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RESEARCH PAPER

Household Crowding Measures: A Comparison and External Test of Validity

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Abstract
Analysts may have multiple measures of household crowding, and so need to know which measure to emphasise. We analyse the relationships between alternative subjective and objective crowding measures and assess how well these alternative measures predict a measure of residential satisfaction. Statistically, a perceived crowding (PC) measure outperforms the people per bedroom (PPBR) measure, an objective measure of crowding. However, there may be bias in the relationship between PC and the residential satisfaction variable. Amongst objective measures, the Canadian National Occupancy Standard also outperforms PPBR. Nevertheless, all three measures are highly correlated and each helps to predict levels of residential satisfaction. Thus, any of the three measures provides a valid indicator of household crowding when assessing housing stress.

Keywords Cross-sectional models · General welfare · Well-being · General regional economics · Economic sociology

JEL codes Cross-Sectional Models (C21) · General Welfare · Well-being (I31) · General Regional Economics (R12) · Economic Sociology (Z13)

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1 Introduction

Residential satisfaction (RS) is related to many factors derived from the social and physical aspects of the living environment. The causal relationship is discussed by Rodgers (1982), who highlighted the causal impact of household crowding and density on both dwelling and neighbourhood satisfaction. Crowding can be measured both subjectively (self-rated) and objectively (data driven), and different crowding scales incorporate different degrees of subjectivity. We examine the degree to which different crowding scales help predict residents' satisfaction with their living conditions in order to rank the scales in terms of their validity as crowding measures.

We focus on residential satisfaction as our housing-related outcome as opposed to a market-based variable as is often used in urban economic studies (Cheshire & Sheppard 2004) for a number of reasons. The principal reason is that people move infrequently due to high transactions costs of moving so their current housing circumstances may not be well summarised by recent market transactions. For instance, they may have changed their family circumstances (marriage, or birth of a child, etc.) since they last moved dwelling, or their income may have changed, or their house may have deteriorated or been improved since their last shift. These changes will be reflected in their reported residential satisfaction but will not be reflected in market transactions which instead relate to revealed preferences. The use of subjective measures in the economics literature has become more common since Easterlin's (1974) study on the economics of happiness. Deaton (2010, 2016), for instance, has argued for greater emphasis to be placed on self-reported measures of material wellbeing relative to objective measures such as incomes, finding that the former may have greater content than the latter for explaining overall life satisfaction. In the New Zealand context, Perry (2015) and Carver and Grimes (2016) find that subjective factors relating to consumption adequacy help to predict overall life satisfaction even after controlling for incomes.

Residential satisfaction reflects a combination of objective and subjective characteristics of the living environment relative to an individual's understanding of the characteristics of a desirable living environment. It therefore provides an overall summary statistic for how an individual views the quality of their residential situation. It is reasonable to posit that an appropriate crowding measure is one that helps to explain variations in residential satisfaction across individuals, after controlling for other factors. (For further discussion on the appropriateness of residential satisfaction measure see Torshizian 2017.)

The sample population of this study is the Auckland region, including the city of Auckland, which has consistently been ranked as one of the top five cities in the world in which to live according to the Mercer Quality of Living survey (Mercer 2015). While the city is polycentric, approximately 33 per cent of its population live in the Central Auckland urban zone (Grimes & Liang 2009; Johnston et al. 2009; Maré et al. 2011).

Auckland has been experiencing a very sharp increase in population and housing prices over the last decade (Torshizian 2016). According to Statistics New Zealand census data, the proportion of Auckland's population that lives in crowded houses remained almost static between 2006 and 2013[1]. However, Morrison and Torshizian (2017) and Superu (2018) show that the distribution of household crowding is skewed, and the result is an

[1] See: https://archive.stats.govt.nz/browse_for_stats/people_and_communities/housing/auckland-housing-1991-2013.aspx.

increase in seriously overcrowded houses over this period. Furthermore, crowding can be measured in different ways, and to be confident in interpreting whether observed crowding is impacting on residential satisfaction, valid measures of crowding are needed. Alternative measures differ on how subjective they are, ranging from a purely objective measure (for example, crowding measured as the number of people per room) to a subjective measure (for example, based on qualitative survey information). In the present study both objective and subjective measures are tested in terms of how well they help to predict residents' reported residential satisfaction. In examining the impact of each measure on residential satisfaction, we control for other factors that may contribute to functional overcrowding, such as having a cold house which may cause residents to leave some rooms unheated and empty, thereby effectively increasing crowding. Factors that lead to functional crowding such as this may be better reflected in the subjective measure of crowding than in objective measures, consistent with Deaton's emphasis on considering self-rated measures of wellbeing.

In the next section we review the crowding concept and the three main measures used in this study, and then discuss the central hypothesis of the paper. Section 3 presents the data and some information about the three measures of crowding. The research design section discusses the methods used in the study. The final section includes our results and suggestions for future research.

2 Alternative Crowding Measures

The choice of crowding measure across studies will depend both on the focus of the study and on the availability of alternative household crowding measures (Goodyear et al. 2011; Baker et al. 2013). In their review of studies that related household crowding to infectious diseases, Baker et al. found people per room to be the most common crowding measure followed by people per house and people per bedroom[2]. A study of the negative relationship between household crowding and educational outcomes (Lopoo & London 2016) defined crowding as having more household members than rooms in one's residence. Conceptually, however, it is not clear why certain crowding measures have been adopted in various health and education contexts suggesting that researchers have, at least on some occasions, adopted a conveniently available measure as opposed to one that provides the most relevant information to the field of study. One way to interpret our contribution is to ask whether this 'adoption by convenience' in such studies is likely to produce misleading findings.

Bonnes et al. (1991) highlighted the need for consideration both of crowding perceptions and of objective measures of crowding. We incorporate both types of measures in our study. Baker et al. (2006) provided a comprehensive description of household crowding in New Zealand using census data from 1991 to 2006. Based on their analysis using the Canadian National Occupancy Standard (CNOS) measure of crowding, 10.4 per cent of New Zealand's population was exposed to household crowding in 2006, compared with 10.1 per cent in 2001 and 11.9 per cent in 1991.

