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**Respiratory Health of Pacific Island Immigrants  
and Preferences for Indoor Air Quality Determinants in New Zealand**

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## **Abstract**

Indoor air quality affects respiratory diseases, such as asthma, and can be altered by devices that lower dwelling humidity and raise temperature. Several countries have initiated schemes that subsidize devices such as heat pumps based on putative health benefits but the valuations of these devices by the affected populations remains unknown. We investigate preferences for devices that affect indoor air quality, dampness, and warmth, using a choice experiment with a sample of Pacific Islander immigrants in New Zealand. This is a high risk group for respiratory disease, who typically rent crowded and inadequately heated dwellings. Using both conditional logit and panel mixed logit models we find reasonably precise estimates of the willingness to pay for four improved heating and humidity control devices, which would cover the capital costs of two of the devices, and add up to about three-quarters of the cost of the other two devices.

## **Keywords**

respiratory health  
indoor air-quality devices  
choice experiments

## **JEL Codes**

C25; I12; Q53

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## 1. Introduction

The quality of indoor air is an important determinant of respiratory disorders such as asthma and chronic obstructive pulmonary disease (COPD). Indoor air quality may be affected by whether residents smoke, by how weatherproof is the dwelling and the severity of exterior air pollution, but most especially, by the use of a variety of devices that affect dwelling humidity and temperature, particularly in winter when more time is spent indoors. Such devices include clean heating (for example, flued gas heaters, heat pumps), heat-recovery ventilation systems (HRV), and de-humidifiers. The positive impact on respiratory health of replacing ineffective and polluting forms of heating, such as unflued gas heaters, with cleaner and more effective devices is demonstrated by randomized control trials (Howden-Chapman *et al.* 2008; Preval *et al.* 2010). For example, children in the treatment groups make fewer visits to the doctor and have fewer days off school due to asthma, and the value of these health benefits exceeds the costs when the intervention is targeted to households with high rates of asthma.

Evidence from such trials has supported the development of national targeted grants schemes for retro-fitting insulation in dwellings and installing improved heating, such as Warm Homes Plus in Northern Ireland and Warm Up New Zealand. But it is unclear what values the affected population themselves place on improved heating, since randomized trials typically give the improved heating devices away for free and the national schemes lack plausible methods of estimating how much of the subsidized activity might have occurred anyway. Moreover, renters pose a particular problem for cost-benefit analysis of such schemes; the heating devices are typically immobile and landlords receive the device for free (or with a subsidy), so it is difficult to target the intervention to mobile beneficiaries. Thus, the analysis by Preval *et al.* (2010) assumes that households stay for the entire 12-year period over which costs and benefits are simulated (the assumed lifetime of the heating device) or that moving households with a high proportion of asthmatics are replaced by households with similarly high asthma rates.<sup>1</sup> A further problem for economic evaluations is that landlords may increase the rent on properties for which they have received subsidized heating devices, affecting the distribution of who benefits.

It may therefore help to have more direct evidence on the willingness to pay (WTP) for improved heating devices by populations that suffer from a high burden of respiratory disorders. Such evidence may help determine who should pay for improved heating devices, since interventions applied to landlords (for example, subsidized installations or regulated

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<sup>1</sup> The assumption of immobility is particularly ill-suited to New Zealand (the context of the study by Preval *et al.* 2010) since 2006 Census data reveal that 55 percent of the population changed their usual residence from five years earlier. ([http://www.stats.govt.nz/browse\\_for\\_stats/population/Migration/internal-migration/are-nzs-moving-longer-distances.aspx](http://www.stats.govt.nz/browse_for_stats/population/Migration/internal-migration/are-nzs-moving-longer-distances.aspx)).

minimum heating standards for rental properties) may ultimately be borne by tenants, depending on the supply and demand conditions in the rental market. Evidence on the WTP for improved heating devices is also useful because existing studies value health improvements according to foregone costs, such as for visiting a doctor or hiring a caregiver to look after children when asthma prevents them going to school, but do not factor in the value of the reduced disutility due to sickness, which is a part of the WTP.

In this study we use choice experiment data collected from a sample of Pacific Island immigrants located in the upper North Island of New Zealand. We explore the preference structure over household devices that can affect indoor air quality, dampness and warmth. We contrast these preferences with the current availability in the respondent's dwelling of each of these devices. We focus on Pacific Island immigrants because they are an at-risk group for respiratory disorders, they often have little familiarity with these disorders from their home countries, and they typically live in crowded and inadequately heated dwellings that are rented rather than owner-occupied.

An existing literature examines respiratory health of immigrants, finding that those coming from countries with lower rates of asthma than the country of destination experience a time-dependent increase in asthma symptoms and in other respiratory disorders (Ballin *et al.* 1998, Gibson *et al.* 2003). Since immigrants often live in poorly heated and crowded dwellings, the literature on housing adequacy and respiratory health (Gorman and Asaithambi 2008) is potentially informative about interventions that might be useful for this at-risk group. But preferences for indoor air quality determining devices amongst such immigrant populations are yet to be adequately investigated. Information is similarly lacking on the distribution of willingness to pay for each category of these commonly available devices. Pivoting on current rental costs and dwelling characteristics, the present study derives such estimates from stated binary choices between experimentally designed alternatives, and relates them to current availability of the devices.

