, q_2)$) to specify the intra- and inter-cluster similarity using the following formula:

$$d(p,q) = d(q,p) = \sqrt{(p_1 - p_2)^2 + (q_1 - q_2)^2} \quad (1)$$

Equation (1) is equivalent to the Pythagorean theorem and it can be re-written as follows:

$$d(p,q) = \sqrt{r_1^2 + r_2^2 - 2r_1 r_2 \cos(\theta_1 - \theta_2)} \quad (2)$$

where:

(r_1, θ_1)—the polar coordinates of the point p;

(r_2, θ_2)—the polar coordinates of the point q.

Based on the Euclidean equation mentioned in Equations (1) and (2), we could calculate the Euclidean distance of each point in the dataset with the k identified points.

Stage 3:

In the last stage, k clusters of cities were created by assigning the point of each data to its nearest cluster. In the K-means model, observations are considered as vectors of variables' values. In this method, N objects (attributes) are divided into different predefined clusters (k = 1,2, ..., K), with each object belonging to the cluster with the nearest mean [37]. The main objective of the K-means clustering method is to minimize the sum of the squares of the distance between observations and their nearest mean. Therefore, the sum of the squared function for the kth cluster is defined as follows in Equation (3):

$$ESS(k) = \text{arg min}_{c_i \in C} dist(\, x_i, c_k)^2 = \text{arg min } \sum_{k=1}^{K} \sum_{i=1}^{9} \|x_i - c_k{}^2\| \quad (3)$$

where:

x_i—a vector of ith variable (i.e., distribution cost based on the distribution distance in km), where i = 1, 2, ..., 9;

c_k—the centroid for the kth cluster, where k = 1,2, ..., K;

dis—the Euclidean distance.

In the K-means model, these steps are repeated until the same k points or centers are assigned to clusters in consecutive stages. Therefore, in this study, we used the K-means clustering method to classify cities based on their characteristics.

3.1.2. Hierarchical Clustering Method

In this study, hierarchical cluster analysis was performed to check the robustness of the results of the K-means model following Valadkhani et al. [29]. The hierarchical clustering algorithm divides objects into groups with similar characteristics that are distinct from each other. In the first stage of the hierarchical method, each observation is placed in a separate cluster. Then, two steps are performed repeatedly as follows: (1) the model recognizes the two groups (clusters) that are the closest together and then (2) it merges the two most similar clusters. This procedure continues until all the clusters are combined, and at the last stage, only one cluster exists. The results of the hierarchical clustering analysis are generally illustrated in a tree diagram (dendrogram). Hierarchical algorithms are performed as follows:

1. Find the smallest element d_{ij} remaining in D. The distance between clusters i and j are represented as d_{ij} (let cluster i contain n_i objects).
2. Merge clusters i and j into a single new cluster.

3. Compute a new set of distances d_{km} using the distance equation as follows:

$$d_{km} = \alpha_i d_{im} + \alpha_j d_{jm} + \beta d_{ij} + \gamma |d_{im} - d_{jm}| \tag{4}$$

where m is any cluster other than k. It must be noted that new distances replace d_{im} and d_{jm} in D ($n_k = n_i + n_j$).

4. Steps one to three are repeated ($N - 1$ iterations) until D includes only one cluster that contains all objects.

3.2. ANOVA Test

We classified cities into groups with similar characteristics and applied an ANOVA test to determine whether petrol prices differed significantly between clusters. The Kruskal–Wallis H test was used to analyze variances in this study. It must be noted that the size of the sample was too small, and the normal distribution assumption was not held in the dataset, where a normal/Gaussian distribution should be analyzed with the ANOVA test. Therefore, non-parametric methods, such as the Kruskal–Wallis H test, are more powerful than conventional ANOVA for analyzing a non-normal/non-Gaussian distribution. Therefore, this study used a Kruskal–Wallis H test to analyze the variances. The Kruskal–Wallis H test, sometimes called the "one-way ANOVA on ranks", is a non-parametric method that is used to specify whether there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable [38,39]. The process for the Kruskal–Wallis H test is as follows:

1. Data for all groups are sorted in ascending order.
2. Ranks are allocated to the sorted data points.
3. The statistic H is estimated as

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N-1) \tag{5}$$

where:

N—total number of data;
n_j—size of the jth group;
R_j—total sum of ranks in the jth group.

4. The critical chi-square value for the $(k - 1)$th degree of freedom is calculated, where k is the number of groups.
5. Finally, the decision on whether to reject the null hypothesis is made by comparing the value of H with the critical chi-square value. The null hypothesis is rejected if the H statistic is bigger than the critical chi-square value. The null hypothesis is that the medians are equal. Otherwise, the null hypothesis is not rejected if the H statistic is not bigger than the critical chi-square value [40].

3.3. Regression Analysis

The following model was used to estimate the coefficients of variables that affect petrol prices at city levels:

Retail petrol price = f (upstream costs (wholesale or oil price), supply-side factor (distribution cost), competition (station density), demand-side factors (petrol vehicles, diesel vehicles), characteristics of cities (population density, businesses density, public transport, commuting distance)).

It should be noted that upstream cost shocks (wholesale petrol price or crude oil price) are not considered in the cluster analysis due to this variable's similarity between cities. However, previous studies mentioned that upstream costs significantly impact retail petrol prices, and when they change, stations pass these cost changes onto their customers through their prices, i.e., [27]. Hence, it was expected that the upstream costs would significantly affect the retail petrol price, and the effects could vary between different cities. Thus, this section presents the method used to examine the impact of the wholesale petrol price (or crude oil price) on the retail petrol price separately. It was anticipated that the coefficient (β) of the wholesale petrol price (or oil price) varied between cities. Equation (6) presents this simplistic specification as follows:

$$p_{it} = \propto_i + \beta_i wp_{it} + \varepsilon_{it} \quad (6)$$

where:

p_{it}—natural logarithm of the average retail petrol prices (based on cents per liter (CPL)) for the ith city at time t, where i = 1, 2, . . . , 44;

wp_{it}—natural logarithm of the wholesale petrol price (CPL) or the crude oil price (based on Australian dollars per barrel);

ε_{it}—a stochastic residual term.

In the next part, we incorporated a set of variables, including demand-side and supply-side factors, as well as city features, into Equation (6) to find the coefficient of all these factors on the retail petrol prices. These variables only changed between cities and were stable over the sample period, just like commuting distance. The effect of these new time-invariant variables could be estimated by the fixed-effects (FE) Equation (7) as follows:

$$p_{it} = \alpha + \beta wp_{it} + \sum_{j=1}^{9} \gamma_j d_{ij} + \mu_i + \varepsilon_{it} \quad (7)$$

where wp_{it} is the time-varying variable of wholesale petrol price for the ith city at time t (t = 1, . . . , 608, and i = 1, . . . , 44); μ_i refers to individual city-specific effects that are constant over time; d_{ij} is the jth time-invariant variable for the ith city, which only changes between cities, not over time; and ε_{it} is an independent and identically distributed (i.i.d) error term with a mean of zero and a variance of δ^2. In Equation (7), it was assumed that μ_i is uncorrelated with variables wp and d for all time, as shown in Equation (8):

$$E(\mu_i | wp_{it}, d_i) = 0 \quad (8)$$

However, the unobserved individual city-specific effects showed the impact of features in each city, which were not considered in the dataset. Thus, the time-invariant variables, which were city-specific factors, were more likely to be associated with unobserved individual city-specific effects, leading to endogeneity issues. The random-effects (RE) model assumes no correlation between explanatory variables and the random individual effects; therefore, this model could not be applied in this study. In contrast, an FE model considers that the explanatory variables are correlated with the random individual effects [41], but the FE model has a significant disadvantage in that it does not estimate the coefficient of time-invariant variables, and thus, could not be used in this study. The RE model can calculate the coefficient of constant variables over time, but the estimates may be biased because of the existence of correlations in our model.

The Hausman and Taylor (HT) model can be suitable for combining FE and RE models [42]. The HT method can estimate a model with several explanatory variables correlated with the individual city-specific effects [43]. Furthermore, estimated coefficients related to the exogenous time-varying variables are more efficient in an HT model than in an FE model. However, an HT model is problematic in that it is difficult to specify the endogenous and exogenous variables, and the wrong definition can lead to biased results [44]. Thus, the within–between or hybrid model is most appropriate in the context of this study to estimate both types of explanatory variables: time-varying and time-invariant. The Equation (9) of the FE model can be expressed in its demeaned form as follows:

$$p_{it} - \overline{p_i} = \alpha + \beta(wp_{it} - \overline{wp_i}) + \sum_{j=1}^{9} \gamma_j (d_{ij} - \overline{d_{ij}} = 0) + (\mu_i - \overline{\mu_i} = 0) + (\varepsilon_{it} - \overline{\varepsilon_i}) \quad (9)$$

As seen above, when we demeaned everything in Equation (10), all the time-invariant variables dropped out of the model. The following model may, therefore, be used as the "within" estimator:

$$p_{it} - \overline{p_i} = \alpha + \beta(wp_{it} - \overline{wp_i}) + (\varepsilon_{it} - \overline{\varepsilon_i}) \tag{10}$$

Hence, as stated before, an FE model could not estimate the effect of time-variant variables used in this research. However, following Schunck [45], we could decompose the time-varying variables into a between ($\overline{wp_i} = n_i^{-1} \sum_{t=1}^{n_i} x_{it}$) and cluster format ($wp_{it} - \overline{wp_i}$) to test the within effects in the RE model. Following Allison [46], the within–between (or hybrid) model is given in Equation (11) as follows:

$$p_{it} = \alpha + \beta_1(wp_{it} - \overline{wp_i}) + \sum_{j=1}^{9} \gamma_j d_{ij} + \beta_2 \overline{wp_i} + \mu_i + \varepsilon_{it} \tag{11}$$

where:

p_{it}—the average retail petrol prices (CPL) for the *i*th city at time *t*, where *i* = 1, 2, . . . , 44, and *t* = 1, . . . , 608;

wp_{it}—wholesale petrol price (CPL);

$\overline{wp_i}$—cluster mean of the wholesale petrol price for the *i*th city;

d_{ij}—*j*th time-invariant variable affiliated to the *i*th city;

μ_i—individual city-specific effects of unobserved variables;

ε_{it}—a stochastic residual term.

