UNIVERSITY OF WATERLOO
FACULTY OF ENVIRONMENT
School of Planning

Interpreting and Modelling the Housing Market from Individual Behaviours

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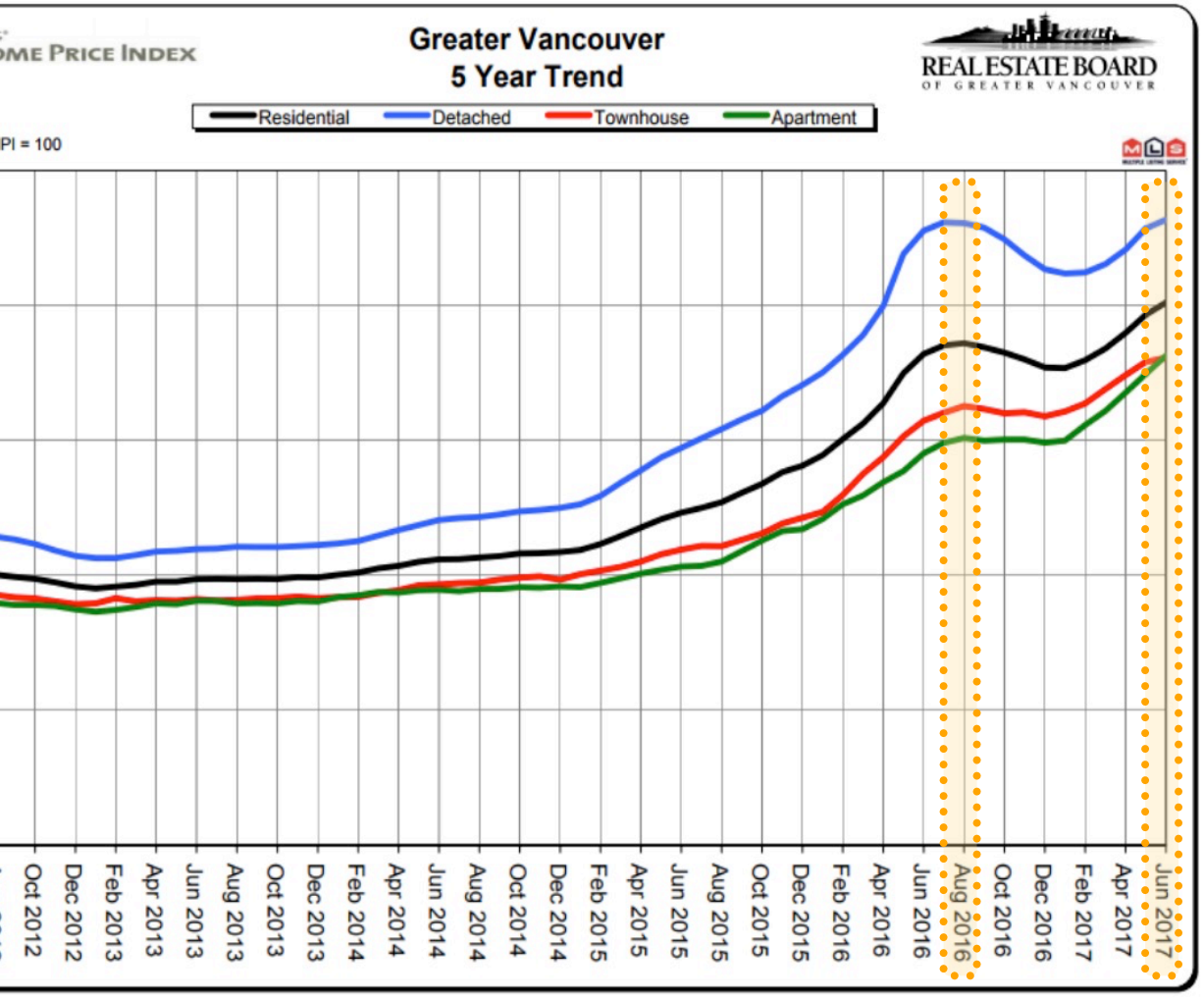
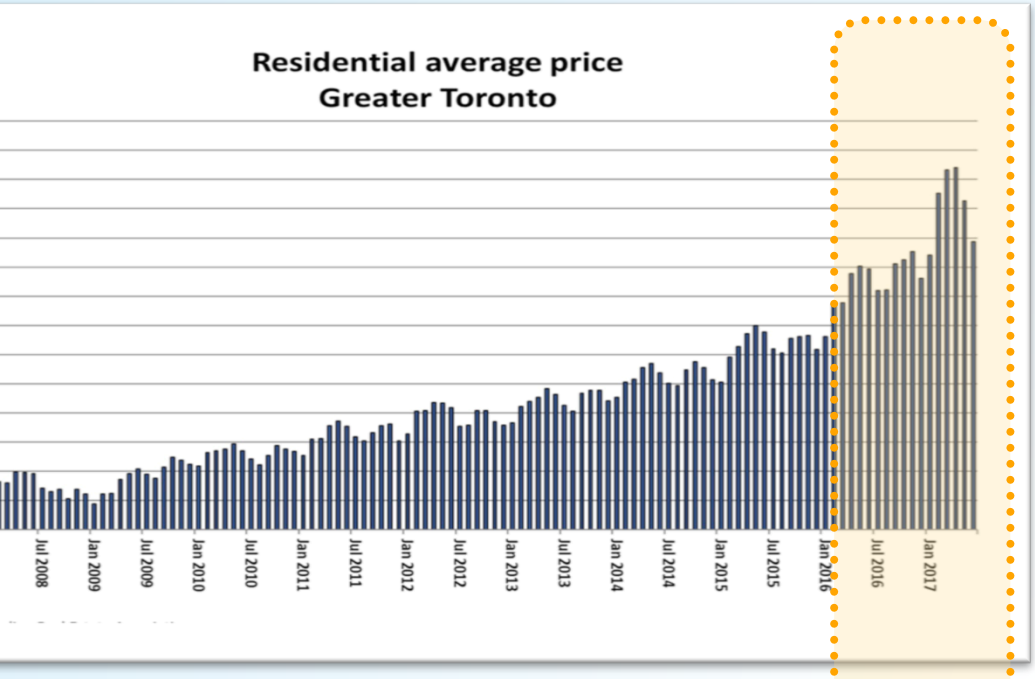
What is exciting about Canadian housing markets?

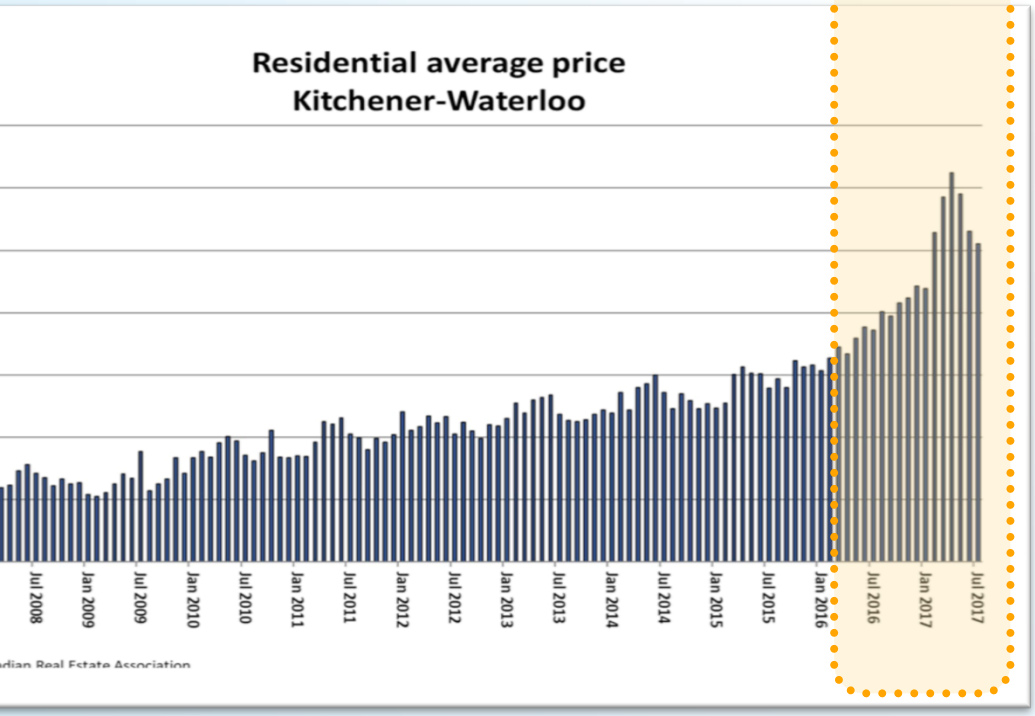
Greater Vancouver Price Trends



(Source: http://www.rebgv.org/monthly-reports)

- July, 2016 - Housing Boo
  20% - 40% price increas
- **August, 2016** - Foreign
  Buyers Tax
- June, 2017 - Prices boun
  back sharply to an avera
  $1,046,982
- ***How will the Empty Ho***
  Tax impact the housing
  market?