Amongst objective indicators, floor area per person is regularly used by the United Nations and World Health Organisation as a quality of life indicator, more particularly as a measure of sustainable human settlement development. The people per room (PPR) index,

[2] In that review, there is no information available about the use of CNOS.

Table 1 Criteria of crowding indexes, inspired by Goodyear, Fabian and Hay (2011)

Index	Based on	Couple status	Age that boys and girls can share	Age that same sex children can share
PPR	Rooms	Not used	–	–
PPBR	Bedrooms	Not used	–	–
APPBR	Bedrooms	Used	–	–
CNOS	Bedrooms	Used	Under 5	Under 18
HIR	Bedrooms	Used	Under 10	Under 10

also known as the American Crowding Index (ACI), is another commonly used crowding index. In the US, a house with more than one person per room is considered crowded, while a house with more than 1.5 people per room is considered very crowded. For instance, in a housing quality study, Cook and Bruin (1994) used PPR as a crowding measure. The PPR measure is a raw crowding measure that does not take into account the type of the rooms nor the characteristics of the residents. For more details, see Table 1.

Another crowding measure is people per bedroom (PPBR)[3], which equals the number of people living in the house divided by the number of bedrooms in the house. A further measure is adjusted people per bedroom (APPBR), which treats a couple as one person rather than two. In the definition of PPBR and APPBR, the number of bedrooms takes into account a room furnished as a bedroom and also includes caravans, sleep-outs and other rooms in cases where they are the only bedroom facilities available in the dwelling. Other rooms are not included in this measure. Crowding indexes do not define how bedrooms are defined.

The PPR, PPBR and APPBR measures do not account for the composition of households (other than couple status for APPBR). Another measure, CNOS, does consider household composition. In this measure, children under 18 years old may share a bedroom if they are of the same sex while children of opposite sex may share a room up to the age of 5[4].

In New Zealand, crowding standards are defined based on the Housing Improvement Regulations 1947 (HIR) (Yoshikawa & Ohtaka 1989)[5]. Within the HIR, children between one and 10 years old are counted as half a person and the number of people per bedroom should not exceed 2.5. Children more than 10 years of age may not share a room.

Perceived crowding[6] (PC) reflects people's subjective evaluations of the number of people living in a small area, generally their dwelling. Since perceptions are subjective, these may be affected by their socioeconomic status or cultural background (Stokols 1972;

[3] This measure is also called room density. To avoid confusion, we refer to it in this study as people per bedroom.

[4] Based on CNOS, a household is considered to be crowded if any of the following criteria is violated: the number of people per bedroom should not exceed two, however parents or couples may share a bedroom; children aged less than five years may share a bedroom; children aged over four and less than 18 years and of the same sex may share a bedroom; children aged between five and 17 years should not share a bedroom with children aged less than or equal to five years and of the opposite sex; single adults aged more than or equal to 18 years and any unpaired children should have their separate bedroom.

[5] While the NZ housing regulations are the only legal standards for crowding they are not generally used.

[6] This measure is also called perceived density. To avoid confusion, we refer to it in this paper as perceived crowding.

Goodyear et al. 2011; Superu 2018). Stokols (1972) argues that a person's understanding of his or her crowding level depends on his/her relative intensity of spatial, social and personal factors and the possibility of changing them. PC may also contain information on individuals' understanding of the sufficiency of the size of rooms and bedrooms, which is not reflected in the other measures of crowding.

The relevance of cultural backgrounds to people's evaluations is known as 'cultural relativism'. For example, sleeping in the living area is prevalent in Japanese culture but not common in some other nations. Thus, households with the same characteristics living in similar living environments may be considered crowded in one country or culture but not in another (Superu 2018). Consequently, besides objective measures of crowding, we include PC, which is measured by the subjective evaluation of the interviewee about the size of his/her own dwelling. The house is considered to be crowded if an interviewee says his or her dwelling is too small. In one culturally-specific study, Schluter et al. (2007) compared PC, PPR and CNOS to report the best measure of crowding for Pacific Island households in Auckland. They used data derived from interviews with mothers of a cohort of infants born during 2000 in Auckland, which yielded a total of 1224 observations. The dependent variable in their study is the overall satisfaction with the home meeting the family's needs, finding PC to be the best measure of crowding for this cultural group.

Rodgers (1982) studied the relationship between crowding and satisfaction with community, satisfaction with neighbourhood and satisfaction with dwelling unit, using data from Detroit metropolitan area. He concluded that the relationship between satisfaction measures and PC is stronger than the correlation with objective measures. Rodgers introduced economic factors, such as income levels, as the main reason for the difference between the explanatory power of subjective and objective measures of crowding.

These limited studies suggest that residential satisfaction is associated with both objective and subjective measures. However, the degree to which the various measures are substitutable (i.e. are correlated with each other) has not been well determined before, and nor has the ability of an objective indicator to add to the explanatory power of a subjective measure, and vice versa. On the basis of previous studies, we hypothesise that perceived crowding is more closely associated with residential satisfaction than are objective measures. Prior to our tests, however, we are agnostic as to whether objective measures add to the explanatory power of subjective measures. In this study we use the two most common measures of household crowding, PPBR and CNOS, and the subjective measure of crowding (PC).

3 Data and Sample

This study was conducted using three waves of the General Social Survey (NZGSS) – 2008, 2010 and 2012 – each of which has approximately 8500 observations[7]. The total number of observations in the Auckland region is 5832. In the survey, respondents answer

[7] The questionnaire for these surveys is available at the following link:
https://archive.stats.govt.nz/~/media/Statistics/browse-categories/people-and-communities/families/general-social-survey/GSSQuestionnaire2008.pdf.
https://archive.stats.govt.nz/~/media/Statistics/browse-categories/people-and-communities/families/general-social-survey/GSSQuestionnaire2010.pdf.
https://archive.stats.govt.nz/~/media/Statistics/surveys-and-methods/completing-a-survey/faqs-about-our-surveys/nzgss/gss-questionnaire-2012.pdf..