The remainder of the paper is as follows: Section 2 provides the background to the study, in terms of the population studied, the sample and survey, and the experimental design. In Section 3 the model specifications and econometric analysis of the choice experiment data are discussed. Section 4 contains the results and discussion and Section 5 the conclusions.

## **2. Background Context, the Sample, and the Survey**

New Zealand has one of the highest asthma rates in the world, with this disorder affecting one in six adults and one in four children (Holt and Beasley 2001). The combined burden of asthma and COPD was second only to the contribution of cardiovascular disease, in terms of

disability-adjusted life years (DALYs) lost in New Zealand in 1996 (Tobias *et al.* 2001).<sup>2</sup> There is sizeable ethnic inequality in the burden of asthma, with the highest rate of increase over the last two decades experienced by children in the Pacific Islands ethnic group, who already have above average hospitalization rates (Pattimore *et al.* 2004). The burden of respiratory illnesses for Pacific Islanders reflects their relatively low economic status in New Zealand, high rates of smoking, and poor standard of accommodation with substantial overcrowding. For example, Pacific Islanders have the highest rate of reporting that their house is either too cold or too small, with 33 percent finding their house too cold compared with the average of just 15 percent for other New Zealanders (SNZ 2013). Consequently, Pacific Island immigrants are a relevant population for deriving the WTP for heating and humidity control devices.

## 2.1 The Sample

Immigrants are a rare population, especially when one focuses on those from a specific region, so obtaining a representative sample can be prohibitively expensive (McKenzie and Mistiaen 2009). We therefore decided to recruit study participants through intercept points where migrant populations are known to congregate, mimicking the approach that may typically be used by health and housing authorities that were rolling out home heating interventions. This has the advantage of making our results relevant for the population most likely to be the subject of such interventions, even if it doesn't allow measurement of the WTP of immigrant populations not found in these locations.

We focused on Pacific Islanders living in urban areas in the upper North Island of New Zealand, where the largest (Auckland) and third largest (Hamilton) cities in terms of Pacific Islanders are just 70 miles apart. Both cities are damp and humid, with mean rainfall of almost 50 inches per year and relative humidity (at 9am) of about 85 percent, and have a temperate climate; Auckland's mean annual temperature is 15 degrees Celsius (59°F), and is 10.9 degrees Celsius in the coldest month (July), while Hamilton's annual mean is 14 degrees Celsius (57°F), with a July average of 8.9 degrees. While not cold on a global scale, these are much lower than what Pacific Islanders are used to in their home countries, where annual average temperatures are around 23 degrees Celsius (73°F) and 21 degrees (70°F) in the coldest month. Moreover, homes in New Zealand are poorly heated and insulated, with average indoor temperatures below World Health Organization (WHO) guidelines (Howden-Chapman *et al.* 2012). A further risk to respiratory health is from 'leaky homes' built in the 1990s after relaxation of building regulations and during a trend of Mediterranean-style designs; these homes allowed external water to penetrate internal cavities, causing mold and

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<sup>2</sup> Specifically, 73,800 DALYs lost due to ischaemic heart disease, 30,100 to stroke (so 104,000 to cardiovascular diseases), 27,800 to COPD and 18,800 to asthma (so 47,000 to respiratory diseases).

the rotting of untreated timber used for the framing of such houses (Howden-Chapman and Bennett 2010). The recent rapid population growth in Auckland and Hamilton means that a high proportion of their housing stock was constructed during this 'leaky home' period.

Recruitment of the sample was mainly through churches and church-based groups (such as choirs), following the approach of some medical studies with a focus on Pacific Islanders in New Zealand (for example, Simmonds *et al.* 2004). The respondents were predominantly (three-quarters) born in Tonga, with the remainder born in the Solomon Islands, Samoa, Papua New Guinea, and Australia and New Zealand. We did not rule out the small number (less than ten percent) of second-generation migrants born in Australia or New Zealand because anthropological studies show that second-generation Pacific Island migrants exhibit similar behavior and values to first generation migrants (Lee 2003). Amongst those born overseas, two-thirds had resided in New Zealand for fewer than ten years.

In order to ensure that the surveys were conducted in the most effective and culturally appropriate way we recruited individuals from these same migrant populations to lead the field work. The interview team leader was a Tongan with a PhD in economics, and she was assisted by a Solomon Islander with a PhD and by other tertiary qualified Pacific Islanders. The questionnaires and any written material given out were available in English and Tongan (English is the language of schooling throughout the Pacific) so comprehension problems should not interfere with the choice tasks. Both the lead author and the interview team leader have carried out several other surveys amongst Pacific Island immigrants in New Zealand (Gibson, McKenzie and Zia 2013, Gibson *et al.* 2013) and the visibility of the research team to this particular community assisted in recruiting participants.

