

# How Do Housing Characteristics Affect Residential Properties Prices In Auckland, New Zealand Before and After COVID-19?

Rosalina Siu

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## Attestation

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

*RSiu*

## Abstract

My study investigates how housing characteristics affect housing prices on residential properties in Auckland, New Zealand. It also examines the effect of these characteristics on property prices before and after the COVID-19 pandemic. For this purpose, I use a random sample of residential property transactions in Auckland, New Zealand for the years 2016 and 2021. Using hedonic regression models, the results show that each housing characteristic has a unique contribution to a property's price. They show that every housing characteristic is statistically significant, except for the number of bedrooms in 2016. For 2021, only floor area and land area are statistically significant. The coefficient signs are as expected for almost every housing characteristic. In particular, a 10-meter squared increase in floor area is correlated with around 2.8% increase in the sale price, *ceteris paribus*. Consumers' willingness to pay has also shifted from 2016, as they are more willing to pay per unit of land area in 2016 than in 2021.

## Chapter 1: Introduction

The hedonic housing prices literature has extensively studied the value of housing amenities and how they are reflected in housing prices. These amenities can include environmental factors, location, number of bedrooms, bathrooms, and more. They are usually classified as either public or property-specific amenities. Hedonic regression is commonly known for its use in estimating demand or values. It is a technique used in real estate economics, to address the challenges associated with studying a highly heterogeneous good, such as buildings. Due to the vast differences between individual buildings, estimating demand for buildings as a whole can be challenging. Therefore, a building can be disassembled into characteristics such as the number of bedrooms, the number of bathrooms, or its lot size. This allows for estimates of the contributory value of each characteristic. While most people expect housing attributes to increase housing prices, studies have also shown that housing attributes can also decrease housing prices or have zero effect. Housing markets worldwide also experience fluctuations in housing prices due to recent changes and unexpected global events. They are exposed to different economic cycles that can cause variations in housing prices over time.

The way in which housing prices are affected by various factors differs from country to country. Several studies conducted in the UK and the USA show a significant rise in real house prices. This trend is observed during the boom-bust cycles of the housing market. However, it is not always true for housing characteristics themselves, as changes in their valuations may not necessarily impact housing prices. In addition, other factors, such as household income, are also related to housing prices. During the boom and recovery periods, the value of housing attributes decreases while a housing downturn leads to an increase in the prices of housing amenities—conversely, a change in household income results in a shift in the demand for houses. As income increases, the demand for housing amenities also increases, and vice versa.

The COVID-19 pandemic has led to significant changes in housing preferences, particularly in OECD countries like New Zealand. As a result of the pandemic, many people are now required to work from home, which has reduced the need for commuting and helped prevent the spread

of COVID-19. This shift towards remote work has also resulted in a change in housing demand from high-population density areas to low-population density areas. People are now spending more time at home, which means they need more space for teleworking and access to a better environment where the disease is less likely to spread.

The New Zealand housing market has experienced a significant shift in housing prices since the outbreak of COVID-19. The country has witnessed one of the highest upsurges in house prices in the world, with an increase of about 20% in 2020. According to the QV House Price Index, there was an average growth of 10.8% in house prices during the same year. Despite the expected decline in housing prices due to the pandemic, there was a significant growth in housing prices from the last quarter of 2020 towards 2021<sup>1</sup>. The Reserve Bank of New Zealand has provided information on why this was the case. The reason behind this growth is the insufficient supply of housing to meet the soaring demand since the outbreak of COVID-19. Due to supply constraints, there has been limited availability of housing materials, and the number of workers has reduced as borders started to close and lockdown restrictions were put in place. This study therefore takes into account the changes in the values of certain housing characteristics before and after the pandemic.

Housing prices have become a topic of interest, particularly in understanding the factors that drive them. Previous studies have mainly focused on macro-economic factors as the key drivers of housing prices. However, this paper aims to contribute to the existing literature by exploring how housing characteristics contribute to housing prices in Auckland (one of the most expensive cities), New Zealand.

Two different models are used to estimate the hedonic regressions. The study period spans from 2016 to 2021. While 2019 best represents the pre-COVID era, the primary focus of the study is on the years 2016 and 2021, which were randomly selected to observe housing price variations over a five-year period. Although it may not directly reflect housing price changes from 2019

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<sup>1</sup> <https://www.rbnz.govt.nz/statistics/key-statistics/housing>. House prices were above sustainable levels. The underlying demand for housing decreased significantly, and mortgage interest rates were rising.

before the pandemic, the results indicate a significant shift in housing prices in 2021, after the pandemic. The 2016 pre-COVID period is also evident in a study by Yiu (2023).

The analysis shows that all housing characteristics except the number of bedrooms in 2016, are statistically significant at 1% and/or 5% significance levels. In 2021, only floor and land area are statistically significant at the 1% and/or 10% significance levels, respectively. The Semi-Log model indicates that about 81% of the observations in the 2021 sample have an increasing effect on housing prices due to an increase in land area. This represents an approximate 1% increase from 2016. The average partial effects for both years are significant, except for the number of bedrooms in 2016. Land area and floor area have larger magnitudes in 2016 than in 2021, indicating an increasing effect on house prices but at a diminishing rate. Under the Box-Cox model, the results are similar, with most of the observations having an increasing effect on housing prices. The average partial effect of bedrooms is now significant at the 5% significance level in 2021 and remained insignificant in 2016. The same magnitudes are observed compared to the previous results obtained using the Semi-Log model.

