Home parking and commuting: exploring new ways of estimating the impact of parking on mobility choices

Omid Khazaeian [1], Mairéad de Róiste [2], Toby Daglish [3],Yiğit Sağlam [4]

1PhD student, School of Geography, Environment and Earth Sciences, Victoria University of Wellington, omid.khazaeian@vuw.ac,nz

2 Senior lecturer, School of Geography, Environment and Earth Sciences, Victoria University of Wellington, mairead.deroiste@vuw.ac.nz

3 Associate Professor, School of Economics and Finance, Victoria University of Wellington, toby.daglish@vuw.ac.nz

4 Senior lecturer, School of Economics and Finance, Victoria University of Wellington, yigit.saglam@vuw.ac.nz

Abstract: We explore how home parking quantity affects households' choices of car ownership and commute mode in the Greater Wellington Region (GWR) in New Zealand. We consider socioeconomic characteristics of commuters from the New Zealand Household Travel Survey between 2003 and 2017, as well as commute time, and characteristics of the residential location. The research makes two important contributions to parking literature. First, we consider commute time for different modes instead of distance. Time better represents perception of commute length. Second, our work is regional in scale, including several urban and rural areas. Almost all current studies focus on urban areas. Results of this study show the significant impact of home parking quantity on car ownership and commute mode. Households with more parking at home tend to have more cars and drive to work. Wellington downtown is surrounded by sprawl suburbs with high residential parking supply. Therefore, spatial structure of the GWR and parking quantity encourage car trips to the downtown. More car trips mean greater demand for parking at the city centre. Hence, there is a relationship between home parking and work parking which is rarely studied in parking literature. This is the focus of our future research.

Keywords: home parking, commute mode, sustainable mobility, Conditional Logit.

Introduction

Commuting can be viewed either as making trips between home and work or as changing parking (i.e. from home parking to workplace parking and vice versa). The first approach has dominated commuting studies (see for example, Beige & Axhausen, 2017; Ding, Liu, Zhang, Yang, & Wang, 2017; He & Zhao, 2017; Hu & Schneider, 2017; Melo & de Abreu e Silva, 2017; Moreno-monroy & Posada, 2017; Rüger, Pfaff, Weishaar, & Wiernik, 2017). However, commuting includes both travelling and parking. Every trip ends at a destination (i.e. home or workplace) where commuters typically spend one third to a half of their day, while their cars are parked. Considering commuting as a combination of flows (trips) and places (parking), cars are most likely to stay in places rather than flow between them.

There is little literature on the relationship between commuting and parking. In the small parking literature, most studies focus on parking downtown (Amer & Chow, 2017; Arnott & Rowse, 2009; Franco, 2017), however, parking at home is also important. Cars are usually parked at home longer than they are in the workplace. Many trips begin, and eventually end,

with the car parked in a residential suburb. Moreover, access to suitable home parking is often one of the factors commuters consider in deciding where to live and how to commute. Access to more carparks at home may encourage a household to have more cars, and consequently, drive to work more often.

Therefore, according to the dominant demand-oriented approach in urban transportation, the main question regarding parking is whether home parking is one of the areas of policy intervention to control transportation demand? If home parking is a significant factor, policy makers can use this knowledge to set appropriate regulations.

In this study, we provide empirical evidence on the impact of residential parking on households' choices of car ownership and travel mode. First, our study is also novel in the regional scale examined. Instead of considering one city, we consider the Greater Wellington Region (GWR) in New Zealand. The GWR has high density suburbs in Wellington city (the main city) and sprawling suburbs surrounding it. We then explore the effect of different residential locations or parking. Second, in contrast to most studies in this area, we consider households' choices of residential location. Commuting is a multi-dimensional issue including a consideration of housing in addition to travel and demographic characteristics. This approach also removes the problem of endogeneity between home parking and car ownership. Finally, we consider travel time instead of distance as proxy for commute length.