## **2.2 Survey Description**

We conducted the survey between December 2012 and March 2013, obtaining data from 249 adults (age 18 and above), who together provide 2,241 choice responses. The first part of the survey asked about use of various home heating devices, and satisfaction with the current dwelling (especially in terms of warmth and dryness) and with health. The survey also covered some background characteristics and details on dwelling tenure and costs, since the choice experiments are based on hypothetical variations in rents for a dwelling similar in all respects to their current one, except in terms of the changes in heating options that were offered under each choice. Information regarding attributes was given to respondents immediately before the choice experiment, including the use of pictures of typical examples of the options that were in the choice sets.

Summary statistics show that 43 percent of respondents were male, with an average age of 39 years (38 years for women and 40 for men). Almost one-half (47 percent) of them had high school qualifications, while 31 percent had some tertiary education (including on-going

and sub-degree courses) and just over one-fifth had no educational qualifications. The employment rate amongst respondents was 51 percent, which is the same as for the overall Pacific Island ethnic group in the March quarter of 2013 in the nation-wide *Household Labour Force Survey* (HLFS). However, the sample had a lower proportion unemployed than in the national survey, with 11.2 percent of respondents being unemployed compared with 15.2 percent in the HLFS. Those participants not in the labor force included housewives, unpaid caregivers and some tertiary students. The average personal income of respondents in the previous 12 months, from all sources, was \$21,500 (based on nine bracketed intervals); this is slightly below the national average of \$24,900 for the Pacific Island ethnic group in New Zealand (which is itself just two-thirds of the overall average income).<sup>3</sup>

In terms of housing, 82 percent of the respondents were renting while just 18 percent were home owners (either with or without a mortgage). Previous studies have shown that the Tongan population in New Zealand has the second lowest rate of home ownership, at around 30 percent in the 2006 Census (SNZ 2012). The even lower ownership rate amongst the respondents here may reflect their recent arrival in the country, and also the secular decline in home ownership rates since 2006. The average weekly rent paid for the dwelling was NZ\$311, while home owners reported an average of \$377 for the hypothetical rent that they could receive if they rented out their dwelling.<sup>4</sup>

By the standards of many populations, these houses are crowded with a median of eight residents per dwelling (mean=7.4) and 2.4 persons per bedroom. There is no significant difference in crowding between owned and rented properties, although the same is not true for all other dwelling attributes. Table 1 displays the mean values for the dwelling and heating variables and also the mean responses to questions about major problems associated with the dwelling, separately for renters and owner-occupiers. Approximately two-thirds of renters have major problems with cold, damp, moldy houses and an even higher proportion have problems with the cost of heating their house. Owner-occupiers are less likely to have major problems with cold and damp, but the other problems are just as widespread as for renters. Fewer than ten percent of the respondents have improved devices that either warm or dry the air, such as dehumidifiers, HRV systems, and heat pumps. The main forms of heating are electric heaters (either in-built or plug-in), open fireplaces, and in-built gas heaters (and also enclosed wood burners for owner-occupiers).

In terms of respiratory health, 53-55 percent of respondents reported that in the last 12 months they had either been woken by an attack of shortness of breath, had wheezed or

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<sup>3</sup> Based on the June 2012 New Zealand Income Survey, which is an income survey supplement to the quarterly Household Labour Force Survey (so is similar to the March Current Population Survey in the United States).

<sup>4</sup> At the time of the survey, NZ\$1=US\$0.83, so weekly rents were approximately US\$260.

had difficulty breathing, or had been unable to do normal activities because of difficulties in breathing. Between 17-25 percent of respondents reported that children in their household also had these symptoms of respiratory disorder within the last 12 months. Yet just seven percent of respondents reported ever having been diagnosed by a doctor or nurse as having asthma or ever having taken medication for asthma and only 15 percent reported that children in their household had ever been diagnosed with asthma or taken medication for asthma. In addition to potentially undiagnosed asthma, self-awareness also appeared to be low, with just four percent of respondents reporting having had an attack of asthma during the last 12 months, even though more than one-half of them reported wheeze and other breathing difficulties that are often symptoms of asthma.<sup>5</sup>

**Table 1: Mean Values of Dwelling and Heating Characteristics and Dwelling-Related Problems**

	Renters	Owners	All Respondents
Weekly rent (hypothetical for owners)	311	377*	323
Household size	7.3	7.7	7.4
Residents per bedroom	2.4	2.3	2.4
<i>Respondent's dwelling has a:</i>			
Heat pump	0.078	0.045	0.072
Electric heater	0.561	0.386*	0.530
Portable gas bottle heater	0.063	0.000*	0.052
In-built gas heater	0.244	0.227	0.241
Open fireplace	0.283	0.227	0.273
Enclosed wood burner	0.015	0.295*	0.064
Dehumidifier	0.049	0.091	0.056
Heat-recovery ventilation (HRV) system	0.034	0.023	0.032
<i>Respondent has a major problem with:</i>			
Dwelling is too cold	0.644	0.455*	0.610
Dwelling is damp or not waterproof	0.654	0.477*	0.622
Visible mold in one or more rooms	0.717	0.773	0.727
Dwelling is too difficult or costly to heat	0.771	0.795	0.775
Sample size	205	44	249

*Note:* \* indicates that the mean for owners is significantly different to the mean for renters, at the 5% level.