Following Raudenbush and Bryk [47], this study used a similar model to the within–between model, which was named the "contextual" model, as follows:

$$p_{it} = \alpha + \beta_1 wp_{it} + \sum_{j=1}^{9} \gamma_j d_{ij} + \beta_2 \overline{wp_i} + \mu_i + \varepsilon_{it} \tag{12}$$

In this model, β_1 was not changed, while β_2 was changed. The estimated β_2 showed the difference between the within and between effects in the model and it could be interpreted as a contextual effect.

3.4. Determinants of Petrol Prices

This study examined the impacts of the following factors that may lead to price differences.

3.4.1. Supply-Side Factors

Upstream cost shocks (changing the price of wholesale petrol and oil) have a significant effect on retail petrol prices. In Australia, crude oil is mostly imported, and the cost of imported oil is based on the US dollar. Hence, the exchange rate from the US dollar to the Australian dollar can indirectly affect retail petrol prices. We examined the effect of wholesale petrol prices and crude oil prices on retail petrol prices across all WA cities. It must be noted that the impact of the USD/AUD exchange rate was considered in this study by converting the price of crude oil from the US dollar to the Australian dollar.

Petrol prices in regional areas can also be higher due to higher transportation and distribution costs [48]. When purchasing petrol from refineries and delivering that to retailers, the shipping cost becomes a critical factor that affects the price of petroleum products. The distance between a retailer and its nearest wholesaler is used as a proxy for transportation costs and is expected to impact petrol prices positively. Consequently, marginal costs can be larger in cities located far away from wholesalers due to higher transportation costs [49]. Tanker trucks deliver petroleum products to petrol stations in distant locations in remote areas. Caltex Australia, for example, measured that the cost of delivery was typically 1.5 to 3.0 CPL higher in regional areas than in capital cities [50]. Pennerstorfer [18] found that distance (a proxy for distribution cost) did not significantly influence petrol prices in Austria, while Valadkhani and Babacan [29] found that the distance between the wholesaler and retailer had a significant positive impact on variations in cross-sectional margins.

3.4.2. Competition

The ACCC [2] reported that the lack of a regular petrol price cycle in most regional locations stems from having less competition in the retail markets. According to the literature, there is a positive relationship between retail petrol prices and the structure of the market in different geographical locations. Tappata and Yan [9] mentioned that the retail petrol markets are less competitive, with low station concentrations in regional areas. For instance, stations located in highly competitive markets should compete with their prices to gain market share, while in the less-populated cities with low station density, there are low levels of competition (like oligopolistic markets) and lower search friction; thus, petrol prices are higher in these cities. Accordingly, this study examined the impact of competition on retail petrol prices.

3.4.3. Demand-Side Factors

Demand and supply imbalances can affect prices in the retail petrol market. Demand shortages can push prices upward and, conversely, prices decrease if the supply exceeds demand. There are different levels of dependency on fuel types between various Australian locations. Diesel is preferred by the mining and agricultural sectors, while the road transport sector prefers petrol. According to the ABS [51], WA has a rich natural resource base, and regional cities are more dependent on agricultural and mining industries. Because of this, diesel demand is higher than petrol demand in some regional cities in WA, resulting in higher petrol prices there. Valadkhani and Babacan [24] found that the number of cars in the vicinity of retailers is a major factor that can result in variations in cross-sectional margins. Vita [52] found that the number of motor vehicles per population has a positive effect on the retail price of petrol at a state level in the USA, while Alm et al. [53] found that the number of vehicles per capita does not have a significant effect on the retail price between states in the USA.

3.4.4. City-Specific Characteristics

Regional factors, including geographic conditions, residential densities, commercial activities, transport availability, and commuting flows, can result in different petrol prices in various areas [54,55]. The density of the population and the population size were found to significantly affect petrol demand. However, the impact of the population (or population density) on retail petrol prices is ambiguous. As Vitae [52] mentioned, an increase in population may increase the demand for petrol, leading to a rise in petrol prices. In addition, highly populated areas have more traffic congestion, which leads to higher fuel consumption per kilometer and higher rental values. These two factors can lead to higher petrol prices in cities.

On the other hand, population density can negatively influence petrol prices. There are alternative transportation modes in populated cities, resulting in a petrol demand reduction. It is expected that the price of petrol will decrease with increasing demand. Moreover, as Valadkhani and Babacan [24] stated, there is a positive relationship between population density and the size of the market (the larger the population density, the greater the market). There are more petrol stations in highly populated cities, leading to greater competition in the market. Hence, retailers can gain a high level of profits through higher volumes of petrol sales rather than only higher margins. However, in less-populated regional cities, where the size of the market is small, petrol demand and competition are limited. Thus, retailers must set higher prices for petrol to cover their costs, keep their businesses, and make profits. This study examined the effect of population density on petrol prices to determine whether population density positively or negatively affects petrol prices.

Although public transportation accessibility can affect petrol demand, its effect on petrol prices is ambiguous. When public transport services increase, the use of private vehicles decreases, with a subsequent decrease in demand for petrol. Therefore, by increasing the number of public transport facilities (which results in reducing the demand for petrol), the price of petrol is expected to decrease. Regional residents who live in isolated areas are generally unable to use public transportation; therefore, they must rely on their own vehicles to get around. Petrol is a supplementary commodity for vehicles and depending on private cars instead of public transport can increase dependency on petrol. Hence, the use of private vehicles in cities with low access to public transport facilities and fewer stations can create a kind of monopoly power or collusion in the retail market, enabling stations to sell their petrol at higher prices. Therefore, this factor can have both a positive and a negative impact on petrol prices, a phenomenon which was examined in this study.

Commuting distance is another determinant that can affect petrol prices across Australian cities. For example, Cooper and Jones [16] found that petrol prices are higher in locations with longer routes in Lexington, Kentucky. The effect of this factor on retail petrol prices was estimated in this study.

It must be noted that other factors, such as the quality of roads, may also be significant, but data for these variables are not available at the city level.

4. Data

The daily retail prices of petrol were sourced from the FuelWatch website, which is affiliated with the Western Australian Government and administered by the Department of Mines, Industry Regulation and Safety. Except for the Perth metropolitan area, cities were distributed within nine regions in WA, as presented in Table 1. The sample period for all locations in the dataset spanned from 1 January 2017 to 31 August 2018.

Table 1. Western Australian cities.

Region	City/Town
Pilbara	East Pilbara, Karratha, Port Hedland
Kimberley	Broome, Fitzroy, Kununurra
Gascoyne	Carnarvon, Exmouth
Midwest	Irwin, Geraldton, Meekatharra
Goldfield–Esperance	Kalgoorlie/Builder, Coolgardie, Esperance, Kambalda, Norseman, Ravensthorpe
Wheatbelt	Cunderdin, Dalwallinu, Dandaragan, Meckering, Moora, Narrogin, Northam, Tammin, Williams, York
Southwest	Bunbury, Manjimup, Bridgetown/Greenbushes, Busselton, Capel, Dardanup, Donnybrook/Balingup, Harvey, Augusta
Peel	Murray, Waroona, Mandurah
Great Southern	Albany, Denmark, Kojonup, Mt Barker
Perth	Perth

Source: FuelWatch.

There are different types of transport fuel in Australia, but this study focused on unleaded petrol (ULP) as the top petroleum product purchased by drivers. The prices of ULP are based on cents per liter (CPL). It must be noted that most cities have more than one petrol station, and thus, we used the average price of all stations in each city. Figure 1 presents the geographical divisions of cities and regions. While WA has over 50 cities, complete information for 44 cities was available.