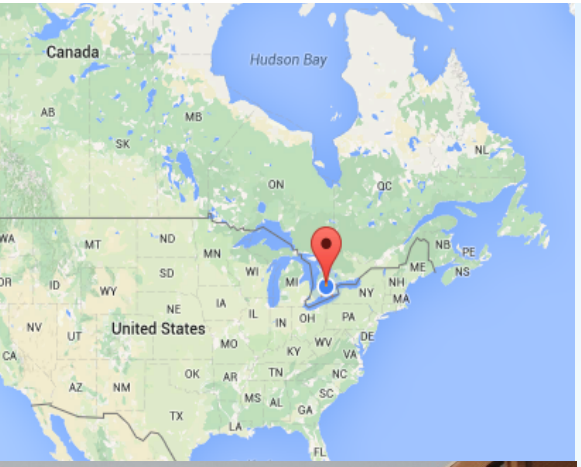


➢ *Toronto market*

- average price up to **$920,791** **April 2017**
- Greater Toronto area also instit foreign buyers/investors taxes

➢ *Waterloo market*

- **before 2016, 3-5%** steady annu appreciation
- **April 2016 - April 2017, 30%** appreciation
- average price surpasses **$500,** April 2017
- quickly normalizes, but price sti **increases 17.4% in July 2017** compared to 2016



Why Kitchener-Waterloo Region?

- **Increasing people** and employment
- **High tech hub** with entrepreneurship and knowledge-intensive economy
- A new light rail transit system as a key strategy urban revitalization and overall economic development strategy
- ***Housing boom (price volatility), but why?***

Toronto speculative buyers?

Foreign buyer tax?

Low interest rate?

Urban growth boundary?

Massive shortage?

Research Questions…

1. *How can we better interpret the housing market dynam Kitchener-Waterloo Region?*

2. *What are the housing demand or preferences among heterogeneous households during the boom?*

   - *How can we analyze the housing demand?*

   - *Specifically, how can we build a **theoretically-grounded, empirical model** to interpret **housing demand** in this Region?*

Why housing demand analysis matters?

Alonso (1964) *proposed the bid-rent theory, and pointed out tha housing prices and location choices are simultaneously determined by a* ***bidding process***

Rosen (1974)*'s first-stage hedonic regression tells nothing abou demand heterogeneity;* ***Second-stage*** *hedonic (basically dema analysis) has endogeneity problem*

Demand analysis matters for assessing policy/environmenta changes, say the LRT implementation

What are the technical problems for demand analysis?

- **Hard to connect Alonso bid-rent theory with empirical demand analysis**

1. *Bid price or WTP is theoretically unobservable and* ***heterogeneous among households***
2. *Utility parameterization problems: hard to know the preference weights*
3. *Lack of demographics (income, household size, etc.) and preference information*

Research Methodology…

- ✓ ***Interpreting the Housing Market Dynamics in Kitchener-Waterloo from Individual Behaviours***

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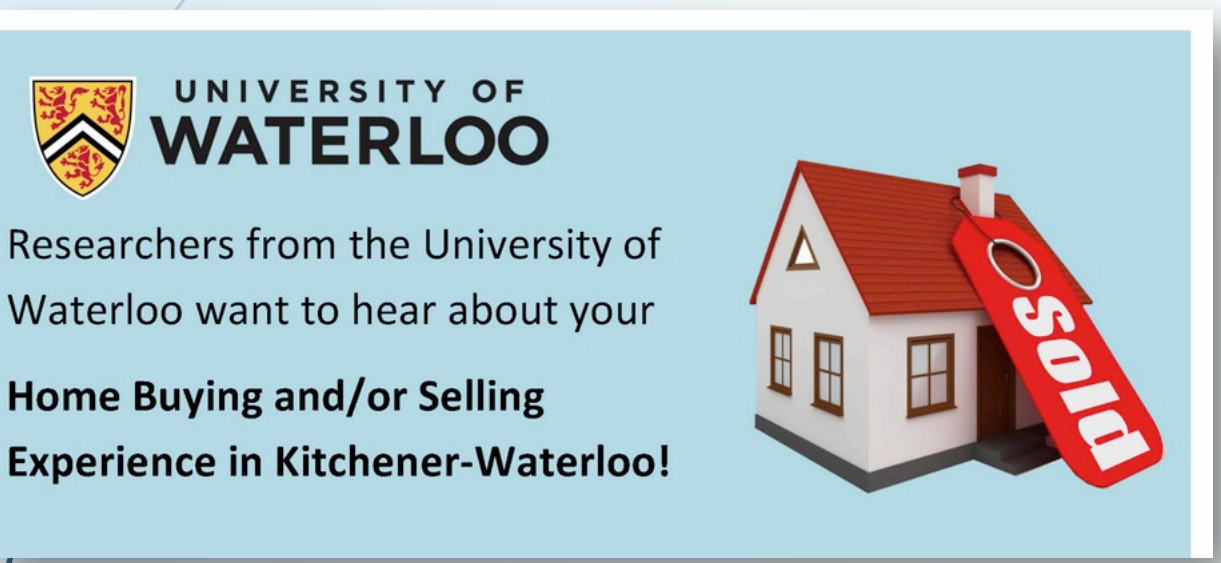
1. Housing Survey – Unpacking Individual Behaviours



- ✓ Residential and neighbour characteristics
- ✓ **Home selling/buying experience**
- ✓ **Location choice prefere**
- ✓ Preferences towards LRT
- ✓ **Household demographic** travel behaviour

- This is the major difference between our survey and other hou
- we ask their ***ideal*** house and neighbourhood characteristics

Housing Survey Summary

- ✓ ***Survey target:*** *Home Buyers and Sellers from 06/2015 - 04/2017*
- ✓ ***Survey mails out:*** *5000 addresses rented from Canada Post*
- ✓ ***Survey responses:***

Responses	
Buyers only	269
Sellers only	61
Both buyers and sellers	88

Total	
Total buyers	357
Total sellers	149
Response rate	10%

2. Housing Demand Analysis - theoretical foundation

- Traditional location choice problem – budget constraint, utility maximization (Alonso, 1964)
- Suppose only two characteristics - ***house size (S_j)*** and ***proximity to CBD (d_j)*** compose the house *j*, the optimization problem can be formulated based on the theory.

3 The optimization problem based on Alonso bid-rent theo

Utility of house *j* provided to household *i*

Individual preferences for house size and proximity to CBD

$$max\ U_{ij} = \beta_i^S log(S_j) + \beta_i^d log(d_j) + c$$

$$s.t.\ \alpha^S S_j + \alpha^d d_j + c \leq M_i$$

A composite commodi

Household income

Implicit market prices for house size and proximity to CBD

Estimated from hedonic regression

$$P_j = \alpha^S S_j + \alpha^d d_j + \epsilon$$

(Bajari and Kahn

Solving the optimization problem, we derive,

$$\frac{\frac{\partial U_{ij}(S_j)}{\partial S_j}}{\frac{\partial U_{ij}(c)}{\partial c}} = \alpha^S$$

$$\beta_i^S = S_{j*}\alpha^S$$

$$\frac{\frac{\partial U_{ij}(d_j)}{\partial d_j}}{\frac{\partial U_{ij}(c)}{\partial c}} = \alpha^d$$

$$\beta_i^d = d_{j*}\alpha^d$$

- A way to "recover" household-level preference parameters in the utility function with strong theoretical foundation.