### 2.3 Experimental Design

Choice experiments use experimental design techniques to identify the effects that attributes of qualitatively different alternatives have on estimated utility. Design techniques are required to define the efficient allocation of attributes and their levels in the alternatives that are combined into the separate choice tasks. Design efficiency is a salient issue when sample sizes are naturally restricted, such as in this study. Drawing from the rapidly expanding

<sup>5</sup> In a study of a different health problem on a similar population, Gibson *et al.* (2013) find a similar result; while 35 percent of a sample of Tongan immigrants in New Zealand had measured hypertension just four percent of them reported that they had ever had a diagnosis of high blood pressure.



literature on efficient designs for stated choice for non-market valuation from small samples (Sandor and Wedel 2001, Ferrini and Scarpa 2007, Scarpa *et al.* 2007, Rose and Scarpa 2008, Bliemer, Rose and Hensher 2009, Vermeulen *et al.* 2011, Kessels *et al.* 2011) we adopted a sequential Bayesian D-efficient design where prior values of the mean and variance of parameter estimates were drawn from a pilot study.

Since our interest was in the willingness-to-pay for improved heating and humidity control devices, the choice tasks excluded two unimproved heating options from those shown in Table 1; the portable gas bottle heater and the open fireplace. The choices were therefore over various combinations of the other six devices listed in Table 1, along with the rental cost variation. The initial design used in the pilot was orthogonal in the differences of the seven main effects, inclusive of the cost variation. The final design consisted of 72 pairwise choice tasks, blocked orthogonally into eight blocks each of nine choice tasks. This was obtained by using Ngene and minimizing the D-error of the multinomial logit model over the allocation of attributes, conditional on the assumed prior values. By allocating a different block to each respondent, after every eight respondents the design was complete. Since these blocks were allocated to 249 respondents, (44 home owners and 205 renters) we collected 31 balanced and complete designs with a minor redundancy.

### 3. Empirical Specification and Econometric Analysis

Of interest is in the implicit values assigned to different devices for indoor air control by the sampled population. These willingness-to-pay (WTP) values can be obtained by estimating a conditional logit model under the assumption that respondents choose their preferred alternative according to the random utility maximization paradigm. Using maximum likelihood, estimates of utility coefficients can be obtained and the ratios of the attribute coefficients with respect to the coefficient for rent give an asymptotically consistent estimate of the marginal WTP for each attribute (Adamowicz *et al.* 1998).

The utility structure that is assumed is linear in the parameters and contains an interaction between the effect of rent change and the status of being a home owner. This is justified by the fact that those who rent are likely to have a different marginal utility of money from those who own the house they live in. The utility structure employed is:

$$U = \alpha \times ASC_{LHS} + \beta_1 \times HRV + \beta_2 \times WoodBurner + \beta_3 \times Elect_Heating + \beta_4 \times Gas_Heating + \beta_5 \times Heat_Pump + \beta_6 \times Dehumidifier + \gamma \times RENT + \delta \times RENT \times 1(HOME\_OWN) + u$$

We have dropped the usual subscripts denoting choice task and respondent for simplicity. In this model,  $ASC_{LHS}$  is an alternative specific constant for the first alternative of the two alternatives presented (hence, it is on the left-hand side (LHS) of the page), with the use of this covariate suggested by the work of, amongst others, Dobel, Diesendruck and Bölte

(2007) to account for left-to-right bias in choice. The variables associated with the parameters  $\beta_1$  to  $\beta_6$  are dummy variables for the presence in the choice alternative of the various heating and humidity control devices, RENT is the cost per week of a house identical to the one in which the respondent lives, but with the set of devices proposed in the design, and the last covariate is the interaction between rent and the home ownership dummy variable. This last variable is included to account for differences in marginal utility of money between respondents who rent and those who are home-owners. In the specified utility structure, the random component  $u$  is assumed to follow an independently and identically distributed (i.i.d.) Gumbel distribution.

A secondary issue of interest is whether the results that are obtained from the fixed coefficient, conditional logit model are robust to the assumptions of independence of choices by the same respondent (that is, allowing for the panel nature of the data where the same respondent is making nine choices). The robustness to the presence of unobserved taste heterogeneity (that is, taste variation across respondents) is also of interest. To address these issues we also report estimates of a panel mixed logit (PMXL) model (Revelt and Train 1998, Train 1998, 2003). The PMXL model has multivariate normal random taste coefficients, with the exception of the coefficients for rent and the interaction between rent and home-owner status. The multivariate nature of the distributional assumption also lets us uncover the correlation across tastes, which illustrates how taste intensities for the various attributes under evaluation co-vary in the population. In other words, this specification assumes that the vector of beta parameters is multivariate normal, while  $\alpha$ ,  $\gamma$  and  $\delta$  are fixed. The estimation of the PMXL model is conducted by simulating the integral of the unconditional choice probabilities by means of 500 Halton draws (Train 2000, Baiocchi 2005).