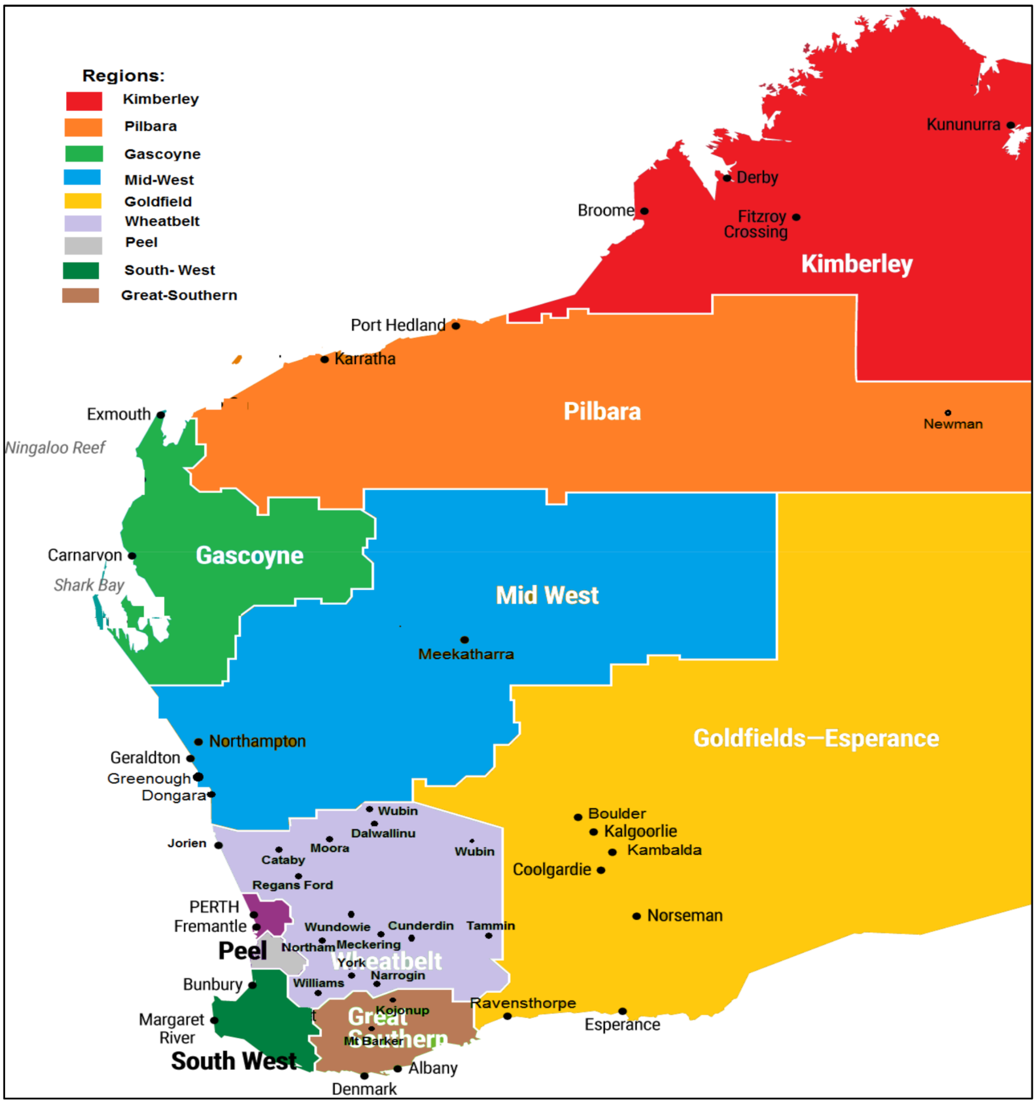

Figure 1. Local government cities and regional boundaries. Source: Western Australia Mineral and Petroleum: Statistics Digest 2016–2017, p. 67.

There are two proxies for the upstream cost: crude oil and wholesale petrol prices. In WA, petrol is supplied by seven wholesalers in different locations, as follows: one in Broome city in the Kimberley region, one in Port Hedland in the Pilbara region, one in Esperance city in the Esperance region, two in Perth, one in Geraldton in the Midwest region, and one in Albany in the Great Southern region. The daily wholesale petrol prices were obtained from FuelWatch beginning on 1 January 2017 and ending on 31 August 2018. Following Valadkhani and Babacan [29], the distance between retailers and wholesalers was considered a proxy for the transport cost. It was assumed that petrol stations in each city purchased petrol from their nearest wholesaler; therefore, we matched the retail prices of petrol in each city to their nearest wholesalers based on the distance. It was expected that the greater the distance between a city and its wholesaler, the higher the transport and distribution costs. We used the Google Maps website and GIS software to find the latitude and longitude and evaluate the distance between retailers and their corresponding wholesalers.

The daily price of oil was extracted from the "Federal Reserve Economic Data Centre". The oil data was based on the US dollar per barrel; thus, data for the daily exchange rate was applied to adapt the US price of oil to the Australian dollar per barrel. The USD/AUD exchange rate was gained from the Reserve Bank of Australia's website.

All information about city-specific characteristics was extracted from the Australian Bureau of Statistics (ABS). Variables including business density, population density, commuting distance, and public transport accessibility are city-specific characteristics [56]. We used the data of the "method of travel to work by employed persons who used tram, train, and bus facilities" as a proxy of the level of public transport accessibility. The ABS contains information related to the number of businesses and households in each city [57]. We calculated the business density and population density using the number of businesses and the number of households in each city divided by the size of each city's area, respectively. The number of businesses in each city was applied to capture the effects of demand changes as a result of business activity [58].

The station density variable (the number of stations per km^2) was considered a proxy for competition. This variable was applied to capture the effects of competition on retail petrol prices. Moreover, there were different levels of fuel consumption between Australian states and cities, reflecting different levels of petrol demand and resulting in different petrol prices. Following Vita [52] and Alm et al. [53], we applied the "total number of registered petrol vehicles divided by city population" as a proxy for petrol demand and "total number of registered diesel vehicles divided by city population" as a proxy for diesel demand. The summary statistics for all variables are presented in Table 2.

Table 2. Summary statistics of the characteristics of 44 cities in WA.

Variables	Mean	Std Dev	Min	Max	Kurtosis	Skewness	Range
Station density	0.005	0.011	0.000	0.057	14.781	3.683	0.057
Population density	22.357	64.633	0.000	320.900	14.094	3.746	320.900
Business density	1.193	4.407	0.000	28.390	35.752	5.820	28.390
Petrol cars/population	0.570	0.322	0.174	2.257	17.350	3.311	2.083
Diesel cars/population	0.436	0.280	0.010	1.630	6.736	1.951	1.620
Public transport	0.034	0.069	0.000	0.335	9.475	3.041	0.335
Distribution cost	206.202	221.329	0.400	1184.600	8.505	2.535	1184.200
Commuting distance	23.559	13.901	5.000	67.800	1.874	1.361	62.800

5. Results

5.1. Cluster Analysis

This study used cluster analysis to classify cities based on their characteristics. The attributes were station density (number of stations per km^2), business density (number of businesses per km^2), population density (number of households per km^2), petrol demand (petrol cars per population), diesel demand (diesel cars per population), public transport, commuting distance, and distribution cost. The histograms of attributes are presented in Figure 2.

The first step in performing a K-means model is identifying the optimal numbers of clusters. To this end, we use different tests, including the silhouette, elbow, affinity propagation algorithm, Calinski criterion, modified BIC criterion, gap statistic, and NbClust tests. Based on the results from all these tests, the optimal number of clusters was three ($k = 3$). Therefore, this study clustered cities into three groups using the K-means model. It must be noted that in the dataset, the attributes had different units (e.g., kilometers, persons, and numbers) or different scales (e.g., 0–5 vs. 0–1000), which were not comparable. Thus, all variables were standardised by converting them to a unitless measure. To do this, we used the scale function that estimated the z-score. After that, we classified the 44 cities into three clusters. Figure 3 shows that cluster two only contained Perth city. Eight cities, namely, Kambalda, Norseman, Coolgardie, Kununurra, Fitzroy, East Pilbara, Ravensthorpe, and Meekatharra, were placed in cluster one. The remaining cities were placed in cluster three.

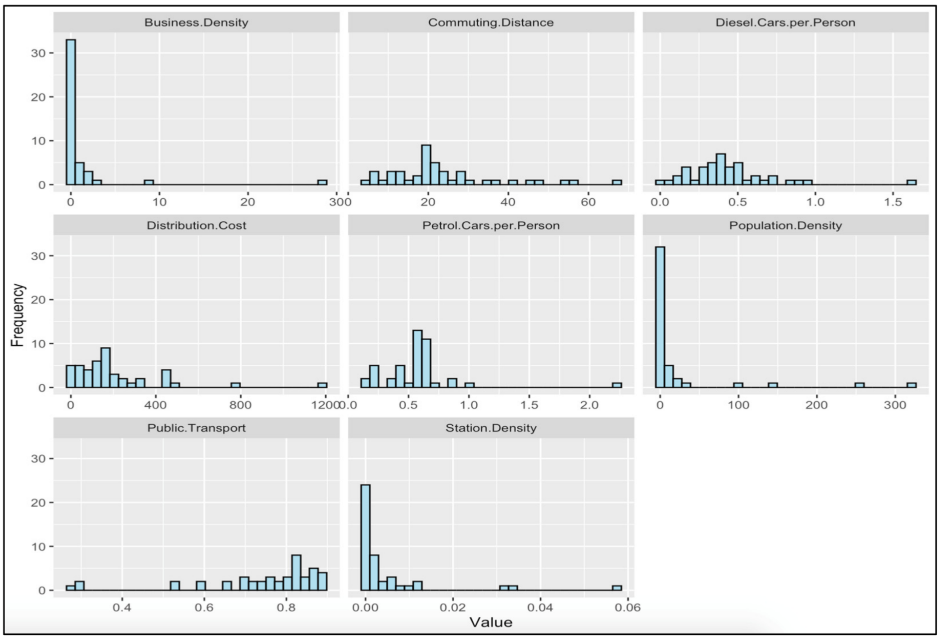

Figure 2. Histograms of attributes.