The analysis of variances for each housing attribute is also tested. The ANOVA results prove that sale prices, floor area, bedrooms, bathrooms, and garages are statistically significant. In other words, there are legitimate results on how housing characteristics are statistically significantly different between the two years. Thus, the increase in house prices in recent years is also due to changes in housing characteristics. People's willingness to pay for land area, bathrooms, and garages has shifted since 2016. Consumers are more willing to pay per unit of land area in 2016 than those in 2021. The same is true for bathrooms. People are not willing to pay a premium for having more of either of the two housing characteristics in a single property in 2021. Garages appear to have negative coefficients in both years. It can be said that it has shifted from being a dis-amenity in 2016 to being neutral in 2021.

This paper is structured as follows: Section 2 reviews relevant literature, Section 3 describes the dataset, Section 4 presents the methodology and analyses results, and Section 5 concludes the paper.

## Chapter 2: Literature Review

Numerous research studies have been conducted on the hedonic modelling theory since its inception in the 1960s. Lancaster (1966) developed a hedonic model using his consumer theory, which provided groundbreaking research on hedonic utility. He argued that goods themselves do not necessarily create utility but are rather valued for their individual characteristics. For example, the utility of owning an expensive phone serves a consumer for several purposes, such as advanced technology in communication and more and better-quality features. Thus, a good's utility does not come from the good itself but rather the aggregated utility derived from its associated characteristics. Moreover, Lancaster established the idea that goods can also be categorized into groups based on the characteristics they possess. For instance, house purchasers base their decisions on housing characteristics such as the number of bedrooms, bathrooms, etc. Following this approach, Rosen (1974) postulated a theory of the hedonic pricing model where he suggested that the total value of an item is the sum of the individual prices of its inherent attributes. In addition, goods such as housing can be disentangled into heterogeneous attributes to determine how each characteristic contributes to the total price.

Many scholarly papers have delved into the connection between housing attributes and their impact on housing prices by utilizing hedonic pricing models. Ball (1973) summarized empirical studies that examined housing prices and their associated features to determine the average value of each attribute. Researchers have shown great interest in determining which housing attributes are most valuable to consumers and how they are reflected in the market. Based on Ball's findings, it appears that high consumer valuations are mirrored in higher market prices, indicating that houses with more desirable attributes are more expensive than others. Ajide and Kareem (2010), Kim et al. (2015), and Mok et al. (1995) are some of the researchers who have explored similar research questions. While some studies have focused on overall housing attributes, including locational, structural, and neighbourhood features, others have concentrated on a specific amenity, as demonstrated in Andersson et al. (2010); Chen and Haynes (2015); Troy and Grove (2008); Yang et al. (2018); Yang et al. (2019).

Multiple studies have been conducted in New Zealand to estimate property prices and examine how housing attributes have evolved over time. Cheung and Fernandez (2021a) investigated whether the pandemic and strict lockdowns in New Zealand have brought significant changes to the dwelling price capitalization of open spaces and beaches. Their findings reveal that consumers' willingness to pay a premium on both open spaces and beaches has shifted after their experience of the pandemic. Consequently, some amenities that were positively or neutrally correlated with property prices before the pandemic now have a negative relationship with property prices after the pandemic. Another paper by Cheung and Fernandez (2021b) explored the housing price effects of green spaces including urban parks, regional reserves, and volcanic parks in Auckland, New Zealand. The study aimed to find the effects of the distance and size of the nearest green space on housing prices. They found that the size of the nearest regional and volcanic park has a positive effect on property prices, while the closest urban park has no effect. Thus, homebuyers' willingness to pay a higher property price increases if the nearest regional reserve and the volcanic park are larger. Moreover, homebuyers are in favour of larger regional reserves and volcanic parks, even if it means living further away from them.

In a study conducted by Yiu (2021), a comprehensive analysis of five countries was undertaken to understand the surge in house prices during the COVID-19 recession. The study focused on the real interest rate hypothesis and included New Zealand in its analysis. Both a one-country time-series regression model and a five-country panel regression model were used to analyze data just before and after the onset of the pandemic. The simultaneous increase in house prices across multiple countries following the COVID-19 outbreak suggested that it was likely due to a common shock rather than individual local factors. Results confirmed that the real interest rate had a significant negative impact on the growth rate of house prices, even after accounting for economic growth factors, unemployment, and cross-country fixed effects. Both the one-country and five-country regression models showed negative coefficients with a similar magnitude of the real interest rate's effect on house price changes. The empirical findings from the five housing markets indicated that a 1% decrease in the real interest rate led to a 1.5% increase in house prices during the COVID-19 recession period, all else being equal. In addition, factors

such as restrictions on foreign home buyers and the continuous increase in housing surplus in New Zealand were also considered, which ruled out the possibility of effects from migration and insufficient housing supply.