Literature

For residential parking, most studies concentrate on the cost of residential parking (Groote, Ommeren, & Koster, 2016; Z Guo & McDonnell, 2013; Seya, Nakamichi, & Yamagata, 2016). The impact of free on-site home parking on households' choices of commute mode and number of cars is neglected outside of Guo (2013a and 2013b). Guo (2013a) who poses three questions. First: does residential parking supply have a causal influence on car ownership and usage? If so, the second question is that is the parking effect large enough, compared to other factors, to justify policy intervention? The impact needs to be both strong and statistically significant to be considered in policy intervention. Third, what is the relative importance among the different residential parking types, such as garage, driveway, and on-street? In Guo's work, households are divided into two different groups in terms of type of parking: households with off-street parking and households with only on-street parking. He applies a nested logit model to capture the causal effect of parking supply on car ownership. He concludes that (in contrast to the dominant literature, which considers household's income and demographic characteristics as important factors affect car-ownership), parking supply has a significant impact on car ownership.

Guo (2013b) focuses on parking convenience and its impact on car usage. He defines parking convenience as parking "certainty" and parking "ease". 1 Different parking types have different levels of certainty and ease. Parking convenience's effect on car usage is measured using a regression model. In this model, variables like mode choice, car usage and Vehicle Mile Travelled (VMT) are dependent variables and explanatory variables are parking convenience and control variables. The percentage of households using each type of parking (garage, driveway and on-street) and the average time of use for each type is measured. He found that households with off-street parking drove considerably more than others. In addition, when two parking types (off-street and on-street) are available, households parked on-street made more trips by car.

[1] Parking certainty is the convenience to find a parking space at a desired place and a desired time and parking ease is the convenience to move the car in and out of the parking place (Guo, 2013b).

Methodology

This study employs a conditional logit model to estimate the impact of explanatory variables on a categorical response variable. Explanatory variables are factors that affect households' choices of car ownership, commute mode and residential location (e.g. parking quantity, income). The dependent variable is the households' choices observed in the data. The estimation process with conditional logit is:

1. Measure utility (preference) that each commuter achieves from each choice using equation 1 (Greene, 2003, P.719):

$$U_{ij} = \sum_n \beta_n X_{ijn} + \varepsilon_{ij} \quad , \qquad (1)$$

where individual "i" gets utility from choosing option "j" based on the set of observables "X". The coefficient vector is given by "β" and ε is the error term (which is logistically distributed).

2. Given the error distribution, calculate the probability that each commuter chooses option "j" as follows:

$$P_{ij} = \frac{e^{\sum_n \beta_n X_{ijn}}}{\sum_l e^{\sum_m \beta_m X_{ilm}}} \quad , \qquad (2)$$

in which P_{ij} is the probability that person i chooses choice j. From equation (2), the probability that each individual chooses the actual choice observed in data can be estimated.

3. To find coefficients, we choose coefficients that maximize the probability that each person chooses the choice that is observed in data. we maximize the following Log likelihood function:

$$\text{Log L} = \sum_i Log P_i(j(i)) \quad , \qquad (3)$$

where $P_i(j(i))$ is the probability that individual i chooses the actual choice (j(i)) observed in data among all his/her alternative choices. We use the Maximum Likelihood (ML) method to estimate the coefficients (β) and their variance.

Case study

The Greater Wellington Region (GWR) includes several urban and rural areas with a diverse range of socio-economic and spatial characteristics. As shown on figure 1, GWR is in the South of the North Island of New Zealand and includes 8 districts with population of 513,900 in 2017 (Greater Wellington Regional Council, 2017).2