#### **4. Results and Discussion**

The conditional logit results are reported in Table 2, with the parameter estimates in the top panel of the table and the marginal WTP estimates in the bottom panels (for renters and owner-occupiers separately). The estimated parameters suggest that there are statistically significant increases in utility from the presence of four of the devices; the heat-recovery ventilation (HRV) system, the enclosed wood burner, the heat pump, and the dehumidifier. The other two heating options (in-built gas and electric heaters) have confidence intervals that include zero. The negative coefficient on RENT indicates that utility falls as rents rise for all respondents, and would do so at a faster rate for owner-occupiers since the coefficient for the interaction term is negative.

The estimates from the panel mixed logit model are reported in Table 3. This PMXL model appears to perform better than the conditional logit model, in terms of both log-likelihood values and the Akaike information criterion (AIC). Specifically, the PMXL model

converges with a maximized simulated likelihood of -1297.18 and an AIC/N of 1.184, which significantly outperforms the conditional logit specification, for which the maximized log-likelihood was -1327.86 and the AIC/N was 1.193. These comparisons suggest that the panel nature of the data, whereby each respondent made nine choices, along with the presence of taste heterogeneity, require a more flexible model than is provided by the conditional logit specification. We therefore concentrate the discussion of the results on those from the PMXL model, while noting that the substantive results are confirmed by both specifications.

**Table 2: Conditional Logit Model Estimates and Implied Willingness to Pay (in NZ\$/week)**

	Coeff.	Sig.	Std.Err.	z-value	p-value	2.5%	97.5%
ASC for LHS alt	0.163	***	0.048	3.44	0.0006	0.070	0.257
HRV	0.837	***	0.068	12.31	<0.001	0.704	0.970
WoodBurner	0.404	***	0.070	5.81	<0.001	0.268	0.541
Gas_Heating	0.114		0.078	1.47	0.1428	-0.038	0.266
Elect_Heating	-0.024		0.063	-0.38	0.7019	-0.148	0.099
Heat_Pump	0.399	***	0.072	5.56	<0.001	0.258	0.539
Dehumidifier	0.236	***	0.070	3.37	0.0007	0.099	0.373
Rent	-0.089	***	0.007	-13.2	<0.001	-0.102	-0.075
Rent × own house	-0.046	***	0.016	-2.8	0.0052	-0.078	-0.014
marginal WTP estimates							
<i>Renters</i>							
HRV	9.457	***	0.968	9.77	<0.001	7.560	11.353
WoodBurner	4.569	***	0.824	5.55	<0.001	2.954	6.183
Gas_Heating	1.284		0.877	1.46	0.1432	-0.435	3.002
Elect_Heating	-0.272		0.713	-0.38	0.7025	-1.670	1.125
Heat_Pump	4.503	***	0.779	5.78	<0.001	2.975	6.030
Dehumidifier	2.666	***	0.795	3.35	0.0008	1.108	4.224
<i>Home-owners</i>							
HRV	6.224	***	0.839	7.42	<0.001	4.579	7.869
WoodBurner	3.007	***	0.604	4.98	<0.001	1.823	4.190
Gas_Heating	0.845		0.584	1.45	0.1478	-0.299	1.989
Elect_Heating	-0.179		0.470	-0.38	0.7026	-1.100	0.741
Heat_Pump	2.963	***	0.584	5.07	<0.001	1.819	4.108
Dehumidifier	1.754	***	0.544	3.23	0.0013	0.689	2.820

Notes: 'ASC' is alternative specific constant, for the alternative provided first (on Left-Hand side of page), 'Sig' is statistical significance at \*\*\*=1% level, \*\*=5% level, \*=10% level. N=249.

We first focus on the means of the random taste coefficients for the PMXL model, which are reported in the top panel of Table 3. All attributes subject to investigation have the expected positive values, but for the in-built gas heater and the in-built electric heater these

are not significantly different from zero. While these two heating options both have statistically insignificant means for the random parameters in the utility function, there is an important difference between the two, which is shown in the bottom panel of Table 3 where the implied standard deviations of the parameter distributions are reported. There is substantial heterogeneity in the distribution of tastes for in-built electric heating, as seen by a statistically significant standard deviation estimate of  $\sigma_3 = 0.719$  around a mean estimated at  $\beta_3 = 0.166$ , but this variation is not apparent for the in-built gas heating option. We conclude that in-built electric heating is ‘disliked’ by some (the proportion predicted to have negative utility coefficients under the estimated normal distribution can be derived by computing the normal cdf for  $\Phi(x=0|\beta_3 = 0.166, \sigma_3 = 0.719) = 0.409$ ) and ‘liked’ by others (the complement to the previous proportion, which is the proportion predicted to have positive utility coefficients), with the ratio of dislikes to likes close to 40:60. In contrast, gas heating is shown to induce indifference since the standard deviation of the parameter distribution is so small and the mean so close to zero ( $\beta_4 = 0.015$  and  $\sigma_4 = 0.144$ ).