A recent study also conducted by Yiu (2023) provided an opportunity to test the impact of monetary policy on the New Zealand housing market during COVID-19. Through a time series regression analysis, the results confirmed that changes in mortgage rates have a significant negative effect on house prices, even when controlling for economic growth and housing supply. This effect was consistent whether the monetary policy was expansionary or contractionary. The robustness tests revealed that a 1% decrease/increase in mortgage rates led to a 5.6% rise/fall in house prices during the COVID period, *ceteris paribus*. Additionally, the results did not support the housing supply hypothesis in the context of New Zealand.

Bicknell et al. (2005) conducted research on the New Zealand wine industry. They used a hedonic price analysis to investigate the relationship between wine prices and three characteristics of wine: grape variety, growing region, and quality. The authors found that the price of wine is influenced by both objective and subjective characteristics that are available to consumers before they make a purchase. Furthermore, the authors found that one of the wine experts' quality ratings significantly contributes to the price of wine, with noticeable differences across regions and grape varieties over time. These findings contradict the results of Schamel and Anderson (2003).

On the other hand, some studies have taken a different perspective on how the COVID-19 pandemic has affected the housing market in New Zealand. For instance, a study by Andres Fernandez and Martin (2022) examined the impact of affordable housing policies in Auckland, New Zealand, following the COVID-19 pandemic. The study found that a targeted program with an income threshold set between \$120,000 and \$150,000 maximizes house sales, while a threshold set at \$96,000 maximizes the number of moderate-income households becoming homeowners. Ali and Song (2022) conducted a study on the factors influencing customer use of New Zealand's real estate digital platforms during COVID-19. The research focused on Trade Me and realestate.co.nz, the two most popular platforms for homebuyers in New Zealand. The

study analyzed customer reviews on these platforms and found that perceived ease of use and usefulness, as well as information and system quality, are the main factors affecting customers' willingness to use real estate digital platforms. The study also observed that the impact of these factors on customer adoption of the platforms reduced after the spread of the pandemic.

Several recent empirical studies have investigated the impact of the COVID-19 pandemic on the housing sector. These studies have focused on changes in consumer demand and behaviours related to property purchases. For example, Ahrend et al. (2022) conducted a study on 13 OECD countries, which found that there has been a shift in housing demand from high population density areas or city centres towards more peripheral areas. This is due to a decrease in commuting and an increase in people working from home as a result of measures to prevent the spread of COVID-19. People's housing preferences have also changed, with a greater need for more space to accommodate teleworking and a desire for better access to high-quality environmental amenities. However, it is important to note that this study did not include New Zealand. Similarly, Guglielminetti et al. (2021) conducted a study in Italy which found that the pandemic has had a significant impact on housing demand, with people shifting from high-population density areas to low-population density areas. This change is mainly driven by a desire for more space within a single property with outdoor spaces (larger dwellings) and the need to be further away from areas where the disease is more contagious (locational preference). Other studies, such as Gupta et al. (2022) and Ramani and Bloom (2021) have documented similar findings.

Liu and Su (2021) conducted a study on how the COVID-19 pandemic has influenced the demand for housing locations in the USA housing market. They found evidence suggesting that people's preference for living in high population density areas has changed. The shift in demand is partly due to the reduced need for living close to jobs as more people prefer to work from home, and irregular visits to consumption amenities. In a study conducted in China, Liu and Tang (2021) explored the impact of an epidemic on housing prices. They discovered that the response of cities and communities to epidemic shocks is varied. Housing prices in affected communities have significantly decreased, while homebuyers are willing to pay a premium on

the average house price to avoid health risks. Another article by Chen and Luo (2022) has also documented changes in house prices pre- and post-pandemic.

Li and Zhang (2021) explored the spatial patterns and heterogeneous distribution of housing price changes across different areas of the U.S. real estate market during the COVID-19 pandemic. The impact of the COVID-19 pandemic on housing prices in the U.S. varied significantly across different regions. The influence of the crisis was observed to differ between urban and rural areas, as well as among different metropolitan areas. It was apparent that the pandemic made people more reluctant to purchase property in densely populated urban areas with high infection rates. Consequently, during the pandemic in 2020–2021, housing price increases were more commonly seen in affordable suburbs, smaller cities, and areas situated away from costly and densely populated urban centers.

Nguyen and Le (2023) analyzed how the COVID-19 pandemic and government policies affected real house prices in five emerging economies: Brazil, China, Thailand, Turkey, and South Africa. The researchers discovered that an increase in the number of confirmed COVID-19 cases led to higher housing prices, while government containment measures reduced them. Additionally, both traditional and non-traditional monetary policies implemented by central banks to address the impact of COVID-19 contributed to an increase in housing prices. Furthermore, these effects were amplified by the US monetary policy through global financial markets.