[2] https://profile.idnz.co.nz/greater-wellington

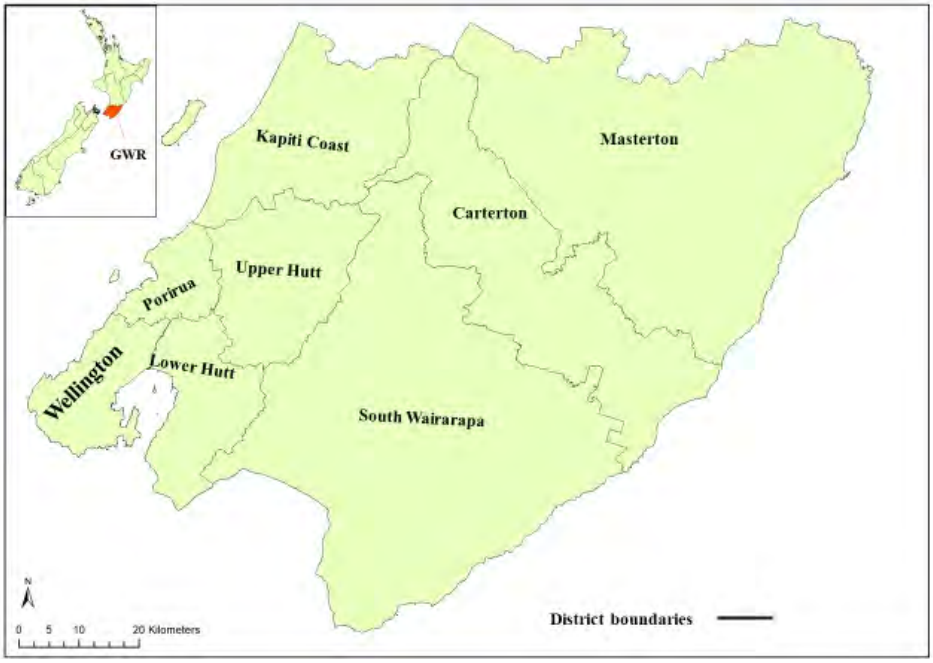

Figure 1: Greater Wellington Region3

In Wellington City, space available for off-street residential parking and on-street parking is restricted. However, in other council areas, low-density suburbs with plenty of space available for parking, parking is mostly free of charge and without time limits. Figure 2 shows two examples of home parking supply in the city and outside. Hence, Wellington City is quite different than other areas in terms of home parking quantity and regulations.

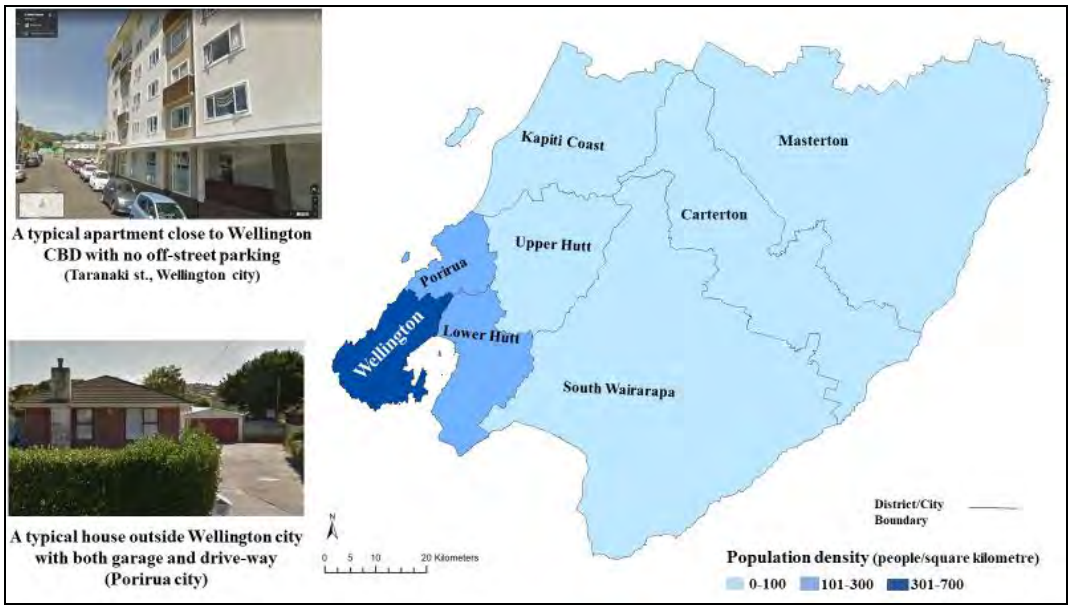

Figure 2: Population density and home parking availability in the GWR4

[3] based on http://archive.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/digital-boundary-files.aspx. Roads are based on Google maps.
[4] Pictures: Google street view. Map: data from stats.govt.nz