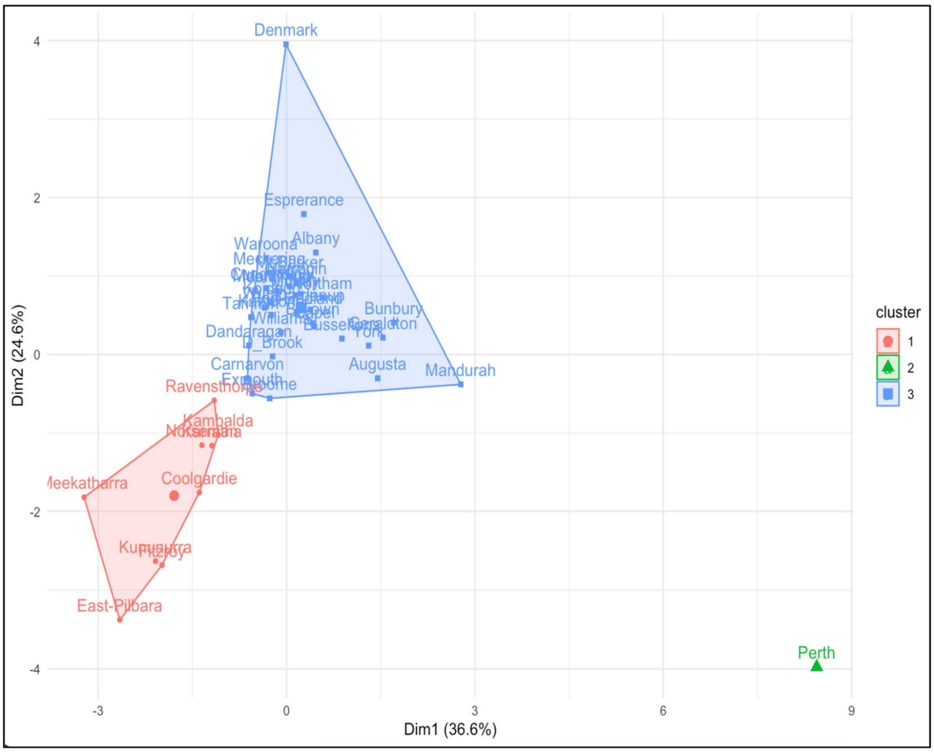

Figure 3. The K-means clustering of cities.

Moreover, following Valadkhani et al. [24], a hierarchical cluster analysis was conducted for the robustness check. Figure 4 illustrates the hierarchical clustering of cities. As shown, the results were in line with the findings of the K-means cluster. For instance, all cities in cluster one in the K-means model were allocated to one specific group in the hierarchical cluster. The only dissimilarity in results was the location of Ravensthorpe. Except for this city, all cities were placed in similar clusters using both the hierarchical method and the K-means model.

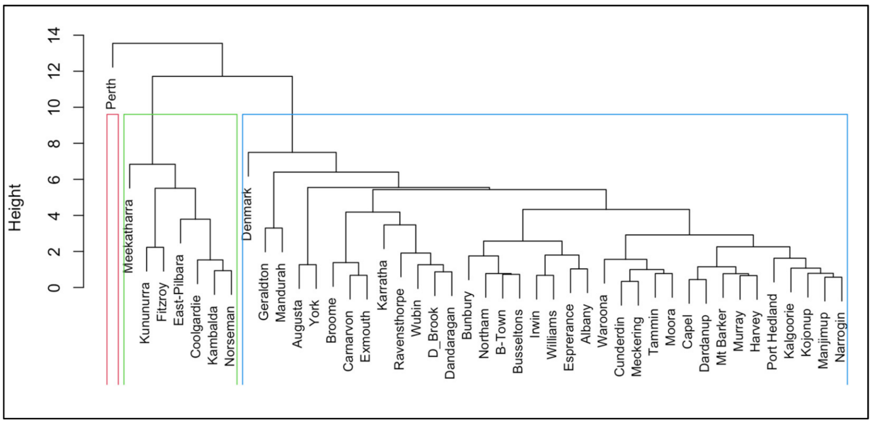

Figure 4. Hierarchical clustering of cities.

For a better understanding of the differences between the three clusters, by extracting and adding the clusters to the initial data, we were able to derive some descriptive statistics about the cluster means at the cluster level. Table 3 displays the summary statistics of the cluster means. In Figure 5, the information presented in Table 3 was used to display the differences between the clusters and the cluster means of their attributes more visibly. As demonstrated, Perth, which was located in cluster two, had features that were in complete contrast with the other cities. Perth had the highest population density and business density in WA, which was not comparable to other cities. Furthermore, it had the largest number of stations in WA. The total number of stations in Perth was more than the total number of stations in all WA regional cities. This showed that the retail petrol markets in regional areas were less concentrated (the number of stations in cities ranged from one station to 22 stations). In regional areas, the lack of stations reduced competition, which led to higher prices. Therefore, it was expected that petrol prices were higher in regional cities than in Perth.

Table 3. Descriptive statistics of attributes at the cluster level.

Clusters/Features	1	2	3
Station density	−0.33012	4.924333	−0.05745
Population density	−0.34246	4.619029	−0.0452
Business density	−0.26814	6.171106	−0.11053
Petrol cars per person	−0.83292	−1.19809	0.255716
Diesel cars per person	0.063911	−1.35642	0.022977
Public transport	−1.51968	0.420818	0.389892
Distribution cost	1.079932	−0.89325	−0.25959
Commuting distance	1.485641	−1.33508	−0.35399

Note: As mentioned earlier, all attributes were standardized and converted to a unitless measure.

Two variables were applied as a proxy for petrol and diesel demand: the number of vehicles using petrol per person (petrol vehicles/population) and the number of vehicles using diesel per person (diesel vehicles/population). As displayed in Figure 5, Perth had the lowest level of petrol vehicles/population and diesel vehicles/population compared with other cities. Moreover, cities in cluster one had characteristics opposite to Perth's features. These cities, for instance, had the lowest level of petrol consumption and the highest level of diesel demand. Moreover, cities in clusters one and three had fewer public transport options than Perth.

The commuting distance and distribution costs were also significantly higher in regional cities compared with Perth. The stations located in clusters one and three were further from their nearest wholesalers and needed to pay more for transportation and distribution. They passed this cost to their consumers by increasing their prices. A lower population density and business activity resulted in less demand for petrol in regional areas than in metropolitan areas. Therefore, selling volumes were remarkably low in regional cities, forcing retailers to increase their prices to maintain their businesses. Generally, it can be argued that the margins of the retail petrol price depend on factors including distribution costs, sale volumes, the cost of storing fuel, and the level of competition. In regional areas, retailers have to pay more for transport, storage, and maintenance; therefore, they must mark up their prices to profit and retain their clients.

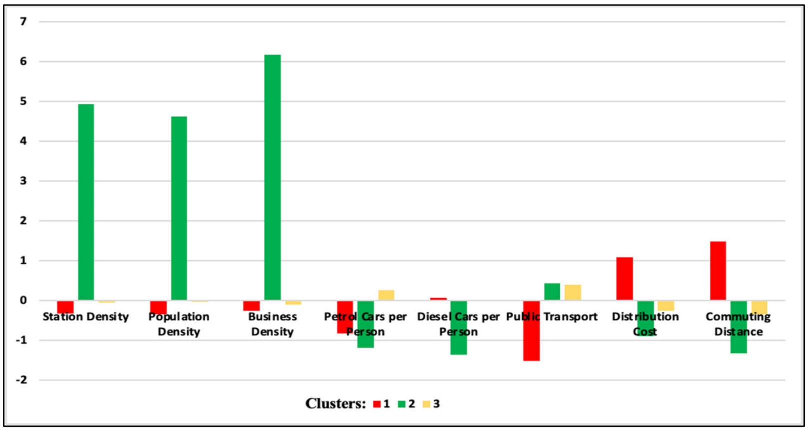

Figure 5. Cluster means of attributes in each cluster. Note: this figure used the information presented in Table 3 to show the cluster means of attributes in each of the three clusters more visibly.

In the previous section, cities were grouped according to similar characteristics. This study focused on finding factors that influenced petrol prices and caused price variances. Thus, in this part, it was vital to determine whether there was any significant difference in prices between the clusters. Consequently, we applied the Kruskal–Wallis test to find whether prices differed significantly between the clusters. The dataset contained the average prices of petrol for each WA city. Cities were classified into three clusters. This study tested the clusters to see whether there was a significant difference between the price means. The results related to the Kruskal–Wallis test are presented in Table 4. The p-value was less than the significance level of 0.05, which meant that there were significant differences in prices between the clusters. Each cluster had cities with similar characteristics, resulting in identical petrol prices. In addition, the mean petrol price varied between clusters.

Table 4. Kruskal–Wallis test.

Kruskal–Wallis Rank Sum Test		
Kruskal–Wallis chi-squared = 14.334	*df* = 2	*p*-value = 0.0007

Table 5 shows all the clusters, cities, and their characteristics. It also shows the average petrol prices in each city. Petrol prices differed significantly between cities, as shown in the graph. Perth had the lowest price of petrol, followed by cities located in cluster three. In contrast, cities in cluster one had higher petrol prices than Perth and most cities in cluster three. This indicated that petrol prices were similar between cities with similar characteristics. It can be argued that supply-side factors, demand-side factors, and city characteristics played significant roles in the petrol-pricing behavior of the cities.

Cities located in cluster one had lower station densities, population densities, business densities, and public transport facilities. In contrast, they had higher distribution costs and commuting distances than other cities. Generally, the findings showed that retail petrol prices tended to be more expensive in less-populated cities with fewer population and business densities, where the number of stations was low and distribution costs and commuting distances were high. The results were in line with the hypotheses stated in this research. For instance, as mentioned in hypothesis (2), cities with low-competition retail markets (low station density as a proxy of competition) had higher petrol prices.

Table 5. Results for cities ranked based on cluster.