There is a significant amount of literature that has extensively developed hedonic pricing models to estimate prices in the housing market. Previous research in the UK and the United States has utilized hedonic pricing analysis to estimate property prices. This has resulted in a vast collection of evidence on how different housing traits affect housing prices, as seen in Ball (1973). In some studies, the results show a high degree of fit expressed by R-squared, with the presence of expected signs and significant variables, as in Wabe (1971). However, in contrast, some findings show contrasting results, with hardly any significant variables. For instance, the results in Evans (1973) differ considerably from Wabe's, where floor area appeared to be insignificant. This apparent inconsistency was due to several reasons including differences in

the independent variables (which in this case were the housing characteristics) included in the regression analysis, and that the dependent variables varied among the assessed papers. Other issues considered were data limitations, sample selection, and the fact that the local housing markets are not affected by the same variables.

A study by Cheung et al. (2021) aimed to investigate the effects of the pandemic on house prices using a price gradient approach. It was conducted in the COVID-19 epicentre in China and found that the results were consistent across different model specifications. The study revealed that the outbreak had reduced house prices in the epicentre by 5.0–7.0% year-on-year according to the price gradient model. Additionally, the study also used the hedonic pricing model, which indicated an immediate 4.8% reduction in house prices after the pandemic outbreak. Although house prices in the entire city rebounded after the lockdown, the price gradient from the epicentre to the urban periphery became less pronounced. This suggests that people have altered their preferences even though the risk is no longer limited to the epicentre. Essentially, people now favour living in low-density residential areas to avoid the risk of infection, resulting in a reduction of the price premium for high-density areas, which became negative after COVID-19 lockdowns.

Furthermore, hedonic models are estimated in several different ways. The most typical models that have been historically employed in the economics literature are particularly the Semi-Log and the Linear models. The former is explained by Malpezzi (2003) and Sirmans et al. (2005) as having the natural log of house price as the dependent variable, a logarithmic specification in the first stage of the hedonic equation, and is regressed on the absolute values of the independent variables in the second stage. Follain and Malpezzi (1980) provided some insights into the advantages of a Semi-Log form over a linear specification. These include the minimization of the heteroscedasticity problem, the ease of interpreting coefficients, and the ability to allow for variation in the dollar of each housing characteristic. Wilhelmsson (2000) used this methodology to evaluate the impact of traffic noise on single-family house values in Sweden. His findings showed a strong negative effect of traffic noise on house value, indicating that the Semi-Log model is preferred over other functional forms. Consistent with this study,

Hughes and Sirmans (1993); Palmquist (1992) have also studied the impacts of environmental attributes, specifically road traffic, on house values. Their results also demonstrate a negative relationship between traffic flow and housing prices.

The Box-Cox modelling approach has been widely used in a number of research papers. Some examples include Blomquist and Worley (1981); Cassel and Mendelsohn (1985); Eberts and Gronberg (1982); Goodman (1978); Halvorsen and Pollakowski (1981); Linneman (1980). However, previous studies have also criticized its use. For instance, while Goodman (1978) and Halvorsen and Pollakowski (1981) have generally rejected the linear model using a Box-Cox model, Cassel and Mendelsohn (1985) do not recommend the use of a Box-Cox transformation.

## Chapter 3: The Data

The data used in this research is the 10% random sample of residential property transactions in Auckland, New Zealand in 2016 and 2021, extracted from the Real Estate Institute of New Zealand. The original data set includes a total of 17 variables and 4,881 observations. The data set provides information on property transactions, and property and housing characteristics. Property characteristics include tenure, its location within the Auckland region, category, and building age. Housing characteristics include floor area and land area in 10 meters squared, the total number of bedrooms, bathrooms, and garages. Transaction characteristics include the sales method in which the property was sold, the valuation price, the transaction price, and the sale year.

Out of the initial 4,881 observations, several outliers and a few variables were left unused and omitted to fit the purpose of this research. This leaves 8 variables and 3,088 observations and two newly generated variables for regression analysis. There were 8 variables used for descriptive summary, and 6 were used for hedonic regressions. Several other criteria were employed to accommodate for the homogeneity of the properties included in the sample.

Properties are omitted if:

1. Land area is equal to 1 (24 observations)
2. Number of bathrooms is equal to 0 and greater than 5 (1,562 observations)
3. Number of bedrooms exceeds 8 (23 observations)
4. Number of garages is greater than 6 (160 observations)
5. Sale price is greater than \$5,000,000 (18 observations)

**Table 1***Summary statistics*

Variables	Observations	Mean	St. Deviation	Minimum	Maximum
			<u>2016</u>		
Sale price in NZD	1,462	1052140	578398.6	65000	5000000
Floor area in 10m <sup>2</sup>	1,460	16.38507	7.686689	2.9	73.4
Land area in 10m <sup>2</sup>	1,299	78.73264	49.30841	5.4	784.8
Number of bedrooms	1,462	3.47948	.9297297	1	8
Number of bathrooms	1,462	1.705198	.7909224	1	5
Number of garages	1,462	1.556088	.8276952	0	6
Valuation	1,372	739.8743	442.4348	33500	5900000
Building age	1,385	1975.112	25.53202	1880	2020
Variables	Observations	Mean	St. Deviation	Minimum	Maximum
			<u>2021</u>		
Sale price in NZD	1,626	1302843	659544.9	44000	4945000
Floor area in 10m <sup>2</sup>	1,581	15.42005	7.204333	2.1	55.6
Land area in 10m <sup>2</sup>	1,204	76.92558	90.55399	6	2346
Number of bedrooms	1,626	3.379459	1.110751	1	8
Number of bathrooms	1,626	1.777368	.8504866	1	5
Number of garages	1,626	2.235547	1.357551	0	6
Valuation	848	1014972	523047.4	2017	4500000
Building age	1,482	1978.138	26.60461	1860	2020