Survey data

The New Zealand Household Travel Survey (HTS) was conducted by Ministry of Transport (MOT) from 2003 to present. A number of MeshBlocks (MBs) are randomly selected and then, across consecutive years households within these MBs are interviewed on two consecutive travel days until all households in that MB have been surveyed.5 Our sample includes commuters with fixed workplace in the GWR (2155 commuters in 1540 households).

Data and explanatory variables

- **Home parking quantity**
  Home parking quantity is defined as two variables in our model. First is a dummy variable indicating whether the household lives inside Wellington City (D_{City}). Second is the interaction of this dummy variable and the percentage of households in each MB with home parking ($D_{City} * Parking$).

- **Travel time:**
  We use an adapted transport network based on a road network from Kim Ollivier and Co and updated by Daglish *et al*. (2015) in ESRI's ArcMap.[6] This network measures travel time and cost based on road restrictions (e.g. one-way roads) and costs (including traverse time and fuel consumption for each edge of network). In measuring travel time for walking and cycling, the network considers speed based on the slope of each edge in the network, particularly suitable for the hilly terrain in Wellington. Cyclists are assumed to follow similar road rules to drivers. An amended network considers Public Transport (PT). A journey to work by PT accounts for walking or driving to a PT stop and walking from the last stop to work.

- **Household Socio-economic characteristics:**

We control for the following characteristics based on the HTS data. Household's income is classified in table 3.

Table 3. Household income

Income range ($)	classification	Measure
0	No income	0
1-20,000	Low income	1
20,001-50,000	Middle-low income	2
50,001-70,000	Middle-high income	3
70,001-100,000	High income	4
$100,000^{+}$	Very high income	5

In the model, we use this measure as a variable for income. We also include the following covariates:

5 A MeshBlock (MB) is the smallest geographic unit for which statistical data is reported by Statistics New Zealand. "Area Unit" (AU) is the next smallest census area.
6 Kim Ollivier and Co network is described at https://koordinates.com/supplier/corax/

- Number of driving licence per household
- Commute mode of each commuter
- Ethnicity
- Age and gender
- Number of cars per household
- Households with children
- Number of people in household working in Wellington CBD

- **Built environment features:**
  - Market house value in each MB:
    "A Rating Valuation is a three-yearly assessment of a property's value in relation to current market values" (Wellington City Council, 2019). We take the median of RV in each MB to avoid very high or low values. As MBs are small and few houses in them are sold each year, we calculate the ratio of median sale price over median RV of sold houses in each MB and for each year. This ratio gives an idea of the difference between market value and RV. We multiply this ratio by the median RV of that MB for that year to calculate our measure of market house value. Homes.co.nz provided median RV, median sales prices and median RV of sold houses in each MB for each year for all the GWR for the period of 2003 to 2017. [7]

  - North-facing (sunlight):
    Sunlight is a key factor in Wellington housing demand. As a proxy, we use North-facing houses as this study is conducted in the southern hemisphere. Our measure is the percentage of residential area in each MB that is North, North-east and North-west facing.

  - Proximity to commercial areas: Close proximity to shopping centres and supermarkets is attractive. We measure drive time from residential locations (MB centroid) to commercial centre of the neighbourhoodNumbering

Results

As shown in figure 3, in Wellington city, home parking quantity varies considerably among MBs. Residential blocks in the CBD are dominated by apartments where, on average, only half (55.9%) have parking on the property. This value increases to 60.86% in suburbs surrounding the CBD, and to 77.22% all of Wellington City.

