Home Heating and Asthma in New Zealand

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Abstract

New Zealand has one of the highest asthma prevalence rates among developed countries and previous research attributes this partly to poor socioeconomic conditions and to insufficient home heating in particular. Retrospective empirical studies from overseas suggest that home heating is associated with asthma rates. However, the evidence to date is not conclusive. In this paper, I build a theoretical model and empirically investigate the link between home heating and asthma hospital admissions in New Zealand using panel data techniques and controlling for endogeneity. The hypothesis that higher electricity prices (via less adequate heating) increase asthma admissions is tested.

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Keywords: Asthma, Heating, Electricity prices

1. Introduction

New Zealand has one of the highest asthma prevalence rates among developed countries and previous research attributes this partly to poor socioeconomic conditions in certain neighbourhoods (or among certain ethnic groups) and to insufficient home heating in particular (Ellison-Loschmann et al, 2004; Statistics NZ, 2007a; Petronella and Conboy-Ellis, 2003; Butler et al, 2003; and Crane et al, 1998).

Retrospective empirical studies from overseas suggest that home heating (or the lack thereof) is associated with higher asthma rates (e.g., see Borooah (2007) for recent evidence from Ireland) and a limited number of randomized controlled trials seem to support this hypothesis (Barton et al, 2007). However, the evidence to date is not conclusive, many of the studies available do not control adequately for the endogeneity of home heating, and rigorous analyses of New Zealand asthma data are sparse.

In this paper, I build a theoretical model and empirically investigate the link between home heating and asthma hospital admissions in New Zealand using panel data techniques and controlling for endogeneity. Regional asthma admission rates obtained from the National Minimum Dataset (NZHIS, 2007) (are merged with 1996, 2001, and 2006 regional Census information on home heating (Statistics NZ, 2007b and 2007c). To account for the possible endogeneity of home heating (and to receive annual explanatory data), the viability of annual regional electricity prices (Ministry of Economic Development, 2007) as a proxy for the existence and the type of home heating is investigated. If electricity prices are good predictors of home heating, they will be used in a reduced form estimation of asthma admission rates. The hypothesis that higher electricity prices (via less adequate heating) increase asthma admissions will be tested.

Individual-level survey data from the New Zealand General Social Survey will be used to corroborate findings from the above analyses and to help interpret the results. The New Zealand General Social Survey provides individual-specific data on health outcomes, housing conditions, and various socio-economic indicators. Specifically, the participants are asked to identify any major problems with their house/flat from a list which includes ‘it’s damp’ or ‘it’s too cold or difficult to keep warm/heat up’.

This project provides valuable information as to the best use of government resources in targeting asthma rates. Effective resource allocation in the control of asthma would be especially beneficial for lower socioeconomic groups.

The remainder of this paper is organised as follows: Section two describes the relevant background literature, section three explains the proposed model, section four describes the data which will be used in this study, section five details the planned methodology, section six presents current results, and section seven concludes.

2. Literature Review

Asthma is a severe problem for many New Zealanders. One in six adults and one in four children in New Zealand suffer from asthma symptoms (Holt & Beasley, 2002). New Zealand has one of the highest asthma rates in the world along with other western countries like the USA and Australia.

Infants and children are particularly susceptible to asthma and it is the leading cause of hospital admissions of children (The Asthma and Respiratory Foundation of NZ (Inc.), 2006). Although asthma prevalence is the highest in wealthy countries, within countries, asthma is manifestly a disease of lower socio-economic groups. In New Zealand, asthma disproportionately affects Maori and Pacific-Islanders in both prevalence and severity (Holt & Beasley, 2002).

Approximately 130 deaths a year are caused by asthma attacks in New Zealand. The direct medical costs to the country of treating asthma have been estimated to be $125million, where a more comprehensive measure of costs including indirect costs to the country such as lost productivity and years lost to disability brings that figure up to $700million (Holt & Beasley, 2002). Given this unsatisfactory state, any information that can help guide effective asthma prevention is of high importance. My research will provide evidence as to the effectiveness of improving house heating as a way of combating asthma.

The main avenue for home heating to influence asthma prevalence and severity is through the effect it has on house dust mites (HDM) survival. HDM require a relatively cool and humid environment to survive (Crane et al, 1998). New Zealand's cold, humid climate provides an ideal atmosphere for the proliferation of HDM throughout households. Adequate home heating can prevent HDM from inhabiting households by reducing humidity levels below the level critical for the survival of HDM. Other avenues for home heating to affect asthma are through the effect on indoor temperature and through the effect on mould growth.