The four devices with statistically significant mean estimates for the respective random taste coefficients in the utility function are the heat-recovery ventilation (HRV) system, the heat pump, the enclosed wood burner and the dehumidifier (ranked in order of the size of their means), that is,  $\beta_1$ ,  $\beta_5$ ,  $\beta_2$ , and  $\beta_6$ . While the heat pump and wood burner have similar estimated means, the estimated standard deviation of the parameter distribution is 60 percent larger for the heat pump, which suggests that there is much greater heterogeneity in tastes for this device. These results can also be interpreted in terms of the proportion of respondents disliking a device, which is lowest for the HRV system, at 11 percent disliking it, followed by the wood burner at 20 percent. In contrast, the heat pump and dehumidifier have a dislike-like ratio close to 30:70; although between these two devices the heat pump has a much higher estimated mean and spread of the random taste coefficients.

The results for the non-random parameters in the utility functions are shown in the second block of Table 3. Importantly for our distinction between renters and home-owners we note that the interaction term for home-owners is statistically significant. This result provides empirical corroboration for our expectation that different implicit values for air control devices will be generated by the two tenure groups.

Because of the full correlation structure of the multivariate normal used in the PMXL model we can also derive the correlation matrix of the random taste coefficients. This is reported in Table 4 and shows a positive and strong correlation for several pairs of devices, including the in-built electric heater and the dehumidifier (0.94), and the in-built gas heater and the HRV (0.92). There is also a moderate positive correlation between the HRV and the heat pump (0.75), while the strongest negative correlation is -0.52 between the dehumidifier and the wood burner.

**Table 3: Panel Mixed Logit Model Estimates  
with Full Correlation Structure of Random Coefficients**

	Coeff.	Sig.	Std.Err.	z-value	p-value	2.5%	97.5%
<i>Random parameters in utility functions</i>							
HRV	1.060	***	0.110	9.62	<0.0001	0.844	1.276
WoodBurner	0.510	***	0.102	5.02	<0.0001	0.311	0.709
Elect_Heating	0.166		0.120	1.38	0.1665	-0.069	0.402
Gas_Heating	0.015		0.074	0.21	0.8338	-0.129	0.160
Heat_Pump	0.527	***	0.113	4.67	<0.0001	0.306	0.748
Dehumidifier	0.334	***	0.096	3.47	0.0005	0.145	0.522
<i>Nonrandom parameters in utility functions</i>							
ASC for LHS alt	0.318	***	0.066	4.85	<0.0001	0.189	0.446
Rent	-0.100	***	0.008	-11.83	<0.0001	-0.117	-0.084
Rent × own house	-0.058	***	0.021	-2.78	0.0054	-0.099	-0.017
<i>Diagonal values in Cholesky matrix L</i>							
Ns HRV	0.867	***	0.155	5.61	<0.001	0.564	1.170
Ns WoodBurner	0.603	***	0.162	3.72	0.0002	0.286	0.920
Ns Elect_Heating	0.636	***	0.192	3.31	0.0009	0.260	1.013
Ns Gas_Heating	0.002		0.152	0.01	0.9894	-0.296	0.300
Ns Heat_Pump	0.332		0.363	0.91	0.361	-0.380	1.043
Ns Dehumidifier	0.005		0.207	0.02	0.9815	-0.401	0.411
<i>Below diagonal values in L matrix. <math>\Omega = L L^T</math></i>							
WoodBurner: HRV	0.095		0.205	0.46	0.6422	-0.306	0.497
Elect_Heating: HRV	0.253		0.250	1.01	0.3107	-0.236	0.742
Elect_Heating: WoodBurner	-0.220		0.255	-0.86	0.3895	-0.720	0.281
Gas_Heating: HRV	0.134		0.106	1.26	0.2083	-0.075	0.343
Gas_Heating: WoodBurner	-0.004		0.114	-0.03	0.9751	-0.228	0.221
Gas_Heating: Elect_Heating	0.053		0.117	0.45	0.6515	-0.177	0.282
Heat_Pump: HRV	0.733	***	0.184	3.98	0.0001	0.372	1.094
Heat_Pump: WoodBurner	0.430	*	0.241	1.78	0.0744	-0.042	0.903
Heat_Pump: Elect_Heating	0.319		0.293	1.09	0.2755	-0.255	0.893
Heat_Pump: Gas_Heating	-0.122		0.510	-0.24	0.8106	-1.121	0.877
Dehumidifier: HRV	0.225		0.169	1.33	0.1823	-0.106	0.555
Dehumidifier: WoodBurner	-0.356	*	0.208	-1.71	0.0867	-0.762	0.051
Dehumidifier: Elect_Heating	0.437	**	0.180	2.43	0.0151	0.085	0.789
Dehumidifier: Gas_Heating	-0.003		0.209	-0.01	0.9891	-0.412	0.406
Dehumidifier: Heat_Pump	0.013		0.194	0.07	0.9467	-0.368	0.394
<i>Implied Standard deviations of parameter distributions</i>							
sd HRV	0.867	***	0.155	5.61	<0.0001	0.564	1.170
sd WoodBurner	0.611	***	0.163	3.75	0.0002	0.291	0.930
sd Elect_Heating	0.719	***	0.188	3.82	<0.0001	0.350	1.088
sd Gas_Heating	0.144		0.102	1.41	0.1579	-0.056	0.344
sd Heat_Pump	0.974	***	0.196	4.97	<0.0001	0.590	1.359
sd Dehumidifier	0.607	***	0.194	3.12	0.0018	0.226	0.987