Table 1 shows the summary statistics for the dependent variables. The average sale price for houses increased in 2021 compared to 2016. However, the standard deviation for sale price in 2021 is more spread out from the mean given its high value, as opposed to 2016. This indicates an inconsistency in sale prices. This similar interpretation for sale price can also be applied to valuation as its mean and standard deviation have also increased from 2016. The housing characteristics are a little controversial, with floor and land area both decreasing in 2021, despite increased average sale prices. There are no significant differences in the mean values for

bedrooms, bathrooms, and garages for both years. The variations in the number of observations are due to missing data or incorrect data entry.

## Chapter 4: Methodology, Analysis and Results

The Semi-Log model

Malpezzi (2003) and Sirmans et al. (2005) describe this model as having the natural logarithm of house prices as the dependent variable. The model uses a logarithmic specification in the first stage of the hedonic equation, which is regressed on the absolute values of the independent variables in the second stage. The model is also known for its ease of interpretation and allows for variation in the dollar value of each characteristic.

The Semi-Log model is:

$$\log(\text{saleprice}) = \beta_0 + \beta_1 \text{floorarea} + \beta_2 \text{landarea} + \beta_3 \text{bedrooms} + \beta_4 \text{bathrooms} \\ + \beta_5 \text{garages} + u$$

**Table 2**

*Hedonic regression using the Semi-Log model*

Variables	Log sale price	
	2016	2021
Floor area in 10m <sup>2</sup>	.0280705*** (.0018487)	.0266532*** (.0022713)
Land area in 10m <sup>2</sup>	.0005374*** (.0002003)	.0002* (.0001167)
Number of bedrooms	.0191304 (.0138822)	.0238447 (.0148911)
Number of bathrooms	.0680989*** (.0169134)	.0234376 (.0166353)
Number of garages	-.0312234** (.0127223)	-.0011821 (.0076285)
Constant	13.12942*** (.0436076)	13.46954*** (.0406907)
Number of observations	1,299	1,189
R-squared	0.3577	0.2850

*Note.* Standard errors are presented in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

The Semi-Log model with interaction and quadratic terms:

$$\log(\text{saleprice}) = \beta_0 + \beta_1 \text{floorarea} + \beta_2 \text{landarea} + \beta_3 \text{landarea}^2 + \beta_4 \text{bedrooms} \\ + \beta_5 \text{floorarea} \cdot \text{bedrooms} + \beta_6 \text{bathrooms} + \beta_7 \text{garages} + u$$

**Table 2. 1***Hedonic regression using the Semi-Log model with interaction and quadratic terms*

Variables	Log sale price	
	2016	2021
Floor area in 10m <sup>2</sup>	.0404691*** (.0051763)	.0506322*** (.0053193)
Land area in 10m <sup>2</sup>	.0019998*** (.000382)	.0006504*** (.0002229)
Land area squared	-3.21e-06*** (7.19e-07)	-2.76e-07** (1.20e-07)
Number of bedrooms	.0735068*** (.0247258)	.1321613*** (.0256853)
Floor area*Bedrooms	-.0031948*** (.0012014)	-.0061734*** (.0012148)
Number of bathrooms	.0763707 *** (.0168406)	.0324727* (.0165489)
Number of garages	-.0394605*** (.0127684)	-.0048317 (.0075767)
Constant	12.84304*** (.0906157)	13.04219*** (.0892079)
Number of observations	1,299	1,189
R-squared	0.3702	0.2996

*Note.* Standard errors are presented in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

**Table 2. 2***Turning points and average marginal effects*

	Turning point		dy/dx	
	2016	2021	2016	2021
Land area	311.4953271	1178.26087	.0014947***	.0006082***
Bedrooms			.0193882	.028374*
Floor area			.0290305***	.0280103***
Number of observations	1,299	1,189	1,299	1,189

*Note.* \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

Table 2 includes the hedonic model estimates for two years, where the dependent variable is the log sale price. The log sale price is used instead of raw sale price values, as raw values tend to have outliers that are unlikely to have a normal distribution. Thus, taking the natural log of sale prices can transform the distribution closer to normality. The independent variables are the six physical housing characteristics: floor area, land area, bedrooms, bathrooms, and garages. The

coefficients for floor area, land area, bedrooms, and bathrooms indicate that they are positively correlated with the dependent variable in 2016. This means that on average, for every one-unit increase in each of these independent variables, the sale price also tends to increase.

Particularly, a 10-meter squared increase in floor area is correlated with around 2.8% increase in the sale price, *ceteris paribus*. Every housing characteristic is statistically significant at either the 1 or 5 percent significance level indicated by the significant stars, except for the number of bedrooms. For 2021, each housing characteristic has a positive coefficient except for bedrooms. Surprisingly, it appears to have a negative coefficient, indicating a negative relationship. The number of bedrooms, bathrooms, and garages is insignificant, which is very unexpected. The floor area and land area are statistically significant at the 1 and 10 percent significance levels respectively. The number of observations varies in both years due to missing or incorrect data. The model has been successful in explaining at least 30% of house prices, although it has decreased from 37.57% to 33.65%.