Table 2 PPBR summary statistics

	Observations	Mean			*P*_value*	Min	Max
		2008	2010	2012			
Unrestricted PPBR	5816	1.041	1.081	1.041	0.158	0.2	8.0
Restricted PPBR	5715	1.006	1.038	1.006	0.171	0.2	2.1

*The *P* value corresponds to the test of the null hypothesis that the means of this variable across three waves of data (2008, 2010 and 2012), are equal

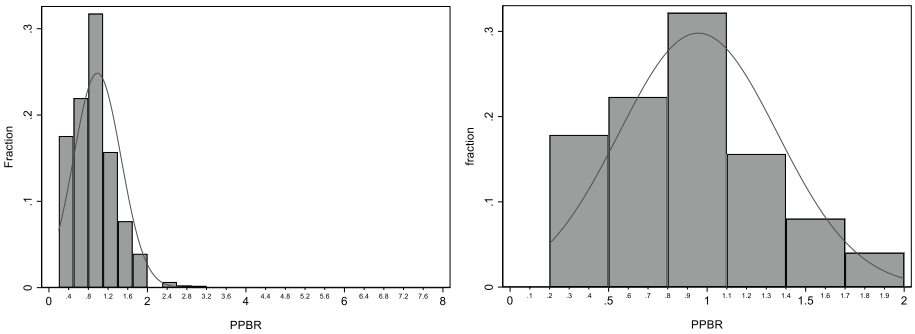

Fig. 1 The distribution of PPBR. *On the left-hand side, the probability density function (PDF) is illustrated before omitting the outliers. The figure on the right-hand side depicts the PDF after restricting the variable to values ≤ 2 (98.2 per cent of the sampling population). The horizontal axis is the number of people per bedroom

questions about their usual residence. Therefore, they are considering the primary residence in their evaluation of their living environment.

Residential satisfaction is the outcome of interest in the current study. The variable is derived from answers to the NZGSS question: 'How do you feel about where you are currently living'. Five categories were defined for the answers to this question. Based on the distribution of the answers, we have aggregated the five categories into two groups: satisfied and dissatisfied[8]. We tested the effect of different aggregations of the dependent variable on the results and found no significant effects[9].

3.1 Descriptive Statistics

We describe the variables that are central to answering our research question; other variables used in the study are described in the "Appendix". The distribution of the outcome variable (RS) comprises 63% of respondents being dissatisfied with their residential

[8] The distribution is very negatively skewed such that 84 per cent of observations fit into two groups: 'very satisfied' and 'satisfied'. Considering the high proportion of the 'satisfied' group, we distinguish between those who are 'very satisfied' and all others – i.e. the residential satisfaction variable is dichotomous.

[9] We compare the impacts of the explanatory variables between a model using the five-category output and a model using the binary output. The results are not significantly different. For identifying the correct re-categorisation, we use the Brant test (Brant 1990).

Table 3 Household size versus CNOS

Household size	Household crowding (CNOS)			
	At least one bedroom needed	No bedrooms needed	One bedroom spare	Two or more bedrooms spare
One person	0.00	0.19	0.34	0.48
Two people	0.01	0.08	0.26	0.65
Three people	0.02	0.20	0.48	0.30
Four people	0.05	0.24	0.38	0.33
Five people	0.11	0.43	0.31	0.15
Six people	0.25	0.36	0.27	0.12
Seven people	0.26	0.34	0.30	0.10
Eight people	0.40	0.31	0.20	0.10
All households	0.14	0.27	0.32	0.28

N = 5715. Rows sum to 1.0; decimals are rounded

Table 4 Household size versus PPBR

Household size	Household crowding (PPBR)						PC
	(0.0, 0.3]	(0.3, 0.6]	(0.6, 0.9]	(0.9, 1.3]	(1.3, 2.0]	> 2.0	Small house (%)
One person	0.12	0.69	0.00	0.19	0.00	0.00	6.6
Two people	0.00	0.24	0.48	0.24	0.00	0.04	7.8
Three people	0.00	0.00	0.33	0.53	0.13	0.00	14.3
Four people	0.00	0.00	0.14	0.38	0.41	0.07	15.2
Five people	0.00	0.00	0.00	0.63	0.37	0.00	18.5
Six people	0.00	0.00	0.00	0.28	0.34	0.38	18.3
Seven people	0.00	0.00	0.00	0.00	1.00	0.00	24.5
Eight people	0.00	0.00	0.00	0.00	0.73	0.27	27.0
All households	0.01	0.14	0.21	0.37	0.25	0.02	10.8

N = 5715; intervals for PPBR shown at head of columns; rows sum to 1.0; decimals are rounded

environment and 37% being satisfied. Thus a little over one-third of respondents report that they are 'very satisfied' with their current dwelling.