Notes: See Table 2.

**Table 4: Implied Correlation Structure of Random Parameters  
from Panel Mixed Logit Model**

	HRV	WoodBurner	Elect_Heating	Gas_Heating	Heat_Pump	Dehumidifier
HRV	1	0.156	0.352	0.930	0.752	0.371
WoodBurner	0.156	1	-0.247	0.120	0.553	-0.521
Elect_Heating	0.352	-0.247	1	0.660	0.420	0.947
Gas_Heating	0.930	0.121	0.660	1	0.808	0.624
Heat_Pump	0.752	0.553	0.420	0.808	1	0.264
Dehumidifier	0.371	-0.521	0.947	0.624	0.264	1

Finally, marginal WTP estimates can be derived at the estimated means of the taste parameter distributions. Because of the separate rental cost coefficients derived for renters and home-owners we obtain separate WTP estimates for the two groups. These are reported in Table 5 for the PMXL model and in the lower part of Table 2 for the conditional logit model with fixed parameters. The results are similar, so we focus on the former. Renters display a higher marginal WTP by virtue of a marginal utility of money that is closer to zero than that estimated for home-owners (the interaction term between rent and home-ownership is negative). Based on the point estimates, the HRV system is the most valued device at the margin. For this device, renters revealed a willingness to pay of NZ\$10.60 per week and for owners it was NZ\$6.70 per week. The next two devices, the heat pump and the enclosed wood burner, are valued almost equally, at about half the value placed on the HRV system. The lowest statistically significant marginal valuation is obtained for the dehumidifier, at NZ\$3.30 per week by renters and NZ\$2.10 per week by home owners.

**Table 5: Implied Marginal Willingness to Pay at the Means of Random Parameters  
from Panel Mixed Logit Model**

	WTP	Sig.	Std.Err.	z-value	p-value	2.5%	97.5%
<i>Renters</i>							
HRV	10.559	**	1.286	8.21	<0.0001	8.038	13.080
WoodBurner	5.082	***	1.077	4.72	<0.0001	2.971	7.194
Gas_Heating	1.657		1.184	1.4	0.1617	-0.663	3.977
Elect_Heating	0.154		0.734	0.21	0.8336	-1.285	1.594
Heat_Pump	5.247	***	1.094	4.8	<0.0001	3.104	7.391
Dehumidifier	3.326	***	0.954	3.49	0.0005	1.456	5.196
<i>Home-owners</i>							
HRV	6.689	***	1.015	6.59	<0.0001	4.700	8.679
WoodBurner	3.220	***	0.734	4.39	<0.0001	1.781	4.659
Gas_Heating	1.050		0.758	1.38	0.1661	-0.436	2.535
Elect_Heating	0.098		0.466	0.21	0.8337	-0.815	1.010
Heat_Pump	3.324	***	0.761	4.37	<0.0001	1.833	4.816
Dehumidifier	2.107	***	0.638	3.3	0.001	0.858	3.357

Notes: WTP is willingness to pay, in NZ\$ per week. Other notes, see Table 2.

How do the willingness to pay estimates compare with the costs of these devices? In order to convert the flow of weekly payments into a lump sum, we assume that each device has a life of 12 years and we use a discount rate of 0.05, following the assumptions used by Preval *et al.* (2010). We use the WTP of renters in the calculations, implicitly asking whether the willingness of renters to pay higher rent would enable a landlord to pay back the cost of one of these devices without any government subsidies. The results in Table 6 suggest that the HRV system and dehumidifiers could be fully paid back by tenants' willingness to pay higher rent for dwellings with these devices, while for the heat pump and the enclosed wood burner the WTPs add up to between two-thirds and three-quarters of the capital cost.