Randomised housing improvement studies have attempted to assess the causal effect of home heating on asthma rates. The Watcombe housing study (Barton et al, 2007) studied the effects on self-reported asthma rates in households with improved heating and insulation and found a significant but negligible effect on asthma prevalence. Two randomized controlled studies in New Zealand (Howden-Chapman et al, 2007, 2008) looked at the effects of housing improvement on asthma and like the Watcombe study found significant but negligible effects on asthma. Crane et al (1998) looked at the effect installing a Mechanical Ventilation Heat Exchange system had on the presence of dust mites in the home and found no significant effects. All of these controlled randomized studies plus other similar ones have a few systematic drawbacks: due to the substantial costs of the studies, the time period is often short and the sample size small, asthma is mainly measured by self-reports of symptoms, survey participants cannot be 'blinded' which is especially problematic when relying on self-reports, and there are problems with participant compliance. Although some of the studies try to address some of these issues (e.g., the Watcombe study included a nurse assessment of asthma symptoms to compliment a portion of the self-reports) the evidence they provide supporting the causal link between home heating and asthma is underwhelming and there is a need for further investigation.

Other studies have addressed the correlation between asthma and home heating using cross-sectional observations. Two of these studies looked at the relationship between home heating and asthma and found a negative correlation (Butler, Williams, Tukuitonga, & Paterson, 2003); Borooah, 2007). However, these studies did not adequately control for wealth, an inherent problem with using cross-sectional data for this type of analysis.

One issue with disentangling the relationship between home heating and asthma is that home heating is endogenous due to it being highly correlated with wealth (and possibly other observable and unobservable household characteristics) and there are many potential mechanisms besides home heating which correlate asthma with wealth. Plausible connections found in the asthma literature include: education, childhood fruit intake, smoking, living in polluted areas, and underlying racial tendencies.

Education is possibly the most important factor contributing to low asthma severity amongst higher socio-economic groups. Michael Grossman's classic paper (Grossman, 1972) explains that education is highly correlated with better health outcomes because people with higher education are not only more likely to have healthy lifestyles, but can also use health inputs more effectively. The nature of asthma is such that it cannot be cured or successfully prevented (at least with current medical knowledge) but it can be effectively managed through the use of inhalers. For the best management of asthma, it is vital that the patient understands how and when to use the inhalers and when they need further assessment from a general practitioner (this may also be further exacerbated by low-income families avoiding general practitioner visits due to cost). Previous literature indicates that the role of education is important for explaining the difference between severity of asthma amongst low-income and high-income households (Borooah, 2007).

Propper & Rigg (2006) found that low childhood fruit intake was correlated with high asthma rates; it is very plausible that childhood fruit intake is higher amongst wealthy families. Smoking along with inhaling second hand smoke has been suggested to have a causal relationship with asthma rates (Propper & Rigg, 2006) and, in New Zealand, smoking rates are the highest amongst low-income families. Highly polluted areas can trigger asthma due to the higher particulate matter in the air; it is plausible that low-income families live in areas with more pollution.

Underlying racial tendencies may play an important role in the relationship as well, particularly in New Zealand. Maori and Pacific-Islanders are disproportionately represented in asthma prevalence and severity statistics. For example, Maori are four times more likely to die from asthma than no-Maori (The Asthma and Respiratory Foundation of NZ (Inc.), 2009). It is unclear how much of this relationship is due to the fact that both Maori and Pacific Islanders are also disproportionately represented in lower socio-economic groups; however, there does seem to be a disparity that cannot be explained by observable differences in socio-economic factors.

My research addresses the endogeneity of home heating in a way that has not been attempted in the literature: by using electricity price as an instrument for home heating. This will provide a rigorous analysis of the direct effect that home heating has on asthma without the influence of income or other unobserved factors related to both home heating and asthma.

3. Model

The main goal of this research is to investigate how much of an effect home heating has on asthma rates. As discussed above, evidence that suggests there is or at least should be a relationship is plentiful. Hence, a naïve form of my model is as follows:

$$Asthma = f(home\ heating)$$

However, this simplistic model does not account for the problem of endogeneity; both asthma and home heating are correlated with income and other factors – including unobservable ones. This can be illustrated as follows:

$$Asthma = f(income, home\ heating),$$
$$Home\ Heating = f(income)$$

Although in theory observable factors such as household income could be measured and controlled for in the above model, accurately accounting for all endogenous factors would be practically impossible and their omission would lead to a biased estimate of the effect of home heating on asthma rates. To account for this endogeneity, my research will introduce an instrumental or proxy variable that is uncorrelated with income (and most of the other plausible endogenous factors) but highly correlated with home heating: electricity price. High electricity prices will reduce electricity consumption (an ordinary good). As home heating is a large component of the total electricity usage in New Zealand, it is likely that the amount of home heating used will be significantly influenced by the price of electricity. Since electricity prices are not correlated with income and other household characteristics, the effect that they have on asthma rates will solely be through the effect on home heating. The main form of my model can be expressed as:

$$Home\ heating = f(\ electricity\ price)$$
$$\rightarrow Asthma = f(\ electricity\ price)$$