[7] Homes.co.nz is one of the institutions in New Zealand presents information about properties' features.

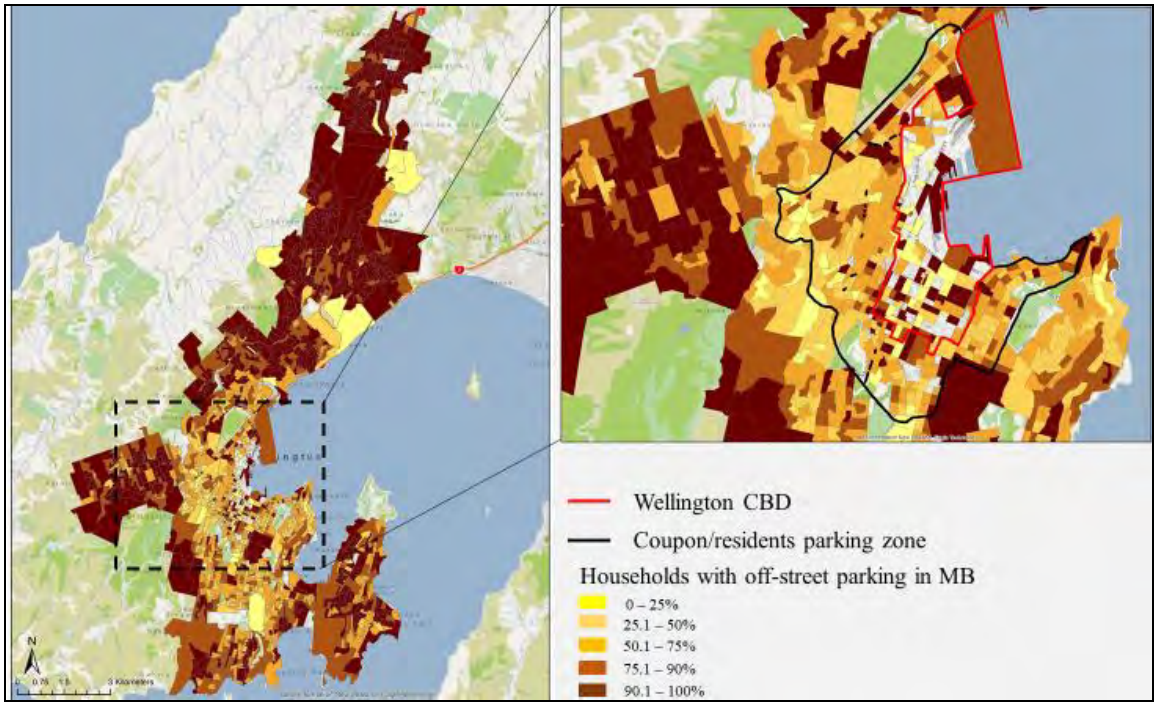

Figure 3. Home parking quantity in Wellington city

Closer to the downtown, households are less likely to live in a suburb where all houses have parking.

The difference between Wellington City and outside in terms of home parking quantity generates a considerable difference in car ownership and commute mode. According to figure 4, preference of households living in the city for having only one car or not to have a car is more than households outside. However, two or more cars are more popular outside Wellington City.

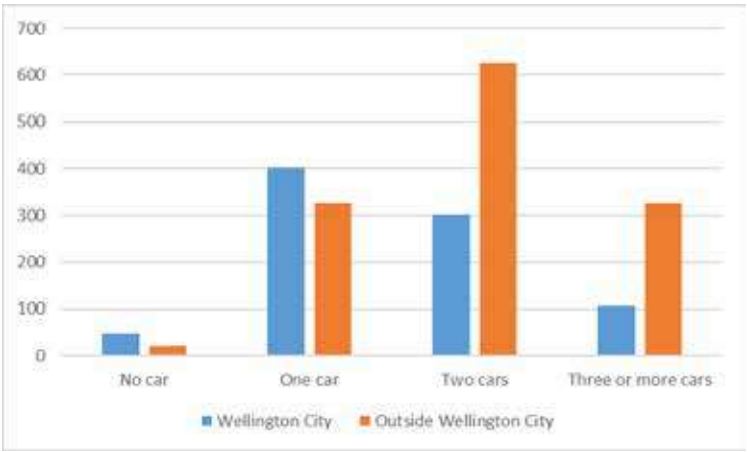

Figure 4. Number of commuters in the sample in Wellington City and Outside in car ownership categories