Cluster	Cities	Region	Mean Petrol Prices	Station Density	Population Density	Business Density	Petrol Vehicles/Pop	Diesel Vehicles/Pop	Public Transport	Commuting Distance	Distribution Cost
1	Fitzroy	Kimberley	164.44	0.00007	0.1	0.002	0.192	0.132	0.523	42.1	768.8
1	Meekatharra	Midwest	154.75	0.00161	0	0.001	0.327	1.63	0.292	54	452.9
1	Norseman	Goldfield	154.11	0.00012	0	0	0.242	0.401	0.693	56.1	180.8
1	Ravensthorpe	Goldfield	146.83	0.00011	0.2	0.026	0.568	0.397	0.532	36.1	165.8
1	East-Pilbara	Pilbara	145.93	0.00518	0	0	0.175	0.375	0.272	67.8	450
1	Kambalda	Goldfield	143.36	0.00039	0	0.001	0.229	0.342	0.771	48.1	290.6
1	Kununurra	Kimberley	142.89	0.00001	0.1	0.006	0.364	0.185	0.587	28.5	1184.6
1	Coolgardie	Goldfield	138.91	0.00002	0.1	0.004	0.174	0.182	0.585	45.7	324.8
3	Kojonup	Great Southern	137.04	0.00004	0.7	0.173	0.636	0.468	0.757	17.7	149.8
3	Moora	Wheatbelt	133.54	0.0013	0.6	0.1	0.59	0.889	0.767	20.1	148.3
3	Dalwallinu	Wheatbelt	143.04	0.0021	0.2	0.127	0.875	0.349	0.723	23.2	217.6
3	Carnarvon	Gascoyne	145.97	0.00031	0.1	0.014	0.451	0.419	0.663	9.3	442.8
3	Esperance	Goldfield	138.95	0.00013	0.3	0.039	1.001	0.383	0.829	13.9	8.4
3	Exmouth	Gascoyne	158.67	0.00004	0.4	0.043	0.436	0.257	0.652	6.1	498.1
3	Kalgoorlie	Goldfield	141.73	0.00003	0.3	0.021	0.573	0.465	0.799	10.2	339.1
3	Mt Barker	Great Southern	134.58	0.00038	1.1	0.149	0.641	0.405	0.878	24.4	50.6
3	Broome	Kimberley	154.09	0.00055	0.3	0.023	0.413	0.01	0.692	7.3	462.1
3	Irwin	Midwest	136.12	0.00013	1.5	0.168	0.614	0.154	0.827	18.6	50
3	Port Hedland	Pilbara	146.16	0.00481	0.8	0.037	0.436	0.498	0.71	10.6	2.2
3	Karratha	Pilbara	149.89	0.00299	1.5	0.063	0.444	0.445	0.302	19.5	188.7
3	B-Town	Southwest	137.62	0.011	3.5	0.369	0.648	0.323	0.834	19.1	200.4
3	Manjimup	Southwest	138.14	0.00015	1.3	0.175	0.569	0.597	0.822	15	183.3
3	Cunderdin	Wheatbelt	136.13	0.00091	0.6	0.075	0.661	0.643	0.782	21	127.5
3	Meckering	Wheatbelt	136.13	0.00045	0.6	0.075	0.661	0.706	0.818	21	107.3

Table 5. *Cont.*

Cluster	Cities	Region	Mean Petrol Prices	Station Density	Population Density	Business Density	Petrol Vehicles/Pop	Diesel Vehicles/Pop	Public Transport	Commuting Distance	Distribution Cost
3	Tammin	Wheatbelt	134.67	0.0008	0.4	0.044	0.564	0.715	0.696	19.8	150
3	Narrogin	Wheatbelt	133.54	0.00094	3.1	0.299	0.573	0.48	0.838	10.3	152.6
3	Williams	Wheatbelt	134.38	0.00054	0.4	0.076	0.601	0.115	0.75	21.3	136.2
3	Geraldton	Midwest	138.41	0.00534	139.1	0.062	0.199	0.583	0.856	6.6	0.4
3	Albany	Great Southern	137.57	0.00001	8.8	0.806	0.857	0.178	0.867	20.5	1.9
3	Denmark	Great Southern	137.56	0.0002	3.3	0.397	2.257	0.823	0.812	19	50.1
3	Waroona	Peel	137.17	0.00102	5	0.375	0.645	0.957	0.88	27.8	69.3
3	Mandurah	Peel	134.41	0.00062	259	8.376	0.628	0.528	0.871	25.5	33.5
3	Murray	Peel	136.48	0.00295	10.4	0.659	0.54	0.529	0.885	28	32.4
3	Augusta	Southwest	138.74	0.03296	7.4	0.943	0.59	0.296	0.824	14	257.3
3	Busselton	Southwest	137	0.00951	26.8	2.748	0.581	0.312	0.854	19.2	162.1
3	Capel	Southwest	138.07	0.00256	32.3	2.036	0.55	0.401	0.833	21.2	130.1
3	Dardanup	Southwest	137.16	0.00156	27.3	1.497	0.516	0.48	0.862	18.4	129.9
3	D-Brook	Southwest	138.15	0.00521	3.9	0.451	0.601	0.314	0.784	29.4	248.5
3	Harvey	Southwest	135.09	0.00015	16.1	0.913	0.604	0.597	0.858	22.6	95
3	York	Wheatbelt	133.78	0.03091	1.7	0.186	0.743	0.206	0.824	24.3	78
3	Northam	Wheatbelt	135.66	0.00704	7.8	0.558	0.632	0.267	0.874	19.9	77.1
3	Bunbury	Southwest	138.11	0.01255	95.2	1.917	0.677	0.293	0.885	13	122.4
3	Dandaragan	Wheatbelt	135.93	0.00184	0.5	0.075	0.62	0.418	0.736	35.4	143.1
2	Perth	Perth	131.39	0.05749	320.9	28.39	0.184	0.057	0.809	5	8.5

5.2. Regression Analysis

Due to the identical size of this variable between the cities, the wholesale petrol price (or crude oil price) was not included in the cluster analysis. It was expected that changes in the wholesale prices (or crude oil prices) had varying effects on the retail prices in each city, causing different pricing behaviors. Hence, we examined models A and B using Equation (6) to identify the effect of the wholesale price (or crude oil price) on retail petrol prices across cities. Table 6 presents the estimated results by considering the wholesale petrol price as an explanatory variable, and Table 7 presents the results of the same estimation by considering crude oil prices as an explanatory variable.

Table 6. The relationship between the retail petrol price and wholesale petrol price. Model A: $logp_{it} = \alpha_i + \beta_i\, logx_{it} + \varepsilon_{it}$.

City	α_i			β_i (x_{it} = Wholesale Price)			$\overline{R^2}$	AIC	Schwarz Criterion	HQC
	Coef.	Std. Error	p-Value	Coef.	Std. Error	p-Value				
Exmouth	1.728	0.065	0.000	0.678	0.013	0.000	0.687	−4.642	−4.634	−4.639
Fitzroy	5.208	0.005	0.000	0.017	0.001	0.000	0.320	−9.996	−9.982	−9.991
Coolgardie	0.621	0.049	0.000	0.900	0.010	0.000	0.866	−4.629	−4.621	−4.626
Esperance	0.763	0.021	0.000	0.869	0.004	0.000	0.916	−5.227	−5.223	−5.226
Albany	0.082	0.012	0.000	1.006	0.002	0.000	0.929	−5.116	−5.114	−5.115
Denmark	0.724	0.048	0.000	0.876	0.010	0.000	0.863	−4.653	−4.644	−4.650
Kojonup	0.490	0.032	0.000	0.925	0.007	0.000	0.913	−5.067	−5.061	−5.065
Mt Barker	0.706	0.043	0.000	0.876	0.009	0.000	0.840	−4.475	−4.468	−4.472
Irwin	1.373	0.023	0.000	0.748	0.005	0.000	0.849	−4.864	−4.861	−4.863
Waroona	0.686	0.024	0.000	0.870	0.005	0.000	0.943	−5.634	−5.628	−5.631
Augusta	2.079	0.020	0.000	0.598	0.004	0.000	0.786	−4.884	−4.882	−4.883
B-Town	0.612	0.034	0.000	0.896	0.007	0.000	0.896	−4.927	−4.921	−4.924
Bunbury	0.894	0.026	0.000	0.840	0.005	0.000	0.820	−4.421	−4.419	−4.420
Busselton	1.387	0.015	0.000	0.739	0.003	0.000	0.871	−5.067	−5.065	−5.066
Capel	0.221	0.041	0.000	0.977	0.009	0.000	0.810	−4.053	−4.050	−4.052
Dardanup	0.898	0.025	0.000	0.833	0.005	0.000	0.891	−5.027	−5.023	−5.025
D-Brook	1.235	0.023	0.000	0.769	0.005	0.000	0.913	−5.436	−5.431	−5.434
Manjimup	0.134	0.025	0.000	0.996	0.005	0.000	0.858	−4.365	−4.363	−4.364
Harvey	1.132	0.028	0.000	0.787	0.006	0.000	0.836	−4.661	−4.658	−4.660
Cunderdin	2.596	0.078	0.000	0.483	0.016	0.000	0.591	−4.373	−4.358	−4.367
Meckering	1.733	0.095	0.000	0.662	0.020	0.000	0.651	−3.996	−3.981	−3.990
Tammin	2.540	0.106	0.000	0.492	0.022	0.000	0.449	−3.762	−3.747	−3.756
Dandaragan	1.504	0.025	0.000	0.723	0.005	0.000	0.939	−5.941	−5.933	−5.938
Moora	0.583	0.021	0.000	0.899	0.004	0.000	0.960	−5.940	−5.934	−5.938
Narrogin	0.409	0.030	0.000	0.933	0.006	0.000	0.926	−5.222	−5.216	−5.219
Williams	0.479	0.035	0.000	0.922	0.007	0.000	0.896	−4.869	−4.863	−4.866
York	0.811	0.046	0.000	0.852	0.010	0.000	0.868	−4.757	−4.749	−4.754
Norseman	1.314	0.018	0.000	0.776	0.004	0.000	0.973	−6.647	−6.639	−6.644
Broome	3.929	0.008	0.000	0.009	0.000	0.000	0.852	−4.113	−4.109	−4.112
Meekatharra	2.621	0.024	0.000	0.504	0.005	0.000	0.845	−5.616	−5.610	−5.613
Karratha	1.414	0.032	0.000	0.749	0.007	0.000	0.807	−4.561	−4.557	−4.559
Carnarvon	2.428	0.022	0.000	0.532	0.005	0.000	0.812	−5.279	−5.275	−5.277
Kalgoorlie/Builder	1.707	0.019	0.000	0.674	0.004	0.000	0.818	−4.849	−4.847	−4.848
Kambalda	1.117	0.081	0.000	0.800	0.017	0.000	0.788	−4.305	−4.290	−4.299
Ravensthorpe	2.007	0.059	0.000	0.623	0.012	0.000	0.678	−4.243	−4.235	−4.240
Kununurra	1.773	0.032	0.000	0.669	0.007	0.000	0.807	−4.788	−4.783	−4.786
Port Hedland	0.469	0.029	0.000	0.941	0.006	0.000	0.829	−4.256	−4.253	−4.255
East Pilbara	1.418	0.071	0.000	0.749	0.015	0.000	0.810	−4.580	−4.566	−4.575
Dalwallinu	1.716	0.027	0.000	0.675	0.006	0.000	0.852	−5.091	−5.086	−5.089
Geraldton	0.031	0.036	0.000	1.013	0.008	0.000	0.731	−3.530	−3.528	−3.529
Mandurah	0.550	0.055	0.000	0.906	0.012	0.000	0.480	−2.674	−2.672	−2.673
Murray	0.550	0.065	0.000	0.906	0.014	0.000	0.480	−2.674	−2.671	−2.673
Northam	0.558	0.017	0.000	0.904	0.003	0.000	0.983	−6.790	−6.782	−6.787
Perth	0.730	0.021	0.000	0.868	0.004	0.000	0.449	−2.634	−2.633	−2.634