Regress the expenditure on demographics to recover heterogeneous housing demand…

- Assume that households with similar demographic characteristics have similar preferences.

$$\beta_i^S = f(\boldsymbol{Dem}_i)^S + \eta_i^S$$
$$\beta_i^d = f(\boldsymbol{Dem}_i)^d + \eta_i^d$$

A vector of demographic characteristics collected from housing survey:

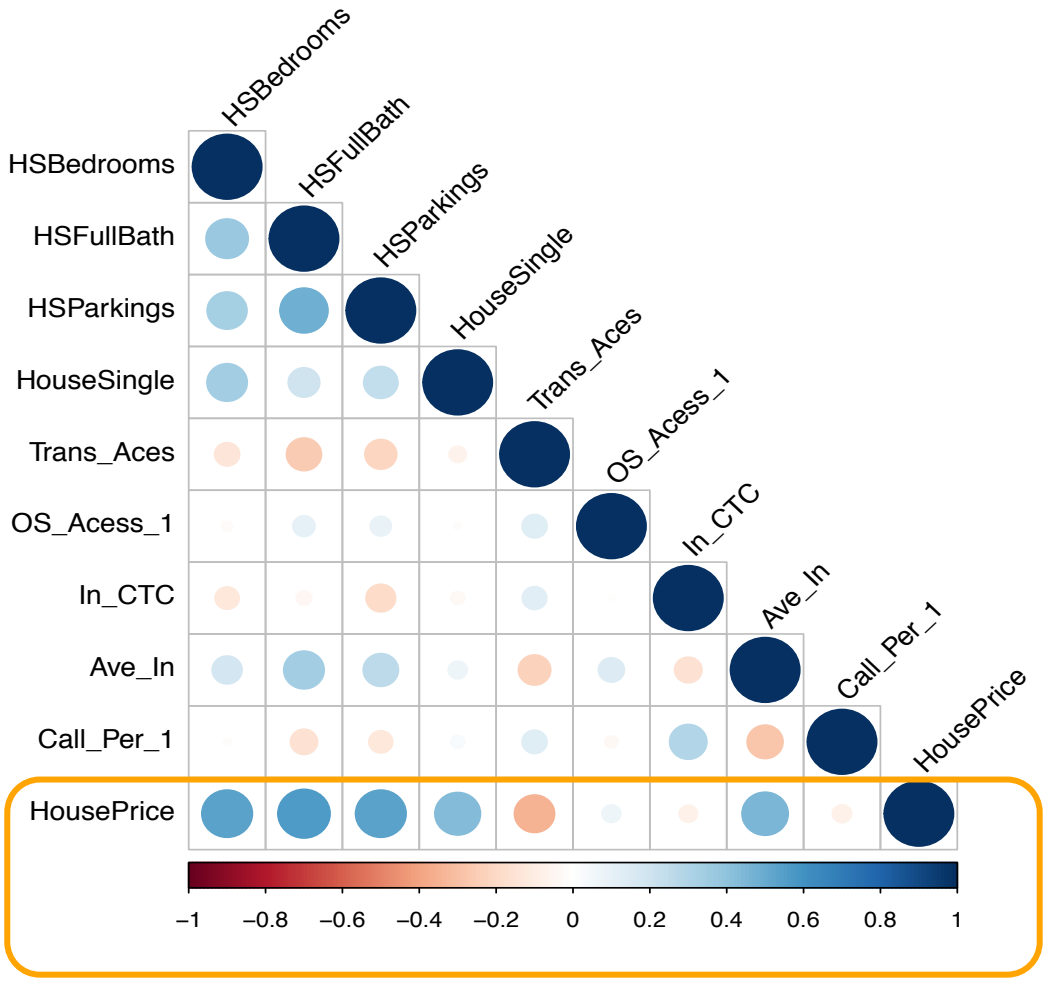
- Household type:
  - Couple with children (dummy)
  - Couple without children (dummy)
  - Lone parent (dummy)
  - More persons (dummy)
  - One person (omitted)

- Employment status
  - Full employment (dummy)
  - Non-full employment (omit
- Highest education (continuous)
- Household income (continuous

Briefly, three estimation steps

(Bajari & Kahn, 2005)	**Step 1**	Estimate implicit prices by hedonic (α)
	Step 2	Calculate expenditures on each characteristic (β)
	Step 3	Regress the expenditures (β) on demographics

Step 1 – Hedonic Regression



Hedonic Regression – OLS Results

Dependent Variable	: HousePrice	Number of Observations:	315
Mean dependent var	: 409296	Number of Variables	: 10
S.D. dependent var	: 142266	Degrees of Freedom	: 305
R-squared	: 0.620390	F-statistic	: 55.384
Adjusted R-squared	: 0.609188	Prob(F-statistic)	: 0
Sum squared residual	:2.42019e+012	Log likelihood	: -4032.03
Sigma-square	:7.93504e+009	Akaike info criterion	: 8084.05
S.E. of regression	: 89078.8	Schwarz criterion	: 8121.58
Sigma-square ML	:7.68313e+009		
S.E of regression ML	: 87653.5		

Variable	Coefficient	Std.Error	t-Statistic	Probability
CONSTANT	-90640.6	29989.4	-3.02242	0.00272
Bedrooms	45317.7	7458.8	6.07574	0.00000
Full Baths	40067.5	8581.98	4.6688	0.00000
Covered Parkings	50458.8	10111.4	4.9903	0.00000
Single-detached house	75231.8	12357.6	6.08788	0.00000
Transit accessibility	-74.4146	17.6984	-4.20459	0.00003
Open space accessibility	29.2855	34.5551	0.847504	0.39738
In CTC	33886.9	19936.3	1.69975	0.09020
Neighborhood ave income	2.96989	0.486314	6.10693	0.00000
Neighborhood safety	825.299	740.494	1.11453	0.26593

Step 2, 3 – Demand analysis for bedroom

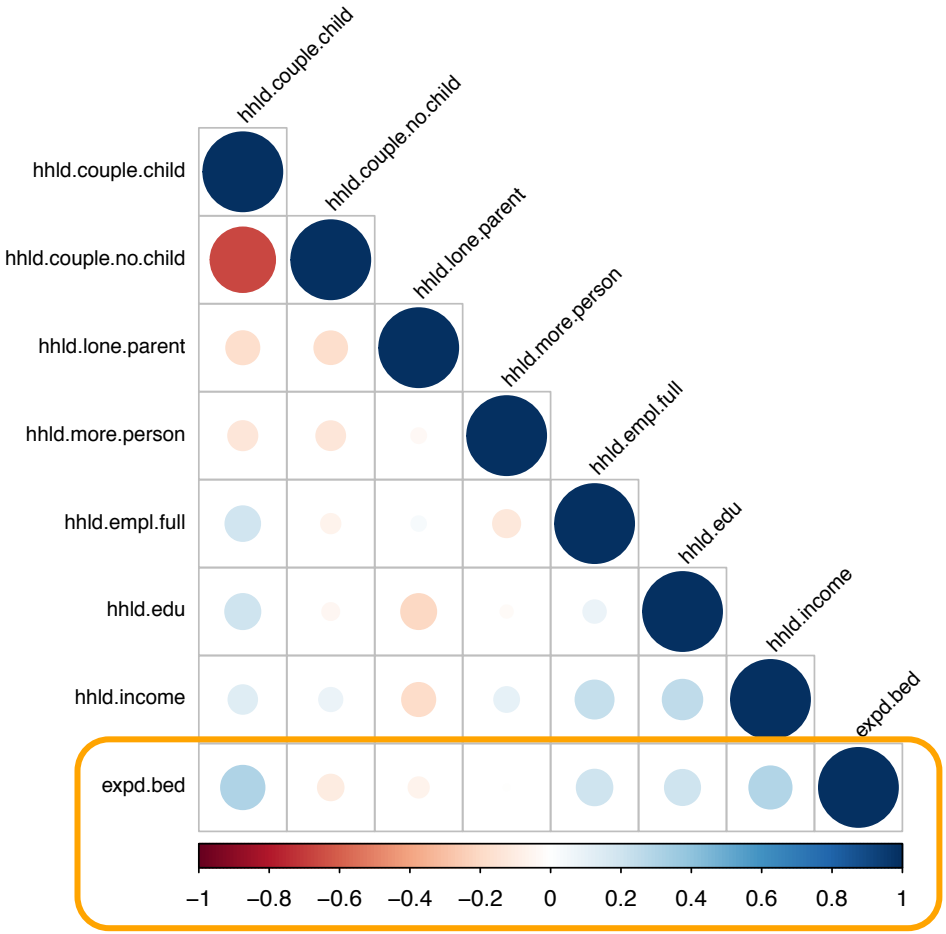


Table 1: Regression of bedroom expenditures on demographics

	Housing and neighbourhood characteristic
	Bedroom
Household highest education	5,085.206*
	(3,020.320)
Household annual income	0.125***
	(0.040)
Household-couple with children	25,071.490***
	(6,033.826)
Household-couple without children	10,757.230*
	(5,943.210)
Household-lone parent	12,615.090
	(9,847.948)
Household-more persons	13,355.430
	(12,029.580)
Household with full employment	9,396.528*
	(5,536.505)
Constant	93,954.640***
	(8,948.351)
Observations	288
R^2	0.187
Adjusted R^2	0.166
Residual Std. Error	29,968.510 (df = 280)
F Statistic	9.190*** (df = 7; 280)
Note:	*p<0.1; **p<0.05; ***p<0.0