The above model as well as the approximate mean values for each housing characteristic can be used to calculate the average sale price over two years: For a 16-meter squared home with 78 meters squared of land area, 3 bedrooms, 1 bathroom, and 1 garage, it predicts an average house price of approximately \$904,133 for 2016. For 2021, the same house results in a predicted house price of around \$1,209,092, a significant increase 5 years later of a property's average sale price from its component parts. This simply means the same property is now worth more, about 33% increase from 2016 to 2021.

Table 2.1 contains results for the Semi-Log model with both quadratic and interaction terms; land area is now squared, and bedrooms is now interacted with floor area. This is to allow for non-linear effects, as I suspect the relationship between the linear dependent variables on the outcome variable is not perfectly linear. The results for both years reveal that every housing characteristic along with the interaction and quadratic terms are very statistically significant, except garages in 2021. In 2016, land area squared is now based on land area. The signs of these two coefficients imply that there is a diminishing effect of land area on sale price. This relationship is concave: as land area increases, house price increases but at a decreasing rate.

For example, the marginal effect for land area in 2016 is calculated as  $\frac{\Delta \log(\text{saleprice})}{\Delta \text{landarea}} = \frac{\% \Delta \text{saleprice}}{\Delta \text{landarea}} = .0019998 - 2(3.21e - 06) = 0.00199338$ . This is about 0.2% increase in

house price. Note that there is a slight difference between .0019998 and .00199338. The same is true for 2021, where there is also a decreasing marginal effect, but at a further decreasing rate of 0.06% (from 0.2% in 2016) increase in house price.

For the interaction term, the effect of the number of bedrooms depends on the level of floor area. Here, I use the mean value of floor area to calculate the partial effect of bedrooms on house price. The mean value of floor area in the 2016 sample is 16.38507. The partial effect can be calculated as  $.0735068 - .0031948(16.38507) = .02115977836$ . At the average floor area in 2016, the effect of bedrooms on house price is about 2.12%. An additional bedroom increases house price by approximately 2.21 standard deviations from the average house price. For 2021, the effect of bedrooms on house price is about 3.7% at the average floor area.

As shown in Table 2.2, about 81% of the observations in the 2021 sample have an increasing effect on housing prices as a result of increased land area, an approximate 1% increase from 2016. The remaining percentage of the observations after the turning point can be ignored, as this could be explained by two possible reasons: the estimated effect of land area on sale price is biased due to other factors that have not been controlled for, or because the functional relationship between land area and sale price in the equation used is not entirely correct. The average partial effects for two years are all significant except for bedrooms in 2016. Land area and floor area have larger magnitudes in 2016 than in 2021: an increasing effect on house prices but at a diminishing rate.

#### The Box-Cox model

The Box-Cox model is another hedonic pricing model commonly employed in the economics literature. Following previous research papers (Goodman, 1978) and (Halvorsen & Pollakowski, 1981), this model is known for its better fit for the data although it also has its complications. The use of this model in addition to the Semi-Log model should provide

consistent results as in the first model with not so much difference. The specification used in this paper is as follows. Note that I only transform the outcome variable but not the regressors.

The basic Box-Cox transformation is:

$$\frac{Y^\lambda - 1}{\lambda} \text{ where } Y = \text{saleprice and the value of the lambda emerges from the model}$$

$$\begin{aligned} \text{boxcoxsaleprice}^\lambda \\ = \beta_0 + \beta_1 \text{floorarea} + \beta_2 \text{landarea} + \beta_3 \text{bedrooms} + \beta_4 \text{bathrooms} \\ + \beta_5 \text{garages} + u \end{aligned}$$

**Table 3**

*Hedonic regression using the Box-Cox model*

Variables	Box-Cox sale price	Box-Cox sale price
	2016	2021
Floor area in 10m <sup>2</sup>	.0020976*** (.0001413)	.0019369*** (.0001684)
Land area in 10m <sup>2</sup>	.0000397** (.0000153)	.0000143* (8.65e-06)
Number of bedrooms	.0016194 (.0010611)	.0022463 (.0011042)
Number of bathrooms	.0054578*** (.0012928)	.0014176 (.0012336)
Number of garages	-.0023356** (.0009724)	.0000428 (.0005657)
Constant	4.930897*** (.0033331)	4.957747*** (.0030174)
Number of observations	1,299	1,189
R-squared	0.3549	0.2834

*Note.* Standard errors are presented in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

The Box-Cox model with interaction and quadratic terms:

$$\begin{aligned} \text{boxcoxsaleprice}^\lambda \\ = \beta_0 + \beta_1 \text{floorarea} + \beta_2 \text{landarea} + \beta_3 \text{landarea}^2 + \beta_4 \text{bedrooms} \\ + \beta_5 \text{floorarea} \cdot \text{bedrooms} + \beta_6 \text{bathrooms} + \beta_7 \text{garages} + u \end{aligned}$$