Turning to the crowding measures, as illustrated in the first row of Table 2, PPBR takes values between 0.2 and 8, with an overall mean of 1.05. We cannot reject the null hypothesis that the mean across years is identical. As depicted on the left-hand side of Fig. 1, 54 per cent of observations have a PPBR less than 0.8, 25 per cent are equal to 1 and 25 per cent are greater than 1 and less than 2.1. To derive a more reliable measure, we drop the outliers that had a reported PPBR between 2.1 and 8 (this represented 101 observations, which is less than 1.8 per cent of the sample population). The kernel density plot

Table 5 Distribution of PPBR versus PC (small-house problem)

People per bedroom	PC: Small-house problem	
	No	Yes
All households	0.89	0.11
$0 < \text{PPBR} \leq 0.3$	0.98	0.02
$0.3 < \text{PPBR} \leq 0.6$	0.97	0.03
$0.6 < \text{PPBR} \leq 0.9$	0.97	0.03
$0.9 < \text{PPBR} \leq 1.3$	0.90	0.10
$1.3 < \text{PPBR} \leq 2.1$	0.79	0.21

N = 5715. Rows sum to 1.0; decimals are rounded

Table 6 Averages of PC and PPBR at different levels of CNOS

CNOS	PC (Crowded %)	PPBR
One or more bedrooms needed	31.0	1.76
No bedrooms needed	24.0	1.38
One bedroom spare	12.3	0.94
Two or more bedrooms spare	3.2	0.60

N = 5715. Decimals are rounded

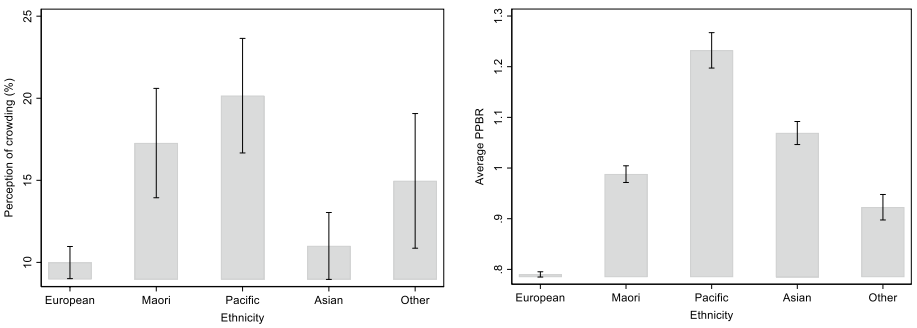

Fig. 2 Perceived crowding and PPBR by ethnicity

by imposing this restriction on the PPBR variable is illustrated on the right-hand side of Fig. 1[10]. The second row of Table 2 provides the resulting summary statistics; the overall mean is equal to 1.02.

Table 3 tabulates CNOS against household size while in Table 4, PPBR and PC are tabulated against household size. Amongst one-person households, the norm is to have at least one spare bedroom according to CNOS while PPBR is mainly between 0.3 and 0.6. The positive correlation between PPBR and household size suggests that members of a large household are not likely to be provided with a commensurate number of bedrooms.

[10] The categories defined on the horizontal axis of Fig. 1 are aggregate categories for the PPBR values that fit within each defined bin. Size of each bin is 0.3.

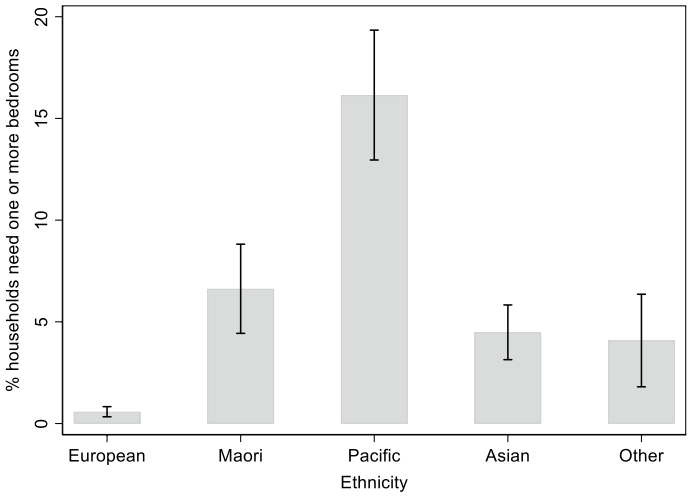

Fig. 3 CNOS (one or more bedrooms needed) by ethnicity

As illustrated in the PC column, as household size increases the proportion of households who perceive their house to be too small also increases.

In Table 5, PPBR is tabulated versus PC. As shown, the percentage of people who perceive their house to be too small increases as PPBR increases. Table 6 shows the average PPBR and the proportions of households perceiving their house being small at different categories of CNOS. As the CNOS categories shift from indications of crowding to indications of spare rooms, both PPBR and PC decline. These raw relationships are all as expected, indicating that alternative crowding measures are providing broadly consistent information.

As discussed by Goodyear et al. (2011), both objective circumstances and cultural norms relating to housing may differ across ethnic groups. The differences in perceived crowding (PC) and the PPBR measure of objective crowding for different ethnic groups is illustrated in Fig. 2 while Fig. 3 illustrates the percentage of households who are categorised in the 'one or more bedrooms needed' category of CNOS. The error bars in Figs. 2 and 3 provide 95% confidence intervals for each category. Across each measure, people of Pacific ethnicity are most likely to face crowding and those of European ethnicity are the least crowded. However, the measures indicate the potential for some difference in cultural responses for Māori relative to those of Asian ethnicities[11]. On average, Asian households have a higher PPBR than do Māori households and have only a slightly lower proportion of households needing at least one bedroom according to CNOS. However, perceptions of crowding are much more prevalent amongst Māori than amongst Asian households. These differences may be due to differing degrees of skewness of crowding within each ethnic group or may reflect different cultural norms about how space should be shared in a house.

[11] We ignore 'Other' in the discussion since this group is very small.

4 Research Design

We test which crowding measure(s) has the greatest explanatory power for explaining residential satisfaction (RS) after controlling for other influences on RS. The equation to be estimated is as follows:

$$y_i = \alpha_0 + \alpha_1 . x_i + \alpha_2 . w_i + \beta.\text{Controls}_i + \varepsilon_i \quad (1)$$

in which the dependent variable (y_i) is individual i's residential satisfaction (measured as a binary variable), and x_i is a vector of our variables of interest, including PPBR[12] and PC. Given that we control for marital status, we do not include APPBR as a variable of interest separate from PPBR, nor do we include PPR since preliminary work indicates that PPBR outperforms PPR as an objective measure in this application (for further details see Torshizian (2017)). Given the categorical structure of CNOS, it is included as a vector of dummy variables, depicted by w_i, with coefficient vector α_2. Thus, α_1 and α_2 are the parameters of interest; and ε_i is the error term. Considering that residential satisfaction is a binary dependent variable; we use logistic regression for ease of interpretation[13].