Figure 5 shows that although Wellingtonians are more willing to walk or cycle to their workplace, driving is much more popular among residents of urban and rural areas outside of the city.

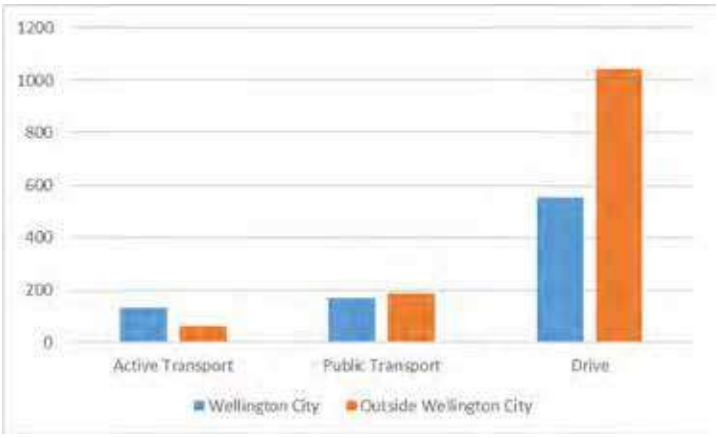

Figure 5. Number of commuters in the sample in in Wellington City and Outside in commute mode categories

According to figure 6, in Wellington city, suburbs with more off-street parking at home are more attractive for households who like to have at least one car. It is mostly the case of sprawl suburbs outside coupon/residents parking zone where more than 75% of houses have either a garage or driveway. Home parking provides a certainty and safety that may make commuters willing to have more cars and drive to work. Therefore, many daily trips to Wellington CBD from suburbs are car trips which may create a congestion delays travelling with public transport.

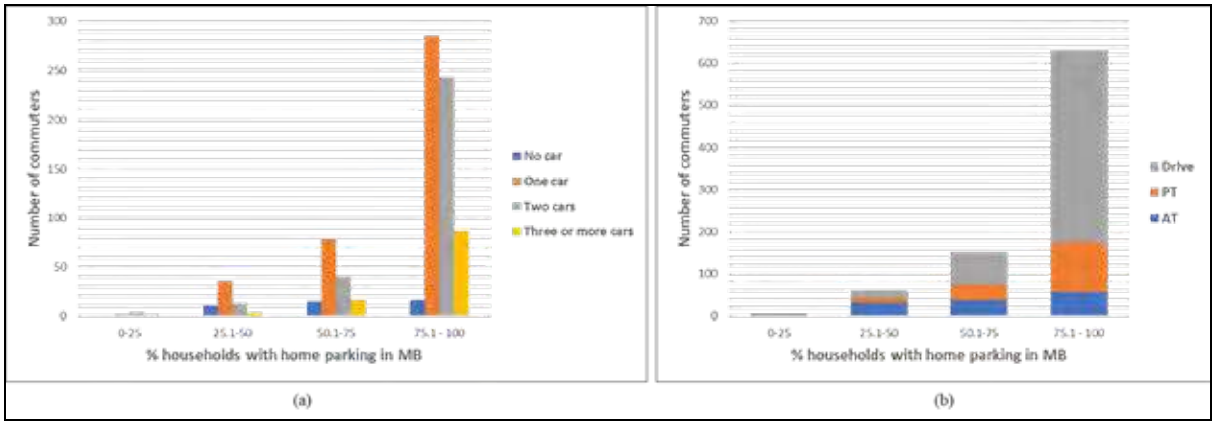

Figure 6. number of commuters in each home parking quantity and car ownership category (figure a) and mode category (figure b) in Wellington city

Car ownership and mode choices also depend on other factors (e.g. income). In the logit model, we control for important socio-economic characteristics and built environment features that might affect commuting choices. Then, we predict the impact of home parking on commuters' choices for the full study area (commuters in the Greater Wellington Region).