Table 7. The relationship between the retail petrol price and crude oil price, Model A: $logp_{it} = \alpha + \beta_i \; logx_{it} + \varepsilon_{it}$.

City	α_0			β_i (x_{it} = Crude Oil Price)			$\overline{R^2}$	AIC	Schwarz Criterion	HQC
	Coef.	Std. Error	*p*-Value	Coef.	Std. Error	*p*-Value				
Exmouth	4.023	0.014	0.000	0.242	0.003	0.000	0.810	−5.143	−5.135	−5.140
Fitzroy	4.293	0.020	0.000	0.187	0.005	0.000	0.355	−3.613	−3.609	−3.611
Coolgardie	3.273	0.019	0.000	0.385	0.004	0.000	0.862	−4.598	−4.589	−4.595
Esperance	3.241	0.011	0.000	0.393	0.003	0.000	0.856	−4.512	−4.508	−4.511
Albany	3.184	0.008	0.000	0.404	0.002	0.000	0.773	−3.895	−3.894	−3.895
Denmark	3.217	0.021	0.000	0.396	0.005	0.000	0.847	−4.416	−4.407	−4.413
Kojonup	3.133	0.018	0.000	0.415	0.004	0.000	0.839	−4.266	−4.259	−4.263
Mt Barker	3.133	0.018	0.000	0.415	0.004	0.000	0.839	−4.266	−4.259	−4.263
Irwin	3.434	0.016	0.000	0.344	0.004	0.000	0.655	−3.636	−3.633	−3.635
Waroona	3.600	0.055	0.000	0.306	0.013	0.000	0.241	−2.077	−2.071	−2.074
Augusta	3.718	0.012	0.000	0.282	0.003	0.000	0.634	−3.942	−3.939	−3.941
B-Town	3.511	0.019	0.000	0.328	0.004	0.000	0.758	−4.228	−4.222	−4.226
Bunbury	3.376	0.010	0.000	0.360	0.002	0.000	0.825	−4.454	−4.451	−4.453
Busselton	3.538	0.009	0.000	0.320	0.002	0.000	0.737	−4.166	−4.164	−4.166
Capel/Colie	3.394	0.015	0.000	0.356	0.003	0.000	0.775	−4.160	−4.156	−4.158
Dardanup	3.354	0.016	0.000	0.364	0.004	0.000	0.751	−3.986	−3.982	−3.985
D-Brook	3.581	0.011	0.000	0.313	0.003	0.000	0.865	−5.037	−5.033	−5.036
Manjimup	3.295	0.014	0.000	0.379	0.003	0.000	0.702	−3.654	−3.652	−3.653
Harvey	3.275	0.017	0.000	0.378	0.004	0.000	0.728	−3.784	−3.780	−3.783
Cunderdin	4.036	0.031	0.000	0.204	0.007	0.000	0.574	−4.333	−4.318	−4.327
Meckering	3.715	0.038	0.000	0.278	0.009	0.000	0.626	−3.927	−3.912	−3.921
Tammin	4.036	0.042	0.000	0.201	0.010	0.000	0.409	−3.692	−3.678	−3.687
Dandaragan	3.416	0.055	0.000	0.347	0.013	0.000	0.377	−2.472	−2.464	−2.469
Moora	3.310	0.014	0.000	0.368	0.003	0.000	0.872	−4.779	−4.773	−4.777
Narrogin	3.277	0.014	0.000	0.375	0.003	0.000	0.877	−4.784	−4.778	−4.782
Williams	3.174	0.015	0.000	0.401	0.003	0.000	0.882	−4.697	−4.691	−4.695
York	3.289	0.025	0.000	0.373	0.006	0.000	0.779	−4.088	−4.080	−4.085
Norseman	3.677	0.014	0.000	0.316	0.003	0.000	0.886	−5.215	−5.207	−5.212
Broome	3.143	0.016	0.000	0.440	0.004	0.000	0.789	−3.821	−3.818	−3.820
Meekatharra	4.146	0.010	0.000	0.208	0.002	0.000	0.805	−5.411	−5.405	−5.409
Karratha	3.601	0.011	0.000	0.327	0.003	0.000	0.838	−4.737	−4.733	−4.735
Carnarvon	4.087	0.009	0.000	0.208	0.002	0.000	0.748	−5.086	−5.082	−5.084
Kalgoorlie/Builder	3.569	0.011	0.000	0.321	0.002	0.000	0.716	−4.055	−4.053	−4.054
Kambalda	3.501	0.033	0.000	0.338	0.008	0.000	0.768	−4.219	−4.204	−4.213
Ravensthorpe	3.889	0.026	0.000	0.255	0.006	0.000	0.601	−3.996	−3.988	−3.993
Kununurra	4.088	0.017	0.000	0.203	0.004	0.000	0.510	−4.088	−4.084	−4.087
Port Hedland	3.343	0.012	0.000	0.381	0.003	0.000	0.797	−4.158	−4.156	−4.157
East Pilbara	4.126	0.026	0.000	0.197	0.006	0.000	0.376	−3.603	−3.597	−3.601
Wubin/Dalwallinu	3.620	0.013	0.000	0.312	0.003	0.000	0.809	−4.634	−4.629	−4.632
Geraldton	3.326	0.018	0.000	0.372	0.004	0.000	0.548	−3.029	−3.027	−3.028
Mandurah	3.300	0.022	0.000	0.371	0.005	0.000	0.436	−2.582	−2.580	−2.582
Murray	3.299	0.073	0.000	0.372	0.017	0.000	0.441	−2.596	−2.581	−2.590
Northam	3.246	0.036	0.000	0.386	0.008	0.000	0.635	−3.313	−3.304	−3.310
Perth	3.288	0.008	0.000	0.374	0.002	0.000	0.480	−2.746	−2.745	−2.746

The estimated coefficients for α_i and β_i for each city were statistically significant at the 1% level when the explanatory variable was the wholesale price (see Table 6) or crude oil price (see Table 7). The effect of crude oil price and wholesale price on the retail petrol price was positive for all cities, which meant that an increase in the price of supplied petrol (crude oil or wholesale petrol) increased the retail prices, and the inverse behavior occurred when the prices decreased. This result was in line with hypothesis 4: when the cost of the supply-side factors increased, the price of petrol increased.

Moreover, the findings supported the view that cities had different reactions to changes in the wholesale or crude oil prices. As illustrated in Tables 6 and 7, the coefficients of the wholesale petrol prices or crude oil prices differed between cities, resulting in different prices. For instance, the wholesale price had the lowest coefficient regarding retail prices in Broome, Fitzroy, Cunderdin, Tammin, and Meekatharra. In contrast, the highest coefficients belonged to Port Hedland, Capel, Manjimup, Albany, and Geraldton. Despite the fact that Perth, Murray, Mandurah, and Geraldton had the lowest petrol prices, changes in crude oil prices and wholesale petrol prices were not the only reasons. Therefore, if these factors produced different petrol prices in these cities, the crude oil price coefficients would have been higher in these cities than elsewhere, but they were not. There were additional factors, such as city characteristics, that caused city-specific price variations. In addition, the estimated coefficients showed that retail petrol prices were more correlated with wholesale petrol prices than with crude oil prices.

In this section, we incorporated the variables considered in the cluster analysis into panel models to estimate the extent of their effect on petrol prices between cities. We considered three models: fixed-effects, random-effects, and hybrid models. As mentioned earlier, the main disadvantage of fixed-effects models is their inability to evaluate the effect of time-invariant variables, which are constant over time. The random-effects model can estimate the coefficients of time-invariant variables, but it may be biased by the correlation between the explanatory variables and the random individual effects. Allison [46] suggested a hybrid model to overcome these drawbacks. Hybrid models are good alternatives to standard random-effects and fixed-effects models because they provide estimates of time-variant variables and allow for the inclusion of time-invariant variables. The results of the fixed-effects, random-effects, and hybrid models are presented in Tables 8 and 9.