In addition to the variables of interest, the effects of other factors on RS need to be controlled for. In Eq. 1, the control variables are indicated by Controls_i and include: marital status; housing problems (including difficult access from the street, poor condition, damp, cold, having pests and being expensive); and neighbourhood problems (including being located far from work, located far from other destinations, being unsafe, having noise or vibration and having air pollution). All control variables are named and described in the "Appendix".

5 Models and Results

To compare the power of PPBR, CNOS and PC to predict residential satisfaction, seven models are estimated and presented in Table 7. The coefficients are reported as odds ratios, so that the impact is negative if the coefficient is less than 1 and is positive if the coefficient is greater than one.

The same control variables are included in models 1 to 7. For the sake of brevity, the table does not report the coefficients for the control variables; their impacts are very similar to the results of previous studies (Roskruge et al. 2013; Dekker et al. 2011; Dietz & Haurin 2003; Glaeser & Kahn 2001; McCarthy et al. 2001). In particular, compared to homeowners, renters are significantly less likely to be satisfied with their living environment.

[12] In addition to PPBR, we also include PPBR^2. The assumption of a quadratic relationship between this measure of crowding and residential satisfaction is consistent with Rodgers' (1982) findings that these relationships are better described in a curvilinear form than a linear one.

[13] Different methods of resampling may serve to increase the precision of estimates using survey designs by deriving more robust standard errors, proportions, odds ratios and regression coefficients. To do this, a random set of observations is left out at each time of estimation. Replication of this leads to the estimation of the bias of a statistic. This method is called jackknifing.

The NZGSS provides us replicate weights produced by the delete-a-group Jackknife method (Kott 2001). In the dataset, 100 groups are derived by using primary sampling units (PSUs) randomly sorted into each stratum. This strategy results in 100 replicate samples in each, of which one of the groups is omitted and weights are adjusted accordingly. Using these weights in our estimation leads to estimates that tend asymptotically to true values. For more information see Statistics New Zealand (2013).

Table 7 Residential satisfaction as a function of people per bedroom (PPBR), perceived crowding (PC) and CNOS

	Model(1) PPBR	Model(2) PC	Model(3) CNOS	Model(4) PPBR &PC	Model(5) PPBR &CNOS	Model(6) PC &CNOS	Model(7) PPBR & PC & CNOS
PPBR	0.762[a]			0.802	1.591		1.361
	(0.386)			(0.408)	(0.909)		(0.789)
$PPBR^2$	0.913[a]			0.973	0.835		0.929
	(0.222)			(0.242)	(0.217)		(0.250)
PC		0.199***		0.212***		0.218***	0.217***
		(0.041)		(0.044)		(0.046)	(0.045)
CNOS (Two or more spare bedrooms)							
=One bedroom needed			0.277***		0.270***	0.344***	0.300***
			(0.093)		(0.107)	(0.116)	(0.121)
=No bedrooms needed			0.674***		0.639**	0.821	0.740
			(0.095)		(0.131)	(0.115)	(0.152)
=One bedroom spare			0.676***		0.644***	0.736***	0.696***
			(0.064)		(0.082)	(0.069)	(0.088)
Control variables	✓	✓	✓	✓	✓	✓	✓
Observations	4706	4706	4706	4706	4706	4706	4706
[a]PPBR Wald test	0.003			0.103	0.711		0.725
Pseudo R^2	0.1723	0.1860	0.1742	0.1872	0.1743	0.1888	0.1888
AIC	5184	5099	5175	5096	5178	5088	5092

Reported coefficients are odds ratios. Standard errors are reported in parentheses

*$p<0.10$, **$p<0.05$, ***$p<0.01$

[a]The joint significance level for PPBR and $PPBR^2$ is reported on the PPBR Wald test row. The reported AICs are for the models that do not take into account jackknife replications

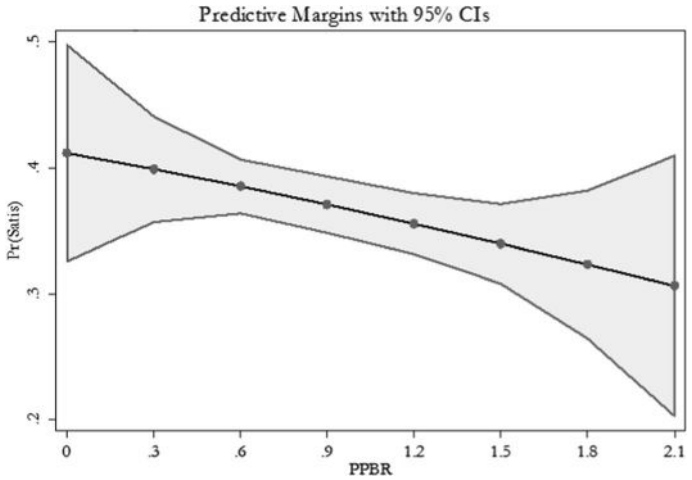

Fig. 4 The probability of being satisfied amongst different PPBR bins (derived from Model 1)

Housing and neighbourhood problems, including living in a poorly conditioned dwelling, having a damp house, having pests, having an expensive house, being far from facilities, living in an unsafe neighbourhood, and having noise and vibration in the neighbourhood, are associated with a lower chance of residential satisfaction. Having better accessibility to facilities, including shops, schools, post shops, libraries and medical services, is associated with higher RS as is satisfaction with council services.

In the first three models, each of the variables of interest is included separately. Of these models, based on the goodness of fit (GOF) criteria (AIC[14] and pseudo R-squared), PC has the highest predictive power for RS. CNOS has slightly higher predictive power than PPBR. Since we have assumed a quadratic form for the models that include PPBR, the joint statistical significance of the coefficients of the variable and its squared form ($PPBR^2$) is reported at the bottom of the table in the '†PPBR Wald test' row[15].