**Table 6: Comparison of Willingness to Pay and Capital Costs for Selected Devices**

	WTP (Renters) NZ\$/week	Net Present Value (NPV)	Capital Cost (installed)	NPV as % of Capital Cost
Heat Recovery Ventilation (HRV)	10.56	\$4870	\$4100	119%
Enclosed Wood Burner	5.08	\$2340	\$3100	75%
Heat Pump	5.25	\$2420	\$3700	65%
Dehumidifier	3.33	\$1530	\$1000	153%

*Notes:* Net present value calculated assuming a device life of 12 years and a discount rate of 0.05.

One implication of finding a willingness to pay for these devices that approximately equals their average cost is that, absent concern over the distribution of benefits, schemes to subsidize or freely provide these devices are not necessarily wasteful in the sense of giving people something that costs much more than the value they place on it. Our results contrast sharply with those reported by Vujcich (2008), who analyzed contingent valuation data produced by the Housing, Heating and Health Study (HHHS), which is the same study used in the cost-benefit analysis of Preval *et al.* (2010). The participants in the HHHS were reported to place an average value on heat pumps which was only one-half of actual cost, and a valuation on wood burners which was less than one-fifth of the actual cost. But there are reasons to doubt these valuations, since the HHHS simply asked respondents how much they would pay for their new heater, with six interval values available (including zero and an open-ended interval above \$5000) rather than deriving these values from a robust choice experiment. Moreover, the questions that were asked by the HHHS emphasized that the heaters would be given away for free, stating that: 'In fact, the heater will be free to you – you will not be asked to pay', which may be likely to lead to a systematic under-reporting of value, compared with what is found from a carefully conducted choice experiment.

Finally, it is interesting to contrast the revealed preferences for these devices with their availability in the dwellings that the respondents either rent or own. The most preferred device, the HRV ventilation system, is available to only three percent of the respondents. The

next most preferred devices – the enclosed wood burner and the heat pump – are available to just 1.5 percent and 7.8 percent of renters (but 30 percent of the owner-occupiers have a wood burner). Conversely, the most common devices available to renters are the electric heater and the gas heater, both of which had a willingness-to-pay that was not statistically significantly different from zero. The mis-match between what is supplied in rental dwellings and what is preferred by tenants suggests that some improvement in indoor air quality might come just from information interventions to show that the willingness of tenants to pay higher rent for dwellings with improved devices may be sufficient for landlords to cover the cost of at least some of these devices.

## **5. Conclusions**

Respiratory disorders impose a high disease burden in New Zealand that is unequally borne over ethnic groups, with the indigenous Maori and the immigrant-origin Pacific Islands populations suffering the most. Previous research has shown that the poor quality of indoor air, which is both too cold and too damp, is an important contributor to these respiratory disorders. These air quality problems reflect the poor standard of construction and insulation of New Zealand dwellings, which is exacerbated by the damp and humid climate and by traditions of relying on ineffective and polluting devices to heat a single room (for example, an open fireplace) rather than on clean and effective heating of the whole house. These indoor air quality problems are likely to be even more serious for Pacific Islanders, who often live in over-crowded rental dwellings that they find difficult to keep warm. Moreover, recent Pacific immigrants are unlikely to be familiar with housing-related causes of respiratory disease, since homes are much warmer and better ventilated in their home countries.

To deal with some of these housing-related health problems, the New Zealand Government recently funded a NZ\$350 million four-year program to subsidize the cost of retro-fitting insulation and installing clean heat sources in 190,000 houses. Similar schemes also have been launched in other countries. Initial evaluations show that the insulation component contributes most to the positive cost-benefit ratio of the New Zealand scheme (Grimes *et al.* 2012), but there has been little analysis of whether some of the subsidized investment might have occurred anyway, and of the value that the affected populations themselves place on improved devices that allow warmer and drier homes. Therefore in this paper we report on an investigation into preferences for household devices that affect indoor air quality, dampness, and warmth. The analysis is based on choice experiment data collected from a sample of Pacific Island immigrants, who are an at-risk group for respiratory disorders and who have a poor standard of housing. Most of this sample rent, and therefore have little day-to-day choice over the heating and humidity control devices that they can use. Amongst these renters, around two-thirds had major problems with cold, damp, moldy houses and more than one-half of them exhibited symptoms of respiratory disease.



The efficient design of the choice experiment meant that even a small sample ( $n=249$ ) yielded reasonably precise estimates of the willingness to pay for four improved heating and humidity control devices, which ranged from NZ\$2.10 to \$10.60 per week in extra rent that respondents would pay for a dwelling with one of these devices. For two of the devices under consideration, this extra rent would be enough to cover the capital cost of installing the device, while for the other two the willingness to pay was equivalent to between two-thirds and three-quarters of the capital cost. Despite this, very few of the dwellings that were rented had any of these preferred devices, although around 30 percent of owner-occupiers had one of the preferred devices – the enclosed wood burner. Our findings contrast with an earlier study which found much lower valuations on improved heating devices, but which used a less reliable contingent valuation method than the estimates here which come from stated binary choices between experimentally designed alternatives. Health-related interventions are made in many sectors other than just housing so more widespread use of efficiently designed choice experiments may be useful for eliciting valuations from amongst the affected populations.

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