Demand for full bathrooms

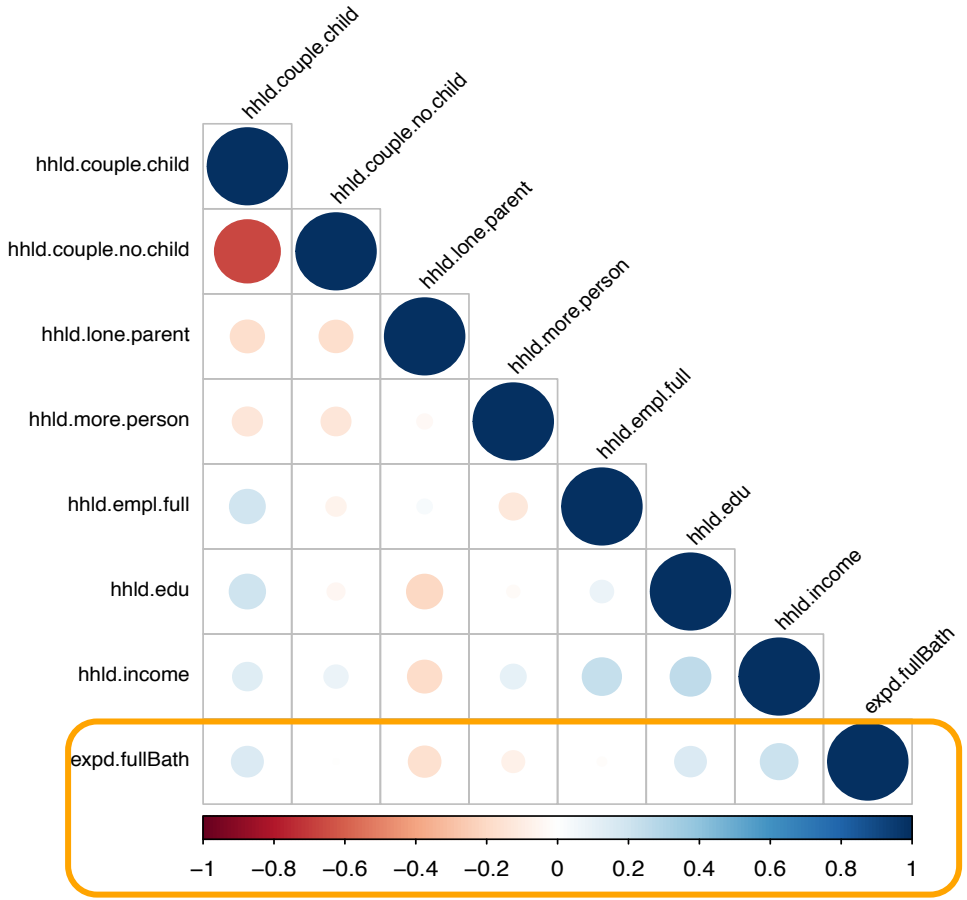


Table 2: Regression of full bathroom expenditures on demographics

	Housing and neighbourhood characterist
	Bedroom
Household highest education	3,006.680
	(2,662.345)
Household annual income	0.110***
	(0.035)
Household-couple with children	7,461.083
	(5,318.682)
Household-couple without children	2,145.291
	(5,238.807)
Household-lone parent	−10,893.010
	(8,680.746)
Household-more persons	−14,692.700
	(10,603.800)
Household with full employment	−7,854.519
	(4,880.305)
Constant	57,976.710***
	(7,887.771)
Observations	288
R^2	0.096
Adjusted R^2	0.073
Residual Std. Error	26,416.570 (df = 280)
F Statistic	4.240*** (df = 7; 280)
Note:	*p<0.1; **p<0.05; ***p<0.

Demand for covered parking space

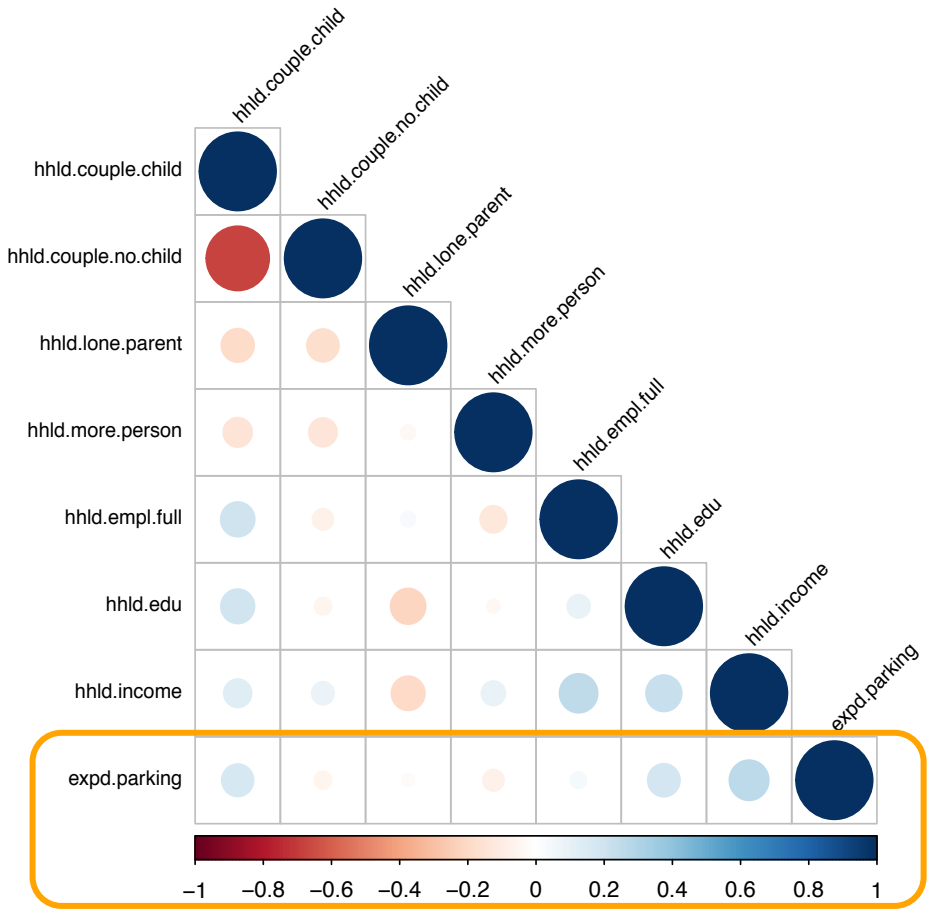


Table 3: Regression of covered parking space expenditures on demographics

	Housing and neighbourhood characteri
	Bedroom
Household highest education	5,730.347*
	(3,007.345)
Household annual income	0.166***
	(0.041)
Household-couple with children	10,092.660*
	(6,097.920)
Household-couple without children	2,309.274
	(6,038.370)
Household-lone parent	12,291.120
	(9,793.062)
Household-more persons	−14,316.560
	(11,890.260)
Household with full employment	−6,646.441
	(5,530.086)
Constant	27,082.420***
	(9,122.804)
Observations	278
R^2	0.117
Adjusted R^2	0.094
Residual Std. Error	29,372.670 (df = 270)
F Statistic	5.128*** (df = 7; 270)
Note:	*p<0.1; **p<0.05; ***p<