Table 8. Determinants that influenced the retail petrol price at a city level when considering the wholesale petrol price as a proxy for the upstream cost.

Variables	Model 1: Fixed Effects		Model 2: Random Effects		Model 3: Hybrid Model	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Wholesale price	0.838 ***	0.0027	0.838 ***	0.0027	0.838 ***	0.003
Mean (wholesale price)					0.618 ***	0.168
Station density			−0.220 **	0.6173	−0.433 **	0.638
Population density			0.004 *	0.0100	0.006 *	0.01
Business density			0.007	0.0081	0.008	0.008
Petrol vehicles/population			0.053 *	0.0312	0.05 *	0.031
Diesel vehicles/population			−0.030 *	0.0141	−0.024 *	0.015
Public transport			−0.049 *	0.0224	−0.059 *	0.024
Distribution cost			0.004	0.0081	0.007	0.008
Commuting distance			0.007	0.0091	0.004	0.013
Adj R^2	0.78		0.78		0.86	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The natural logarithms of all variables were considered in the models.

Table 9. Determinants that influenced the retail petrol price at a city level when considering the crude oil price as a proxy for the upstream cost.

Variables	Model 1: Fixed Effects		Model 2: Random Effects		Model 3: Hybrid Model	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Wholesale price	0.332 ***	0.001	0.332 ***	0.001	0.332 ***	0.001
Mean (wholesale price)					0.123 ***	0.015
Station density			−0.040 **	0.0119	−0.04 **	0.012
Population density			0.014 *	0.0116	0.015 *	0.012
Business density			0.011	0.0091	0.011	0.009
Petrol vehicles/population			0.043 *	0.0350	0.043 *	0.035
Diesel vehicles/population			−0.01 *	0.0151	−0.01 *	0.015
Public transport			−0.10 *	0.0253	−0.11 *	0.025
Distribution cost			0.011	0.0087	0.011	0.009
Commuting distance			0.07 *	0.0216	0.07 *	0.022
Adj R^2	0.77		0.77		0.86	

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The natural logarithms of all variables were considered in the models.

In Table 8, the upstream costs were proxied by the wholesale petrol price as an explanatory variable. Moreover, the crude oil price was considered a proxy for the upstream cost in Table 9 for the robustness check. The variables were statistically significant, with positive or adverse effects. It appears that the results were robust with the use of different upstream cost proxies and the findings were in line with the results of the clustering analyses. A comparison of the estimates from the fixed-effects model (model one) with those from the random-effects model (model two) and the hybrid model (model three) showed that the estimated results related to the time-variant variables (wholesale price and crude oil price) were the same between different models. Moreover, the estimated coefficients for time-invariant variables were almost similar in both the random-effects and hybrid models; there was a slight difference only in the coefficients' size, not in their signs. However, the effects of the time-invariant variables were inferred in accordance with the estimated results of the hybrid model considered in this study.

As presented in Table 8, the coefficient of the wholesale price on the retail petrol price was positive and significant (0.838), which implied that when the upstream costs increased, petrol stations needed to pay more for petrol, and thus, they passed this cost on to their consumers by increasing their prices. Furthermore, an increase in the number of petrol vehicles per capita was associated with higher petrol prices (petrol vehicles/population = 0.05), while an increase in the number of diesel vehicles per capita was associated with lower petrol prices (petrol vehicles/population = −0.024). This indicated a positive relationship between the number of petrol vehicles and petrol prices. The estimated results also showed that an increase in the demand for diesel vehicles could cause an increase in the demand for diesel and a decrease in the demand for petrol, leading to a decrease in petrol prices. These results supported hypothesis 3.

Population density (0.006) positively affected the retail prices of petrol. This result was in line with the findings of Vita [52], Chouinard and Perloff [27], Alm et al. [53], and Bello and Contín-Pilart [28]. The results meant that high-population-density cities had a greater demand for petrol, leading to higher prices.

In Table 8, the effect of station density as a proxy for the competition was significant and negative (−0.433), which meant that stations located in highly competitive markets had lower petrol prices. In cities such as Perth and Mandurah, the station density was higher than in other markets, and these cities had lower petrol prices. This finding revealed the validity of hypothesis 2. As a result, competition and petrol prices were negatively correlated. The price of petrol was lower in cities with more fuel stations. This result was in line with previous studies. For instance, Van Meerbeeck [5] and Yilmazkuday and Yilmazkuday [23] found a negative relation between station density and petrol prices. Moreover, Valadkhani and Babacan [29] found that the station density had a negative effect on the variations in the gross margin series in Australia.

The effect of public transport accessibility on the retail petrol price was significantly negative (−0.059). A sustainable transportation system would reduce reliance on private cars. In regional and remote areas, there are inadequate transportation facilities, and their citizens are highly dependent on using their own cars, which has led to a greater dependence on petrol. Therefore, it can be argued that the rising demand for private vehicles in cities with low public transport accessibility increases the demand for petrol, resulting in an increase in petrol prices. In addition, the results showed that business density, distribution costs, and commuting distance did not significantly impact the petrol price variations between cities. According to the estimated results, it can be argued that petrol/diesel vehicles per capita, station density, public transport, and population density were the significant determinants that resulted in the petrol price variations between cities. The findings were precisely in line with the hypotheses set out at the beginning of this paper. The results reported in Table 9 were similar to those in Table 8. The only difference was in the commuting distance variable, which was significant in the second analysis (0.07).

6. Conclusions

In contrast with the previous literature, by taking a regional perspective, this study aimed to answer the following two main questions: Why do petrol prices vary between cities? Which factors result in cross-sectional price variations? This study included new research that analyzed the determinants that affect petrol prices at the city level. This study classified cities into distinct groups by considering the similarities between the city-specific characteristics. This study examined a wide range of factors that lead to price disparities in petrol in WA's cities. In this study, cities were classified into three distinct groups and the Kruskal–Wallis test revealed a significant price difference in retail petrol prices between the clusters. The results showed that cities with similar characteristics and an identical range of petrol prices were placed in the same clusters. For instance, Kambalda, Norseman, Coolgardie, Kununurra, Fitzroy, East Pilbara, Ravensthorpe, and Meekatharra were in cluster one due to their similar features. Since these cities were located in remote regions with few public transportation options, their residents relied on their private transportation.

This study found that the characteristics of cities, as well as the demand- and supply-side factors, had a significant effect on price variations. It was also found that an increase in the initial cost of petrol (wholesale petrol prices or oil prices) had a significant positive effect on retail petrol prices. This finding was significant because it showed how different cities responded differently to variations in the wholesale or crude oil prices.

Furthermore, we estimated the coefficient of factors that resulted in petrol price differences between all WA cities. Wholesale price, oil price, petrol/diesel vehicles per capita, station density, population density, and public transport accessibility were the main determinants that contributed substantially to the variations in petrol prices between cities. It can be argued that a substantial part of the price disparity stemmed from the specific characteristics of cities, which affected the supply and demand of petrol and affected the pricing decisions at petrol stations. It should be noted that there was a difference of around 33 cents per liter (CPL) between the highest and the lowest petrol prices, which was not negligible. Therefore, this study can be used to enhance the market efficiency and showed that some cities need to be taken into consideration from a social welfare perspective. It also contributed significantly to the understanding of regional petrol markets in Australia. This study complements reports by the Australian Competition and Consumer Commission that state petrol prices differ between Australia's cities and towns.

Petrol prices in regional Australian cities are higher than in capital cities. Consequently, high prices place financial pressures on consumers, mainly on households living in regional and remote cities where public transportation facilities are limited. Furthermore, regional Australian citizens experience the effects of high petrol prices more severely because they must drive long distances to reach destinations, and they have fewer options of where to buy petrol than residents of metropolitan areas where there are plenty of petrol stations. Thus, the petrol price plays a vital role in regional cities. The practical implications of this study can be represented as follows. First, the findings help regional agents to understand the retail petrol markets more accurately. The findings provide critical information for economic agents that interact in this market. To assist drivers in regional areas that are under price pressure, they can consider factors that affect petrol prices and improve these factors. For example, in cities with significantly higher petrol prices, improving public transport facilities would increase consumer satisfaction more effectively.

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References

1. Australian Competition and Consumer Commission. *Report on the Australian Petroleum Market, December Quarter 2021*; ACCC: Canberra, ACT, Australia, 2021.
2. Australian Competition and Consumer Commission. *Report on the Australian Petroleum Market, December Quarter 2019*; ACCC: Canberra, ACT, Australia, 2019.
3. Australian Competition and Consumer Commission. *Petrol Prices and Australian Consumers: Report of the ACCC Inquiry into the Price of Unleaded Petrol*; ACCC: Canberra, ACT, Australia, 2007.