**Table 3. 1***Hedonic regression using the Box-Cox model with interaction and quadratic terms*

Variables	Box-Cox sale price	Box-Cox sale price
	2016	2021
Floor area in 10m <sup>2</sup>	.0032638*** (.0003953)	.0039158*** (.0003935)
Land area in 10m <sup>2</sup>	.0001488*** (.0000292)	.0000461*** (.0000165)
Land area squared	-2.39e-07*** (5.49e-08)	-1.94e-08** (8.88e-09)
Number of bedrooms	.0066983*** (.0018883)	.011137*** (.0019003)
Floor area*Bedrooms	-.0002981*** (.0000918)	-.0005078*** (.0000899)
Number of bathrooms	.006108*** (.0012861)	.0021208* (.0012244)
Number of garages	-.0030406*** (.0009751)	-.0002593 (.0005606)
Constant	4.905748*** (.0069202)	4.922987*** (.0066001)
Number of observations	1,299	1,189
R-squared	0.3686	0.3044

*Note.* Standard errors are presented in parentheses. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

**Table 3. 2***Turning points and average marginal effects*

	Turning point		dy/dx	
	2016	2021	2016	2021
Land area	311.2970711	1188.14433	.0001112***	.0000431***
Bedrooms			.0016485	.0026002**
Floor area			.0021964***	.0020551***
Number of observations	1,299	1,189	1,299	1,189

*Note.* \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

Table 3 presents the results of the hedonic regression where the dependent variable is the Box-Cox transformation of the house sale price. All independent variables are included as in the previous Semi-Log regression model. For 2016, the relationship between sale price and the first four characteristics is convex; for every unit increase in floor area, land area, bedrooms, and bathrooms, house sale price increases on average. On the contrary, the relationship between sale

price and garages is now concave in this model as opposed to the previous model. All housing characteristics for 2016 are statistically significant at the 1 and 5 percent significance levels except for bedrooms. For 2021, all five housing characteristics are positively correlated with sale price. The coefficient sign for bedrooms especially is now convex, which indicates a more plausible result compared to the previous regression. However, it is insignificant, and the same is true for the number of bathrooms and garages. Floor area and land area appear to be statistically significant at the 1 and 10 percent significance levels, respectively. There are missing or incorrect data hence, the variation in the number of observations for the two years. It is about at least 30 percent of the variation in house sale prices is explained by the set of regressors included in this hedonic model.

Results presented in Table 3.1 are equivalent to those in Table 2.1, with the same signs and level of significance. For houses that have a smaller number of bedrooms, their sale price depreciates at a larger rate than those with more bedrooms. This is not surprising as the greater number of bedrooms one property has, the more expensive it gets, and vice versa. The one major difference observed is that with the Box-Cox model, property prices have a greater magnitude of relationship with housing characteristics both in 2016 and 2021 compared to the Semi-Log model. This is consistent with previous studies, that Box-Cox transformation results in a better fit of the data (Goodman, 1978) and (Halvorsen & Pollakowski, 1981).

Table 3.2 provides the same results as in Table 2.2, with most of the observations having an increasing effect on house prices. The average partial effect of bedrooms is now at 5 percent significance level in 2021 and remained insignificant in 2016. The same level of magnitude is also observed compared to Table 2.2.

**Table 4***ANOVA*

Dependent variables	F	Prob > F
Sale price in NZD	124.88	0.0000***
Floor area in 10m <sup>2</sup>	12.77	0.0004***
Land area in 10m <sup>2</sup>	0.39	0.5313
Number of bedrooms	7.27	0.0070***
Number of bathrooms	5.92	0.0150**
Number of garages	274.49	0.0000***

Note. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

Table 4 includes the analysis of variance for each housing characteristic including the sale price for two years in terms of their raw values. It tests whether there are systematic differences between the characteristics of the houses sold earlier (2016) versus later (2021). For sale price, it is proven to be statistically significant given a very low p-value. Floor area, bedrooms, bathrooms, and garages are also statistically significant, which provides some legitimate results on how housing characteristics are statistically significantly different between the two years. Thus, the increase in house prices in recent years is also due to changes in housing characteristics. Land area on the other hand is not quite significant.

**Table 5***Significant differences between coefficients (Willingness To Pay)*

Dependent variables	2016	2021	F	Prob > F
Floor area in 10m <sup>2</sup>	.0280705***	.0266532***	0.39	0.5327
Land area in 10m <sup>2</sup>	.0005374***	.0002*	8.37	0.0039***
Number of bedrooms	.0191304	.0238447	0.10	0.5716
Number of bathrooms	.0680989***	.0234376	7.21	0.0074***
Number of garages	-.0312234**	-.0011821	15.51	0.0001***

Note. \*\*\*p<0.01, \*\*p<0.05, \*p<0.1

Table 5 displays results for differences in willingness to pay for a bundle of characteristics using the coefficients in Table 2. This is explored by testing the coefficients of each housing

characteristic for the first and second years (2016 & 2021). While land area, bathrooms, and garages appear to be statistically significantly different, floor area and bedrooms are insignificant. The differences in coefficients of each housing attribute except for floor area and bedrooms have indicated that people's willingness to pay has shifted from 2016. Consumers are more willing to pay per unit land area in 2016 than those in 2021. The same is true for bathrooms. People are not willing to pay a premium for having more of either of the two housing characteristics in a single property in 2021. Garages appear to have negative coefficients in both years. It can be said that it has shifted from being a dis-amenity in 2016 to being neutral in 2021.