The next three columns include three combinations of two variables at a time; namely, PPBR and PC, PPBR and CNOS, and PC and CNOS. Model (7) incorporates all three crowding variables. Of these, model 6, which includes PC and CNOS, is the best model in terms of the AIC. We note that when included together with PC and/or CNOS, PPBR is not significant even at the 10% level (see models 4, 5 and 7).

PC is included in all of the best performing models, which confirms the important association between subjective evaluations of crowding and RS. CNOS has a higher predictive power than the raw measure (PPBR) but the difference between them is slight. While PPBR does not have as much explanatory power as PC or CNOS, the results across the three variables provide a similar picture in terms of higher levels of crowding being associated with lower likelihood of residential satisfaction.

[14] A lower value of the Akaike Information Criterion (AIC) indicates a better fitting model after taking into account the number of regressors.

[15] The null hypothesis is that the two coefficients of interest (on PPBR and PPBR2) are simultaneously equal to zero. In Model (1), for example, the result of the PPBR Wald test suggest that we can reject the null hypothesis at better than the 1 per cent significance level.

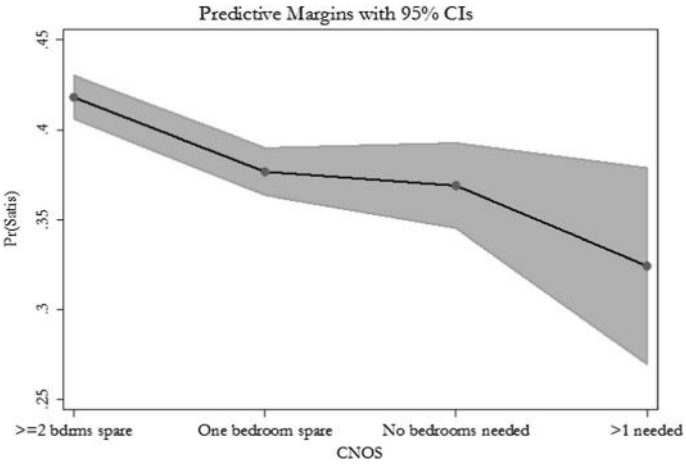

Fig. 5 The probability of being satisfied amongst different categories of CNOS

Based on model 2 results, presented in Table 7 the odds of being satisfied with residential environment for people who perceive their house to be too small are almost 80 per cent lower than those who do not perceive their house being crowded[16]. Marginal effects of PPBR are depicted in Fig. 4, based on model 1. A unit increase in PPBR results in a roughly 9 per cent decrease in RS[17].

Figure 5, based on estimates in model 3, shows that the probability of being dissatisfied for those who need one or more bedrooms (according to the CNOS measure) is 15.3 per cent higher than for those with two or more spare bedrooms. Figures 4 and 5 show that an increase in household crowding decreases the likelihood of satisfaction of those who live in a crowded household relative to those who live in a less crowded house, and the patterns are similar across the two variables.

We have also tested whether there is a difference in the impact of perceived crowding (PC)—the crowding variable with the greatest explanatory power over residential satisfaction—on the residential satisfaction of people with different demographics. After including interaction terms, we found no significant difference between the impact of PC on RS of women versus men, rich versus poor, elderly versus youth, or people of European, Māori and Asian ethnic groups. We do find, however, that the RS of Pacific people is significantly less negatively affected by an increased perception of household crowding than is the case for those of European, Māori and Asian ethnicities. When we use other crowding measures, however, we do not observe any difference in the impact of measured household crowding on RS between the different ethnic groups.

[16] The estimated odds ratios indicate the chance of gaining a higher level of the dependent variable (RS) for a one unit increase in the independent variable (PC). The odd ratios provide an understanding of the relative chance of being satisfied versus being dissatisfied. When the chance of being satisfied is equal to being dissatisfied, the odds ratio is equal to one. Hence, our results suggest that with PC being equal to one (i.e. perceiving house to be small), the odds of people being satisfied with their residential environment (relative to being dissatisfied) is equal to 0.199. This implies 80 per cent lower chance of being satisfied compared to being dissatisfied.

[17] The reported marginal effect of PPBR accounts for the non-linear relationship between RS and PPBR.

Table 8 Relationships between the variables of interest; namely, PC, PPBR and CNOS

Dependent variable	(1)	(2)	(3)			(4)	(5)
	PC	PPBR	CNOS			PPBR	PC
	Logit	OLS	Generalised ordered logit			OLS	Logit
			Need bdrs	No need	1 spare		
PPBR	3.386***		−26.7***	−4.980***	2.709		
	(0.635)		(3.501)	(0.692)	(2.054)		
Squared PPBR	−0.630**		6.854***	−0.613*	−5.48***		
	(0.261)		(1.053)	(0.313)	(1.402)		
Marginal effect (%)	0.106***		0.145***	0.462***	0.221***		
PC		0.321***					
		(0.025)					
Household crowding—CNOS (Two or more spare bedrooms)							
= One bedroom needed						−0.317***	−0.159
						(0.028)	(0.276)
Marginal effect (%)							−0.0277
= No bedrooms needed						−0.705***	-0.828***
						(0.024)	(0.287)
Marginal effect (%)							−0.118**
= One spare bedroom						−1.048***	−2.532***
						(0.024)	(0.309)
Marginal effect (%)							−0.214***
Constant	−5.037***	0.968***	26.30***	7.550***	1.880***	1.733***	−1.163***
	(0.361)	(0.007)	(2.894)	(0.365)	(0.688)	(0.023)	(0.260)
Observations	4706	4706		5715		5715	4706
F	94.06	171.2		374.2		1307.4	55.40
R^2		0.058				0.604	