Demand for open space accessibility

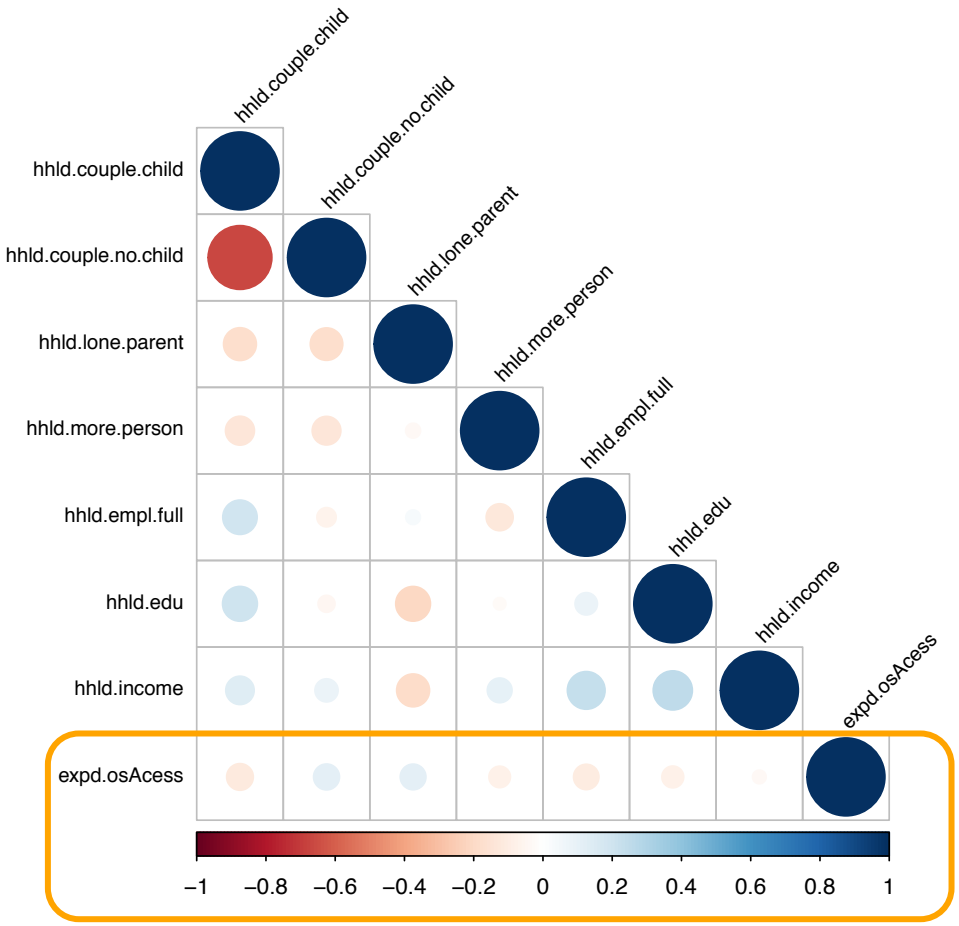


Table 5: Regression of open space accessibility expenditures on demographics

	Housing and neighbourhood characteris
	Bedroom
Household highest education	−338.902
	(436.721)
Household annual income	0.003
	(0.006)
Household-couple with children	−61.976
	(872.456)
Household-couple without children	954.462
	(859.353)
Household-lone parent	2,630.832*
	(1,423.955)
Household-more persons	−2,060.903
	(1,739.406)
Household with full employment	−1,507.609*
	(800.546)
Constant	−4,201.328***
	(1,293.879)
Observations	288
R^2	0.048
Adjusted R^2	0.024
Residual Std. Error	4,333.270 (df = 280)
F Statistic	2.010* (df = 7; 280)
Note:	*p<0.1; **p<0.05; ***p<0

Relative to other studies, this study …

- 1) builds on richer, more detailed data **through a comprehensive housi survey**
- 2) examines the housing market dynamics from **individual behaviours**
- 3) allows a strong direct connection between our implemented model and Alonzo's classic bid-rent theory models by
  - parameterising the utility function for empirical housing study with stro theoretical foundations
  - **recovering heterogeneous housing demand** by combining survey d and theoretical methods within 3-Steps
  - explaining varying preferences among heterogeneous households and thus provides more information than a traditional first-stage hedonic m

Future work …

- **1) Improve current model by**
  - using the stated preferences from survey to validate our proposed model
  - building a multi-level hedonic regression with potential more data
  - using probit models to estimate heterogeneous demand for dicho characteristics, such as In CTC, or Large Yard, Single detached h
- 2) Estimate **heterogeneous household *WTP*** for each house given demographics
- 3) Simulate housing location choices in our **Agent-Based land mark model**: by adding more theoretically-grounded and empirically-valida behaviour rules (especially, utility parameterization and *WTP* estimat from this study)
- 4) Model and better interpret the housing market dynamics

		Estimation steps	Details
ur proposed and estimation method	(Bajari & Kahn, 2005)	Step 1	Estimate implicit prices by hedonic (α)
		Step 2	Calculate expenditures on each characteristic (β)
		Step 3	Regress the expenditures (β) on demographics
	Step 4		Estimate the demand curve for each characteristic
	Step 5		Estimate *WTP* for each characteristic
	Step 6		Estimate the total *WTP* for each house

WTP estimat

Table 1. Scenarios created to simulate the market dynamics for a seller's market

	Scenario 1	**Scenario 2**
gy	Bidding war strategy	Adaptive listing strategy based on the recent transactions
uyers	100	100
llers	80	80
	$\boldsymbol{WTA = hedonic\ price_1}$[1]	$\boldsymbol{WTA = hedonic\ price_1}$
rice	$\boldsymbol{List\ price_t = WTA}$	$\boldsymbol{List\ price_t} = \boldsymbol{WTA} * \left(1 + \boldsymbol{\alpha} * \left(\frac{average\ sales\ price_{t-1}}{average\ list\ price_{t-1}} - 1\right)\right)$, $when\ average\ sales\ price_{t-1} \geq average\ list\ price_{t-1}$, $\boldsymbol{\alpha}$ is a factor ranging from 0 to 1 (norm distribution), reflecting heterogeneous market expectations among sellers
y	$\boldsymbol{Utility} = Cobb - Douglas\ function$	$\boldsymbol{Utility} = Cobb - Douglas\ function$
	$\boldsymbol{WTP} = f(utility, income, \boldsymbol{hedonic\ price_2}$[2]$)$	$\boldsymbol{WTP} = f(utility, income, \boldsymbol{hedonic\ price_2})$
rice	$\boldsymbol{Bid\ price_t} = \boldsymbol{List\ price_t} * \left(1 + \boldsymbol{\beta} * \left(\frac{average\ sales\ price_{t-1}}{average\ list\ price_{t-1}} - 1\right)\right)$, $when\ average\ sales\ price_{t-1} \geq average\ list\ price_{t-1}$, $\boldsymbol{\beta}$ is a factor ranging from 0 to 1(norm distribution), reflecting heterogeneous market expectations among buyers	$\boldsymbol{Bid\ price_t} = \boldsymbol{Hedonic\ price_1} * \left(1 + \boldsymbol{\beta} * \left(\frac{average\ sales\ price_{t-1}}{average\ list\ price_{t-1}} - 1\right)\right)$, $when\ average\ sales\ price_{t-1} \geq average\ list\ price_{t-1}$, $\boldsymbol{\beta}$ is a factor ranging from 0 to 1(norm distribution), reflecting heterogeneous market expectations among buyers
ng	When $Bid\ price \leq WTP$, buyer starts sending offer	When $Bid\ price \leq WTP$, buyer starts sending offer

Housing ma
simulations
different sc

Acknowledgements

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  - Professors: Dawn Parker, Jenifer Dean
  - Students: Yu Huang, Justin Cook, Xinyue Pi
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  - SSHRC Partnership Development Grant (SSHRC # 890-2013-0034) entitled "*LIGHT RAIL TRANSIT AND CORE-AREA INTENSIFICATION: Unpacking Causal Relationships*"
  - SSHRC Insight Grant (SSHRC # 435-2012-1697) entitled "*Urb intensification vs. suburban flight: An integrated residential lan use and transportation model to evaluate residential land mar form and function*"
  - China scholarship programme (Yu Huang)

References

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- Bajari, P., and Benkard, C. L. (2001). Demand estimation with heterogeneous consumers and unobserved product characteristics: A hedonic approach.
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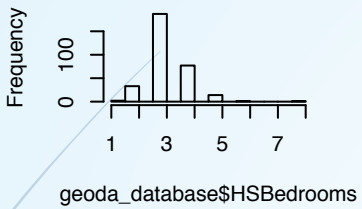
- Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. Journal of Political Economy 82(1), 34–55. https://doi.org/10.1086/260169

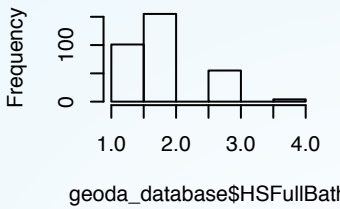
Thank you for your attention!