Tables 4 and 5 look similar in the way their results are reported. However, while Table 4 examines the physical housing characteristics, Table 5 specifically looks at the coefficients of each housing characteristic. For an annual comparison of coefficients, floor area, land area, and bathrooms for the year 2016 appear to be greater than those in 2021. Coefficients for bedrooms and garages were quite smaller in 2016 than in 2021. The coefficient signs are consistent over the two years with garages indicating a negative correlation in both 2016 and 2021, although most of the housing characteristics in 2021 are insignificant. Despite the differences, the outcomes have indicated that they somehow contribute to an increase in house prices except for floor area and bedrooms, as shown in Table 5.

## Chapter 4.1: Discussion

The results from the two modified models used in this paper are used for comparison to those in the Literature Review findings.

Both the Semi-Log model and the Box-Cox transformation have been modified to include a quadratic term and an interaction term in their respective equations. These changes have been made to obtain more accurate and reasonable results specific to the New Zealand context for the years 2016 and 2021. The findings indicate that every housing characteristic is statistically significant at the 1 percent significance level with expected signs in 2016 (the same holds true for both models). For 2021, all attributes are significant except for garages. The study has revealed that housing characteristics are just one of the many factors that affect housing prices. As the demand for larger dwellings, such as those with larger floor area and living space, increases, so do house prices, and vice versa.

Lancaster (1966) and Rosen (1974) have suggested that when determining the total price of an item, the individual characteristics of that item should be considered. Other scholarly articles such as Ball (1973) have studied the value of housing attributes and their impact on housing prices in the UK and the United States. While the results of this study are mostly consistent with those from Ball's, other papers included in his work appear to be inconsistent, see Evans (1973). This inconsistency may be due to various factors, such as different settings, sample selection, variables used.

This study compares the housing market before and after the pandemic, using the years 2016 and 2021. The study examines the differences between housing attributes of properties sold before and after the pandemic, as well as consumers' willingness to pay. The ANOVA statistics show that there are significant differences between the two years for all housing attributes except land area. The study also finds evidence of significant house price changes from 2016 to 2021.

The study tested the housing characteristics for which consumers were willing to pay a premium before and after the pandemic, and found that only land area, number of bathrooms, and garages

were statistically significant. It is surprising that people were not willing to pay a premium for these housing attributes after experiencing the pandemic, as opposed to the results presented in the literature. The literature shows that people demand more space as they spend more time at home after the pandemic. For example, Ahrend et al. (2022); Guglielminetti et al. (2021) found that people's housing preferences have changed after experiencing the pandemic. They are now more interested in moving to less populated areas, away from the city centres where the disease is more contagious. This migration trend has resulted in a new era of working from home, requiring more space to accommodate teleworking. The results of these studies indicate that people demand larger dwellings with more space in a single property with outdoor spaces.

According to a study conducted by Gupta et al. (2022) there has been a significant change in housing prices both in city centres and outside due to the high demand for housing. People now prefer to live further away from high population density areas, which has led to an increase in housing prices in places far from the city. Similarly, Ramani and Bloom (2021) also found that there has been a large movement of people outside of large city centres, leading to a surge in housing prices in suburban areas due to the pandemic. The COVID-19 pandemic has triggered a shift in people's housing preferences, according to studies by Liu and Su (2021) and Liu and Tang (2021) where they are now more willing to pay a premium to avoid health risks. However, the demand shift in housing preferences after the pandemic in these studies does not align with the findings of this paper. The reasons for this discrepancy are discussed in the next section.

## Chapter 5: Conclusion

Based on my research, I find that each housing characteristic in Auckland, New Zealand has its unique contribution to the housing prices. Surprisingly, people are not willing to pay extra for more space in their homes in 2021. This contradicts the common belief that people require more space considering the increase in remote work since the pandemic.

This study has certain limitations that require further investigation to obtain more robust results. Firstly, the sample size or number of observations is insufficient which may have led to insignificance of some variables. A sample size of 50% and a span of 10 years are recommended for this research. This will enhance the goodness of fit and provide more reliable estimates of the relationship between variables. Secondly, there are limitations in variables, such as the lack of information regarding areas in the house that cannot be legally classified as a bedroom, and the quality of renovation. These limitations can be addressed by including missing variables in the regression model, which can increase the percentage of variation explained by the model and provide more precise estimates. These limitations should be further analyzed to improve our understanding of the housing market.

As house price indices may not fully incorporate the effects of COVID-19 on the Auckland housing market, it is suggested that further study should examine other factors such as the economic and behavioural impacts of COVID-19 to better understand the behaviour of Auckland's housing market. This paper also has limitations in areas needed for house price predictions in Auckland, which could be investigated by other researchers. These areas could include testing a monetary policy hypothesis and conducting a cross-country analysis, which can provide crucial evidence to support the real interest rate hypothesis.

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