Standard errors in parentheses

*$p < 0.10$, **$p < 0.05$, **$p < 0.01$

In order to assess how closely the crowding variables are related, we regress each crowding variable on the others; results are presented in Table 8. We list the dependent variables for each model in the first row. The marginal effects are reported below the estimated coefficients to provide information on the joint effect of PPBR (together with its squared term) and the categories of CNOS. In model 1, PC is regressed on PPBR and its squared form using a logit method, while model 2 regresses the inverse relationship using OLS. The results indicate that a one-unit increase in PPBR results in a 10.6 per cent increase in the likelihood of reporting a higher PC[18]. In the third model, CNOS is regressed on PPBR and its squared form by using a generalised ordered logit estimation. Based on the marginal effects, a one-unit increase in PPBR is associated with a 14.5 per cent higher CNOS, when CNOS outcome is 'one or more bedrooms needed'. In the fourth model, 60.4 per cent of

[18] The joint marginal effect of PPBR and $PPBR^2$ is reported on a row below 'squared PPBR'.

the variation of PPBR is explained by CNOS, while in model (5) we find that CNOS is a strong predictor of PC. The results of this table suggest that the crowding variables significantly explain one another and therefore provide broadly consistent indicators of crowding.

6 Conclusion

This paper has tested the hypothesis that residential satisfaction is associated more strongly with a perception of crowding than it is with objective crowding measures. This hypothesis can be interpreted as a specific example of the superior power of perceptions variables relative to objective indicators as measures of living standards as reported by Deaton (2010, 2016). To test this hypothesis, we set out to find the best measure of household crowding in explaining residential satisfaction (RS), where RS is a measure of both objective aspects and subjective characteristics of the living environment. Our crowding perceptions variable (PC) is a subjective measure of household crowding. Our objective crowding measures include people per bedroom (PPBR) and the Canadian National Occupancy Standard (CNOS) measure which adjusts for some characteristics of households, such as partnership status and the number of children.

The impact of crowding on residential satisfaction is estimated by fitting a logistic model for our binary response outcome, residential satisfaction, as a function of the alternative crowding variables. Controls for personal characteristics are included in all regressions. The results indicate that an increase in household crowding, based on any of our measures, lowers residential satisfaction significantly. This confirms Bonnes et al. (1991) findings that the relationship between crowding and residential satisfaction is negative (although the impact of perceived crowding on RS is less negative for people of Pacific ethnicities than for people of other ethnic groups). The slightly greater predictive power over RS of the perceived measure of crowding compared to the objective measures suggests that perceptions are an important manifestation of people's evaluations of their household crowding.

All three measures of household crowding—PPBR, CNOS and PC—are significantly related to each other; in other words, each gives a similar qualitative impact of crowding on residential satisfaction. This suggests that even simple objective measures such as PPBR are a useful predictor of residential satisfaction in the absence of the other measures. Given its wide availability, it can therefore be recommended as a legitimate measure for household crowding.

Another reason for using an objective (rather than subjective) measure of crowding in some contexts is where a subjective variable is used as the dependent variable in an equation. In these cases, the estimated impact of a subjective measure (such as PC) on another subjective measure (such as RS) may be biased as both of these measures are subject to a correlated measurement error (Hamermesh 2004). This problem is avoided by use of the objective (PPBR and CNOS) measures. We note here that this issue implies that the superior performance of PC over PPBR and CNOS reported in Table 7 may over-state the advantage of the subjective measure over the two objective measures, further strengthening the case that the objective measures are legitimate indicators of household crowding.

Our main contribution for analysts investigating the impacts of household crowding is to show that, despite the apparent superiority of the perceived crowding measure, the objective measures are also appropriate indicators of crowding (and they may even be preferred in cases where a subjective measure is used as the dependent variable in a relationship). Within the objective measures, the more complex CNOS indicator slightly out-performs

PPBR. Nevertheless, the PPBR measure performs almost as well as CNOS and gives qualitatively similar results to the perceived crowding indicator. This simple measure—based solely on the number of residents and number of bedrooms in a house—is therefore a legitimate measure of household crowding for use in studies of residential satisfaction.

Appendix

Description of control variables

Descriptive statistics for all control variables are presented in Table 9; all variables in the table are categorical variables. For example, 'Gender' is a binary variable with 0 for females and 1 for males (in NZGSS, this variable is called 'cordv10', as shown in the brackets). The mean of this variable is equal to 0.485, indicating that 48.5 per cent of respondents are male and the rest are female.

Table 9 Descriptive statistics of variables used from NZGSS

Variables	Description	Mean
Gender [cordv10]	1 = 'male'	0.484
Partner [cordv1]	1 = 'Partnered'	0.597
Age [cordv9]	= 15–19	0.093
	= 20–24	0.103
	= 25–29	0.095
	= 30–34	0.089
	= 35–39	0.092
	= 40–44	0.097
	= 45–49	0.094
	= 50–54	0.078
	= 55–59	0.068
	= 60–64	0.056
	= 65–69	0.046
	= 70–74	0.034
	= 75–79	0.024
	= 80–84	0.019
	≥ 85	0.014
Length of living in New Zealand [cordv7]	< 4 years	0.103
	= 4–10 years	0.139
	= 10–25 years	0.107
	> 25 years	0.651

Table 9 (continued)

Variables	Description	Mean
Ethnicity [cordv18]	European	0.607
	Māori	0.044
	European/Māori	0.079
	Pacific	0.188
	Asian	0.028
	MELAA	0.037
	Other	0.026
Education [cordv15]	=No qualification	0.136
	=Certificates	0.479
	=Degree	0.386

Table 9 (continued)