4. Australian Competition and Consumer Commission. *Fuel in Regional Australia*; ACCC: Canberra, ACT, Australia, 2018.
5. Van Meerbeeck, W. Competition and local market conditions on the Belgian retail gasoline market. *Economist* **2003**, *151*, 369–388. [CrossRef]
6. Hosken, D.; Mcmillan, R.; Taylor, C. Retail gasoline pricing: What do we know? *Int. J. Ind. Organ.* **2008**, *26*, 1425–1436. [CrossRef]
7. Taylor, C.T.; Kreisle, N.M.; Zimmerman, P.R. Vertical relationships and competition in retail gasoline markets: Empirical evidence from contract changes in Southern California: Comment. *Am. Econ. Rev.* **2010**, *100*, 1269–1276. [CrossRef]
8. Ghazanfari, A. Regional Patterns for the Retail Petrol Prices. *Int. J. Energy Econ. Policy* **2021**, *11*, 383–397. [CrossRef]
9. Tappata, M.; Yan, J. Competition in retail petrol markets. *Aust. Econ. Pap.* **2017**, *56*, 201–218. [CrossRef]
10. Kvasnička, M.; Staněk, R.; Krčál, O. Is the retail gasoline market local or national? *J. Ind. Compet. Trade* **2018**, *18*, 47–58. [CrossRef]
11. Valadkhani, A.; Anwar, S.; Ghazanfari, A.; Nguyen, J. Are petrol retailers less responsive to changes in wholesale or crude oil prices when they face lower competition? The case of Greater Sydney. *Energy Policy* **2021**, *153*, 112278. [CrossRef]
12. Australian Competition and Consumer Commission. *Petrol Price Cycles in Australia*; ACCC: Canberra, ACT, Australia, 2018.
13. Eckert, A.; West, D.S. Retail gasoline price cycles across spatially dispersed gasoline stations. *J. Law Econ.* **2004**, *47*, 245–273. [CrossRef]
14. Barron, J.M.; Taylor, B.A.; Umbeck, J.R. Number of sellers, average prices, and price dispersion. *Int. J. Ind. Organ.* **2004**, *22*, 1041–1066. [CrossRef]
15. Clemenz, G.; Gugler, K. Locational choice and price competition: Some empirical results for the Austrian retail gasoline market. *Empir. Econ.* **2006**, *31*, 291–312. [CrossRef]
16. Cooper, T.E.; Jones, J.T. Asymmetric competition on commuter routes: The case of gasoline pricing. *South. Econ. J.* **2007**, *17*, 483–504. [CrossRef]
17. Houde, J.-F. Spatial differentiation and vertical mergers in retail markets for gasoline. *Am. Econ. Rev.* **2012**, *102*, 2147–2182. [CrossRef]
18. Pennerstorfer, D. Spatial price competition in retail gasoline markets: Evidence from Austria. *Ann. Reg. Sci.* **2009**, *43*, 133–158. [CrossRef]
19. Zimmerman, R. The competitive impact of hypermarket retailers on gasoline prices. *J. Law Econ.* **2012**, *55*, 27–41. [CrossRef]
20. Ghazanfari, A.; Razmjoo, A. The effect of market isolation on competitive behavior in retail petrol markets. *Sustainability* **2022**, *14*, 8102. [CrossRef]
21. Noel, M.D.; Qiang, H. The role of information in retail gasoline price dispersion. *Energy Econ.* **2019**, *80*, 173–187. [CrossRef]
22. Haucap, J.; Heimeshoff, U.; Siekmann, M. *Price Dispersion and Station Heterogeneity on German Retail Gasoline Markets*; DICE Discussion Paper; DICE: Düsseldorf, Germany, 2015.
23. Yilmazkuday, D.; Yilmazkuday, H. Understanding gasoline price dispersion. *Ann. Reg. Sci.* **2016**, *57*, 223–252. [CrossRef]
24. Valadkhani, A.; Chen, G.; Anderson, J. A cluster analysis of petrol profit margins across various regional and urban locations in Australia. *Australas. J. Reg. Stud.* **2014**, *20*, 159–184.
25. Rietveld, P.; van Woudenberg, S. Why fuel prices differ. *Energy Econ.* **2005**, *27*, 79–92. [CrossRef]
26. Burke, J.; Nishitateno, S. Gasoline prices, gasoline consumption, and new-vehicle fuel economy: Evidence for a large sample of countries. *Energy Econ.* **2013**, *36*, 363–370. [CrossRef]
27. Chouinard, H.H.; Perloff, J.M. Gasoline price differences: Taxes, pollution regulations, mergers, market power, and market conditions. *BE J. Econ. Anal. Policy* **2007**, *7*, 1–28. [CrossRef]
28. Bello, A.; Contín-Pilart, I. Taxes, cost and demand shifters as determinants in the regional gasoline price formation process: Evidence from Spain. *Energy Policy* **2012**, *48*, 439–448. [CrossRef]
29. Valadkhani, A.; Babacan, A. Modelling how much extra motorists pay on the road? A cross-sectional study of profit margins of unleaded petrol in Australia. *Energy Policy* **2014**, *69*, 179–188. [CrossRef]
30. Iglesias, F.; Kastner, W. Analysis of similarity measures in times series clustering for the discovery of building energy patterns. *Energies* **2013**, *6*, 579–597. [CrossRef]
31. Gillingham, K. Identifying the elasticity of driving: Evidence from a gasoline price shock in California. *Reg. Sci. Urban Econ.* **2014**, *47*, 13–24. [CrossRef]
32. Liu, D.; Wang, J.; Wang, H. Short-Term wind speed forecasting based on spectral clustering and optimised echo state networks. *Renew. Energy* **2015**, *78*, 599–608. [CrossRef]
33. Steinhaus, H. Sur la division des corps materiels en parties. *Bull. Acad. Polon. Sci* **1956**, *1*, 801.
34. Ball, G.H.; Hall, D.J. *ISODATA, a Novel Method of Data Analysis and Pattern Classification*; Stanford Research Institute: Menlo Park, CA, USA, 1965.
35. Lloyd, S. Least squares quantization in PCM. *IEEE Trans. Inf. Theory* **1982**, *28*, 129–137. [CrossRef]
36. Guha, P. Application of multivariate-rank-based techniques in clustering of big data. *Vikalpa* **2018**, *43*, 179–190. [CrossRef]
37. Kaur, N.; Sahiwal, J.K.; Kaur, N. Efficient K-Means clustering algorithm using ranking method in data mining. *Int. J. Adv. Res. Comput. Eng. Technol.* **2012**, *1*, 85–91.
38. Kruskal, W.H.; Wallis, W.A. Use of ranks in one-criterion variance analysis. *J. Am. Stat. Assoc.* **1952**, *47*, 583–621. [CrossRef]
39. Corder, G.W.; Foreman, D.I. *Nonparametric Statistics for Non-Statisticians*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
40. Hoffman, J.I. *Biostatistics for Medical and Biomedical Practitioners*; Academic Press: Cambridge, MA, USA, 2015.

41. Baltagi, B.H.; Liu, L. The Hausman–Taylor panel data model with serial correlation. *Stat. Probab. Lett.* **2012**, *82*, 1401–1406. [CrossRef]
42. Breusch, T.; Ward, M.B.; Nguyen, H.T.M.; Kompas, T. On the fixed-effects vector decomposition. *Political Anal.* **2011**, *19*, 123–134. [CrossRef]
43. Hausman, J.A.; Taylor, W.E. Panel data and unobservable individual effects. *Econom. J. Econom. Soc.* **1981**, *49*, 1377–1398.
44. Bell, A.; Jones, K. Explaining fixed effects: Random effects modelling of time-series cross-sectional and panel data. *Political Sci. Res. Methods* **2015**, *3*, 133–153. [CrossRef]
45. Schunck, R. Within and between estimates in random-effects models: Advantages and drawbacks of correlated random effects and hybrid models. *Stata J.* **2013**, *13*, 65–76. [CrossRef]
46. Allison, D. *Fixed Effects Regression Models*; SAGE Publications: New York, NY, USA, 2009; p. 160.
47. Raudenbush, S.W.; Bryk, A.S. *Hierarchical Linear Models: Applications and Data Analysis Methods*; SAGE Publications: New York, NY, USA, 2002; Volume 1.
48. Australian Competition and Consumer Commission. *Fuel Facts: What Drives Fuel Prices in Regional Australia*; ACCC: Canberra, ACT, Australia, 2012.
49. Australian Institute of Petroleum. *Inquiry into Fuel Prices in Regional Victoria*; The Victorian Economic, Education, Jobs and Skills Committee: Canberra, ACT, Australia, 2017.
50. Australian Bureau of Statistics. *Census Data by Geography*; Australian Bureau of Statistics: Canberra, ACT, Australia, 2018.
51. Australian Bureau of Statistics. *Survey of Motor Vehicle Use, Australia*; Australian Bureau of Statistics: Canberra, ACT, Australia, 2018.
52. Vita, M.G. Regulatory restrictions on vertical integration and control: The competitive impact of gasoline divorcement policies. *J. Regul. Econ.* **2000**, *18*, 217–233. [CrossRef]
53. Alm, J.; Sennoga, E.; Skidmore, M. Perfect competition, urbanization, and tax incidence in the retail gasoline market. *Econ. Inq.* **2009**, *47*, 118–134. [CrossRef]
54. Lee, S.-Y. *Spatial Competition in the Retail Gasoline Market: An Equilibrium Approach Using SAR Models*; Department of Economics, The Ohio State University: Columbus, OH, USA, 2007.
55. Li, T.; Sipe, N.; Dodson, J. Social and spatial effects of transforming the private vehicle fleet in Brisbane, Australia. *Transp. Res. Part D Transp. Environ.* **2017**, *51*, 43–52. [CrossRef]
56. Balaguer, J.; Ripollés, J. Do classes of gas stations contribute differently to fuel prices? Evidence to foster effective competition in Spain. *Energy Policy* **2020**, *139*, 111315. [CrossRef]
57. Radchenko, S. Oil price volatility and the asymmetric response of gasoline prices to oil price increases and decreases. *Energy Econ.* **2005**, *27*, 708–730. [CrossRef]
58. Tsuruta, Y. What affects intranational price dispersion? The case of Japanese gasoline prices. *Jpn. World Econ.* **2008**, *20*, 563–584. [CrossRef]