Back-up slides

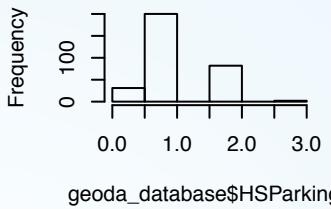
Number of bedrooms



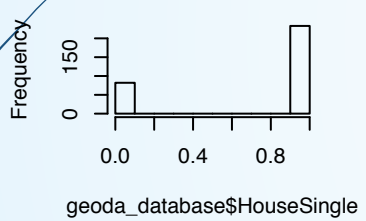
Number of full bathrooms



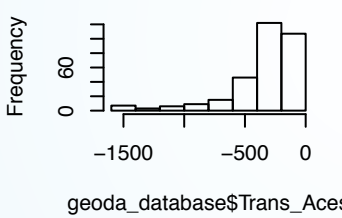
Number of parking lots



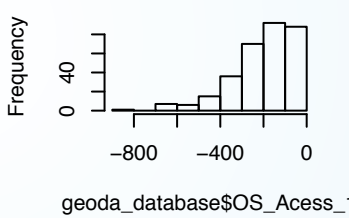
Single–detached houses



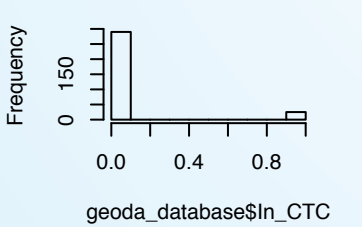
Transit accessibility



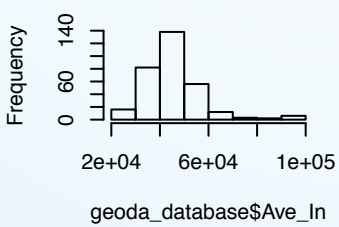
Open space accessibility



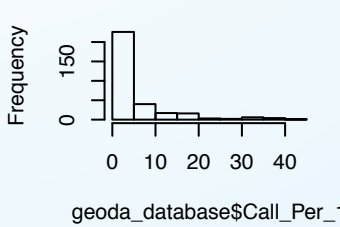
Housese in CTC



Neighbourhood average incom



Neighbourhood safety

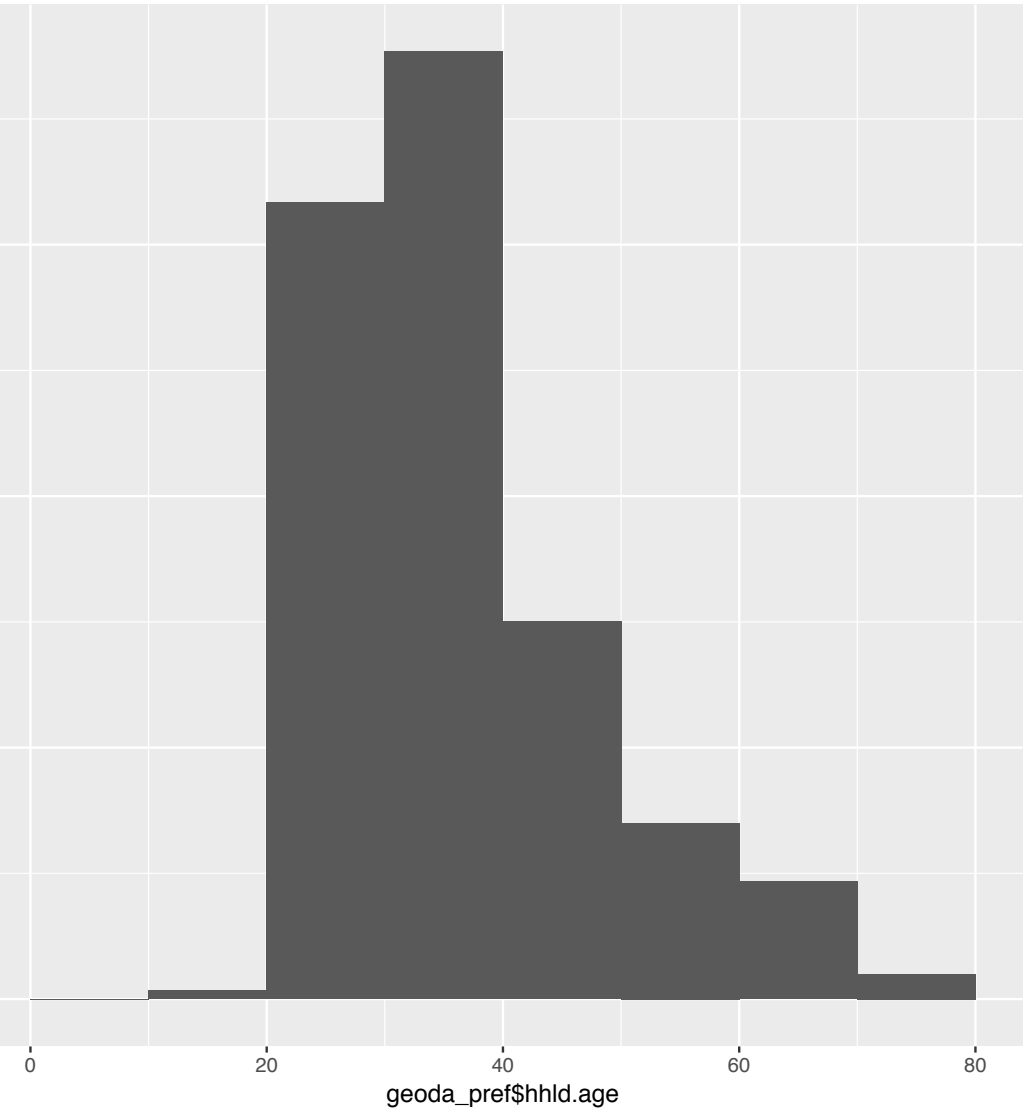


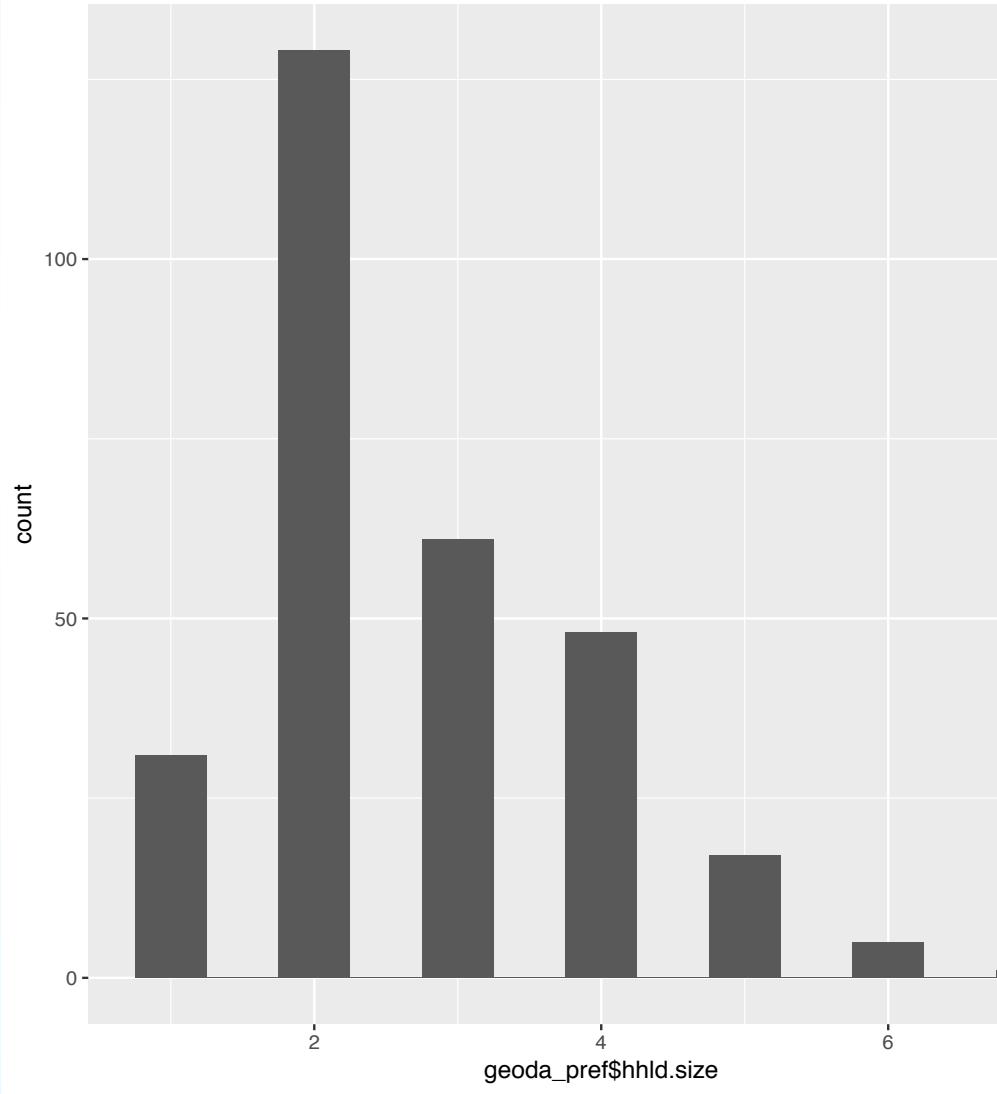
Housing an neighbourh characterist distribution