Variables	Description	Mean
Household income[a] [cordv13]	=Zero	0.005
	=$1–$5,000	0.003
	=$5,001–$10,000	0.006
	=$10,001–$15,000	0.018
	=$15,001–$20,000	0.029
	=$20,001–$25,000	0.026
	=$25,001–$30,000	0.037
	=$30,001–$35,000	0.031
	=$35,001–$40,000	0.032
	=$40,001–$45,000	0.058
	=$45,001–$50,000	0.058
	=$50,001–$70,000	0.093
	=$70,001–$100,000	0.189
	=$100,001–$150,000	0.218
	=$150,001 or more	0.196

Table 9 (continued)

Variables	Description	Mean
Household size [cordv6]	=One person	0.096
	=Two people	0.258
	=Three people	0.208
	=Four people	0.241
	=Five people	0.117
	=Six people	0.052
	=Seven people	0.017
	=Eight people	0.011
Health perception [heaq01]	=Very dissatisfied	0.021
	=Dissatisfied	0.092
	=No feeling either way	0.243
	=Satisfied	0.372
	=Very satisfied	0.271
Ability perception (includes individual's feeling about his/her knowledge, skills and abilities) [kasq01]	=Very dissatisfied	0.002
	=Dissatisfied	0.042
	=No feeling either way	0.074
	=Satisfied	0.631
	=Very satisfied	0.25
Residential Satisfaction [houq01]	=Dissatisfied	0.633
	=Satisfied	0.367

Table 9 (continued)

Variables	Description	Mean
Urban area[b] [ua]	= Main urban	0.942
	= Secondary urban	0.017
	= Minor urban	0.012
	= Rural	0.029
Free time (Individual's feeling about having enough free time) [leiq01]	= Too much free time	0.421
	= The right amount of free time	0.479
	= Not enough free time	0.1
Socialising (Frequency of meeting friends) [socq07]	= Every day	0.087
	= Around 3–6 times a week	0.149
	= Around 1–2 times a week	0.373
	= Around once a fortnight	0.213
	= At least once in the last four weeks	0.178
Local political involvement [humq03]	1 = 'Yes'	0.382
Recycling (How much does the household recycle) [phyq06]	= None	0.011
	= A little	0.02
	= Some	0.11
	= Most	0.556
	= All	0.303
Council services (Individual's feeling about the quality of council services) [phyq05]	= Very dissatisfied	0.025
	= Dissatisfied	0.099
	No feeling either way	0.138
	= Satisfied	0.603
	= Very satisfied	0.135

Table 9 (continued)

Variables	Description	Mean
Green space access (Access to local green spaces including bushes, forests, nature reserves) [phyq13]	= Never want or need to go	0.018
	= None of them	0.01
	= A few of them	0.056
	= Some of them	0.152
	= Most of them	0.437
	= All of them	0.328
Green space state [phyq14]	= Not been to	0.001
	= Very dissatisfied	0.002
	= Dissatisfied	0.03
	= No feeling either way	0.092
	= Satisfied	0.644
	= Very satisfied	0.221
Coastline access (Access to local lakes, rivers, harbours and oceans) [phyq11]	= Never want or need	0.015
	= None of them	0.017
	= A few of them	0.055
	= Some of them	0.15
	= Most of them	0.42
	= All of them	0.343
Coastline state (Household's feeling about the state of coastlines) [phyq12]	= Not been to	0.01
	= Very dissatisfied	0.007
	= Dissatisfied	0.081
	= No feeling either way	0.113
	= Satisfied	0.632
	= Very satisfied	0.157

Table 9 (continued)

Variables	Description	Mean
Water use (How often does the household try to minimise water use?) [phyq09]	=Never	0.085
	=A little of the time	0.107
	=Some of the time	0.267
	=Most of the time	0.398
	=All of the time	0.143
Energy use (How often does the household try to minimise energy use?) [phyq07]	=Never	0.023
	=A little of the time	0.086
	=Some of the time	0.299
	=Most of the time	0.466
	=All of the time	0.126
Facilities access (including shops, schools, post shops, libraries and medical services) [phyq01]	=Never want or need to go to any of them	0.003
	=None of them	0.006
	=A few of them	0.025
	=Some of them	0.058
	=Most of them	0.302
	=All of them	0.606
Year	=2008	0.339
	=2010	0.332
	=2012	0.329

Table 9 (continued)

Variables	Description	Mean
Homeownership status [cordv16]	=Owned, not defined	0.001
	=Owned, mortgage	0.336
	=Owned, no mortgage	0.179
	=Not owned, not defined	0.001
	=Not owned, rent	0.313
	=Not owned, no rent	0.014
	=Family trust, not defined	0.002
	=Family trust, mortgage	0.08
	=Family trust, no mortgage	0.073
Small-house perception [houq03_11]		0.113
		0.104
		0.101
Bad street access [houq03_12]		0.019
		0.024
		0.011
Poor condition [houq03_13]		0.062
		0.05
		0.057
Damp dwelling [houq03_14]		0.107
		0.109
		0.105
Difficult to heat [houq03_15]		0.151
		0.144
		0.151

Table 9 (continued)

Variables	Description	Mean
Having pests		0.062
[houq03_16]		0.066
		0.053
Expensive house		0.074
[houq03_17]		0.064
		0.073
Far from work		0.048
[houq04_11]		0.049
		0.03
Far from facilities		0.033
[houq04_12]		0.037
		0.018
Unsafe neighbourhood		0.041
[houq04_13]		0.032
		0.035
Noise and vibration		0.123
[houq04_14]		0.123
		0.102
Air pollution		0.04
[houq04_14]		0.034
		0.029
Observations	5715	

[a]Strictly speaking, we should inflation adjust the thresholds for personal and household income, but this is not a practical approach owing to the questionnaire design; due to the categorical design of the income variable, we are not aware of individuals' absolute value of income. CPI inflation from the quarter one of 2008 to the second quarter of 2012 was approximately 12 per cent

[b]The definition is based on the 1996 Census. Based on this, definition of urban area types differ based on how strong their economic ties are, how active they are from cultural and recreational point of view, how well they offer services to businesses, how easy it is to access their transportation network, and their prospective development

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