Estimation results

The results of our Logit model, shown on table 4, are consistent with our hypothesis about parking and commuting choices. Having cars is popular among households outside Wellington city. However, in the city, these choices are less popular.

Table 4. Logit model results

Variable	*Coefficient*	*T-stat*	*Variable*	*Coefficient*	*T-stat*
Dcity	0.42	0.50	*AT*	-2.27	-9.07
DcityParking	-0.17	-0.16	*PT*	-1.14	-7.28
One car	2.33	8.35	*Dcity_AT*	4.97	7.05
Two cars	2.64	9.57	*Dcity_PT*	1.94	2.48
Three or more cars	1.58	5.38	*DcityParking_AT*	-4.99	-6.25
*Dcity*one car*	-2.47	-3.06	*DcityParking_PT*	-2.04	-2.35
*Dcity*two cars*	-5.58	-5.34	*Log (house prices)*	-0.89	-4.06
*Dcity*three or more cars*	-3.26	-2.94	*Income* log (house prices)*	1.65	4.56
DcityParking one car*	3.05	3.12	*Log (commute time)*	-0.44	-4.80
DcityParking two cars*	5.74	4.75	*Income* log (commute time)*	0.33	2.20
DcityParking three or more cars*	2.91	2.23			

More parking at home is generally attractive for households. Residential parking supply in the city is not as much as outside, therefore, people with at least one car prefer to live outside Wellington to benefit from high residential parking supply.

Driving is a popular choice among households living outside Wellington city where almost all houses have parking. However, limited home parking and congested streets in Wellington city encourage households to walk, cycle or take public transport to work.

Therefore, higher parking quantity at home means more car ownership which means a greater proclivity to drive. More car trips could be translated into more demand for parking at the downtown (which contains most of workplaces). Hence, there is a mutual relationship between home parking and parking at the CBD and we should consider them simultaneously in urban transport planning.

Residential location is another important choice. People usually like to live closer to their workplaces but there is a trade-off between commute time and house price. The ratio of the coefficient of log(time) to the coefficient of log(price) gives us an idea of how much more a household is willing to pay to get closer to the workplace of the household's head. The ratio of 0.49 means that household is willing to live in a house worth 0.49% more to reduce head's commute time by 1% (0.01 hour). For example, imagine a household rents a NZ$ 500,000 house which is one hour from the head's workplace. They are willing to live in a

house costing 500,000 *0.0049 = NZ$ 2,450 more to reduce commute time by 0.6 minutes. In the other word, this household might move to a NZ$ 622,500 house to live 30 minutes closer to work, keeping all other features constant.

Income also plays an important role in this trade-off. Low income households prefer to save money by living in cheaper houses and as close to work as possible. On the other side, well-paid commuters who can easier afford monetary costs of commuting with fast travel modes (e.g. fuel, parking) care more about quality of house and residential neighbourhood.

Conclusion

This research sheds light on commuting in a network of cities and rural areas. Wellington City, as the capital of New Zealand, includes many governmental, commercial, cultural and educational businesses mostly in its CBD. However, high supply of home parking in sprawl suburbs encourage commuters to drive to the CBD. It means that urban spatial structure and home parking quantity are two important factors that help increase traffic congestion in peak hours. To improve use of AT and PT, the suggestion here is to put active and public transport in the highest priority and develop their routes and improve their efficiency. Another suggestion is to prevent spreading the city and instead, develop low-rise and high-rise buildings in the suburbs close to downtown.

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