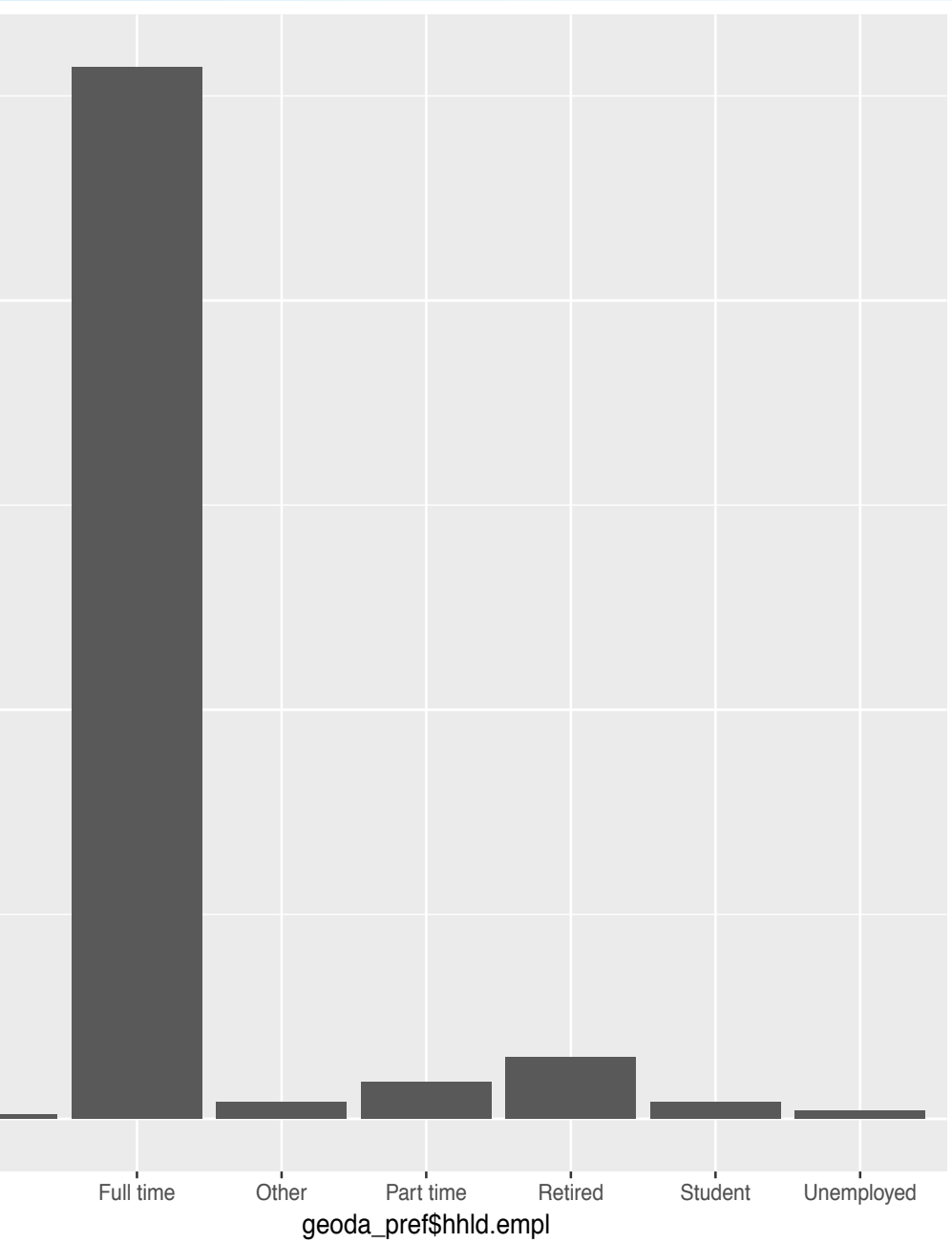
Table 4. Household type definition (Statistics Canada, 2012a, footnotes section)

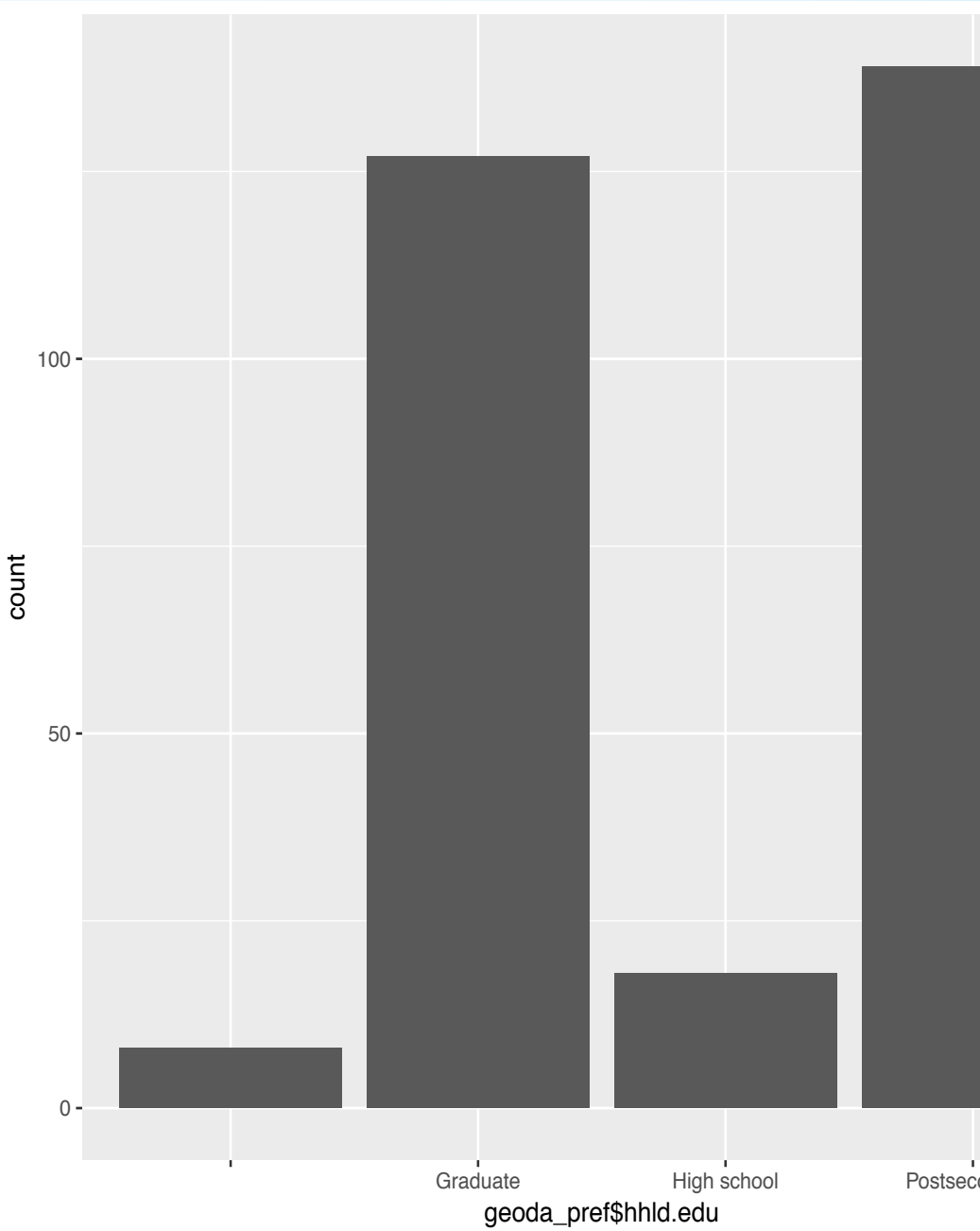
	Household type	Definition
Family households	Couple-family with children at home	Couple households with at least one child aged 24 and under
	Couple-family without children at home	Couple households without children aged 24 and under as well as couple households with all children aged 25 and over
	Lone-parent family	Lone-parent family households regardless of age of children
	Multi-family	Households in which two or more census families (with or without additional persons) occupy the same private dwelling
Non-family households	One-person household	One person living alone in a private dwelling
	Other household	Two or more people who share a private dwelling, but who do not constitute a census family

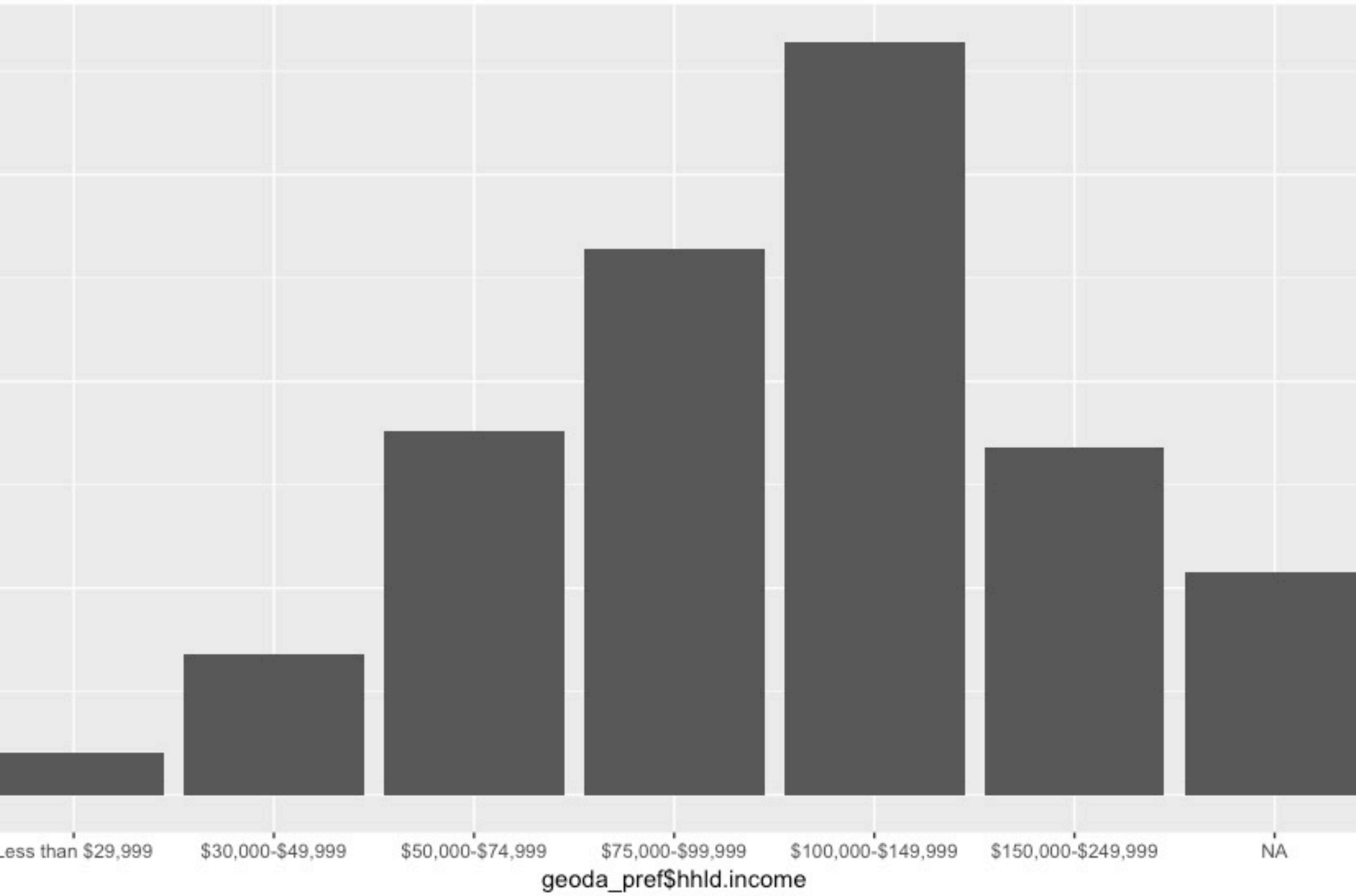
Household characteristics

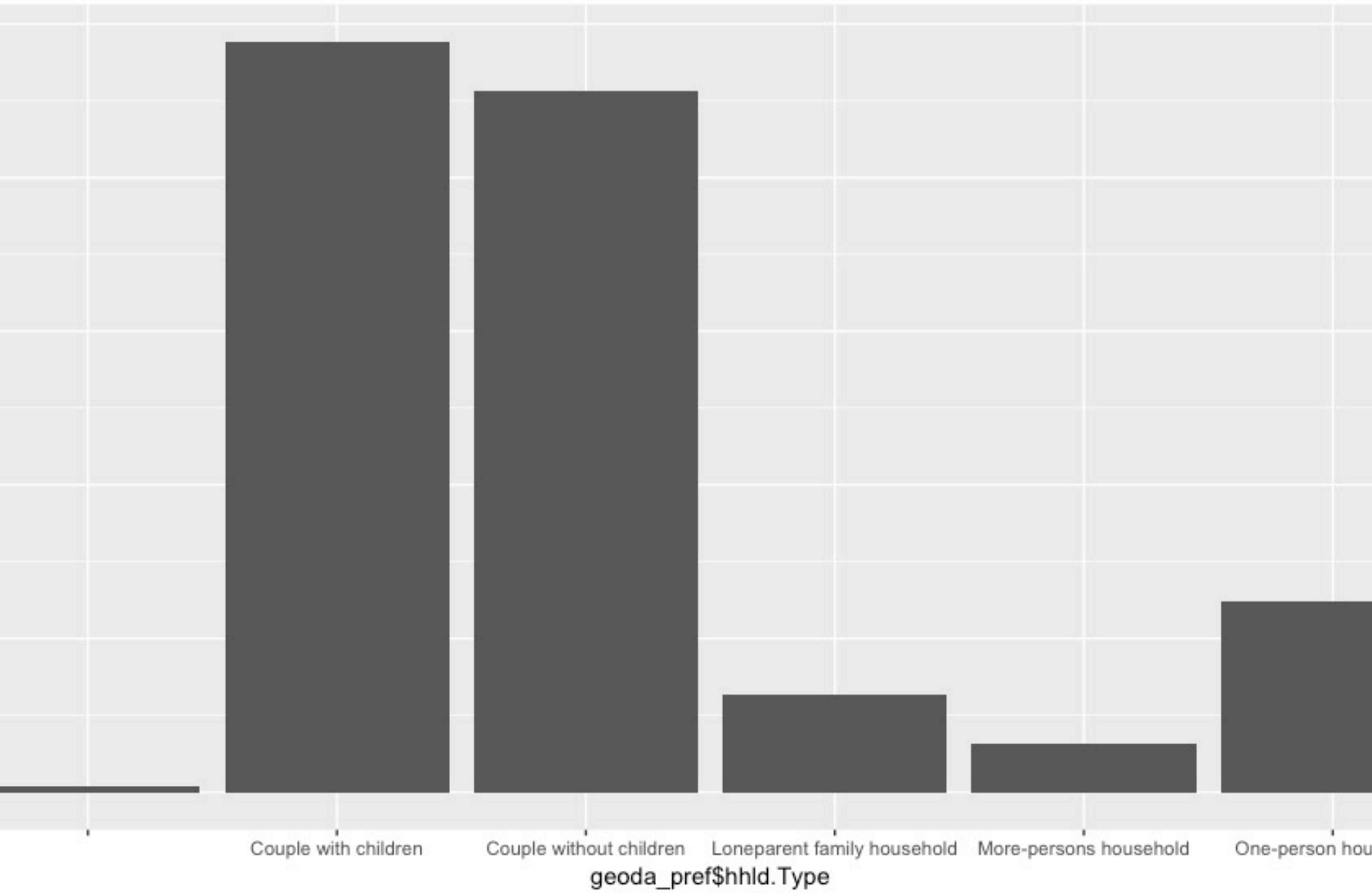





Full time
Other
Part time
Retired
Student
Unemployed
geoda_pref$hhld.empl


100
50
0
count
Graduate
High school
geoda_pref$hhld.edu


Less than $29,999
$30,000-$49,999
$50,000-$74,999
$75,000-$99,999
$100,000-$149,999
$150,000-$249,999
NA
geoda_pref$hhld.income


Couple with children
Couple without children
Loneparent family household
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One-person hou
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By Colin Butler, CBC News Posted: Jun 08, 2016 5:07 PM ET | Last Updated: Jun 08, 2016 5:07 PM ET


Canada
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By Colin Butler, CBC News Posted: Oct 04, 2016 5:30 AM ET | Last Updated: Oct 07, 2016 11:30 AM ET