A concern with the above reduced-form model is that higher electricity prices may cause people to substitute towards non-electrical sources of heating such as gas heaters and wood burners. While this has the potential to counteract the effect electricity prices would have on asthma as the homes may still be heated to a comparable level, the heating appliances themselves may affect asthma. Gas heating - especially unflued varieties - can increase particulate matter in the air of homes and can also increase moisture leading to mould growth plus a higher humidity which helps HDM proliferation (http://www.moh.govt.nz/moh.nsf/indexmh/unflued-gas-heaters-may05; Accessed 17/05/2010). Wood burners may also increase particulate matter in the homes but will also increase particulate matter in the atmosphere outside, worsening the asthma of people in the surrounding area as well as those inside the house. Since the use of alternative fuels such as wood and gas will be influenced by their respective prices relative to electricity prices, we can express the relationships as follows:

$$Use\ of\ altenative\ fuels = f(\ electricity\ price, alternative\ fuels\ price)$$
$$Particulate\ matter = f(use\ of\ alternative\ fuels)$$
$$Asthma = f(\ electricity\ price, alternative\ fuels\ price)$$

4. Data

My data comes from three main sources: asthma hospital admissions data from the Ministry of Health, electricity price data from the Ministry of Economic Development and population statistics from Statistics New Zealand. For my regression analysis, I have used quarterly data by District Health Board (DHB) regions for the period between the third quarter of 2000 to the second quarter of 2009.

Data on the number of households using electric sources of heating as a proportion of total households was provided by Statistics New Zealand for the Census years 2001 and 2006. Unfortunately, only the 2001 dataset has the figures broken down into adequate sub-regions so I have only used data from this year.

The asthma admissions data contains monthly numbers of hospital admissions where the primary diagnosis was identified as asthma separated by five-year age brackets, sex, and three race categories (Maori, Pacific Islander, Other) from July 2000 to June 2009, for each DHB. Although my results will be based on asthma hospital admissions rather than asthma prevalence in general, it seems reasonable to assume the results can be generalised to give an indication of the overall asthma burden. The main reason for using hospital admissions as the measure of asthma prevalence is the availability of data, but another major benefit is that the figures are (relatively) objective as they have been assessed by a health care professional. Self-reported measures of asthma prevalence may be more thorough but would suffer from the inaccuracy associated with self-assessment of health outcomes.

I have aggregated asthma data into quarters rather than months so that the periods coincide with the periods in my electricity price data set. I have also stratified the data by age into three distinct categories: infants (0-4), children (5-14), and adults (15+). The above age brackets were selected for two reasons: 1. The literature suggests that infants and young children are the most affected by asthma and that once adulthood is reached, age has little effect on asthma (The Asthma and Respiratory Foundation of NZ (Inc.), 2006) and 2. using five-year age brackets would be problematic as there would be a large number of zero observations. I ignore gender sub-categories in my preliminary analysis as the literature suggests there should not be any large differences between the two sexes in asthma prevalence.

My descriptive findings (Figure 1.) are consistent with the literature in showing that asthma is the highest amongst infants and children. In particular, there is a distinctive trend of asthma admissions decreasing until adulthood is reached and changing very little from then on (the drop after 50 years is most likely explained by fewer people above that age rather than lower asthma in that group). As previously documented, Maori are disproportionately represented in asthma admission statistics (Figure 2.) Maori only represent 15% of New Zealand population but 34% of asthma admissions. Finally, initial observations indicate that asthma admissions may have been decreasing over the time period of the sample (Figure 3.); this is at odds with previous studies which suggest asthma incidence has been increasing in recent times (Holt & Beasley, 2002).

Electricity price data was obtained from the Ministry of Economic Development's Quarterly Survey of Domestic Electricity Prices. This survey provides quarterly retail electricity price data for each retailer purchasing from a line business from April 1998 to November 2009. The Line Businesses each service a unique geographical area in New Zealand.

The dataset assigns line businesses to regions. However, these regions do not precisely coincide with DHB regions so I have re-assigned the line businesses into regions that fit with the DHBs (Table 1.) Most DHB regions are matched very closely to one or more line businesses; there are a couple, however, that do not fit perfectly. This is especially evident on the Lakes/Waikato border and the Southland/West Coast border. However, this should not be a cause of concern because the area of difference is very sparsely populated and given that the electricity price data is only an estimate, the loss in accuracy due to a different border definition will be trivial.

The dataset also identifies for each region which retailer is the incumbent retailer. Following advice from a representative from the Ministry of Economic Development, I have only used the retail prices from the incumbent retailers as a measure of electricity prices for a line business. From the retailer-level data, I have calculated a weighted average of the electricity price within each DHB region weighted by the number of Installation Control Points (ICP) each line business has. There is sufficient variation in electricity price by region and time period for a reliable regression analysis.

In an extension of this study, I will produce a more accurate measure of retail electricity prices by calculating a weighted average of the price for each DHB region across all retailers as opposed to just the incumbent retailers. The relative weight of each retailer can be estimated by the number of ICPs each retailer controls. Data on the number of ICPs was obtained from the Electricity Commission website (www.electricitycommission.govt.nz; Accessed 20/04/10). This data contains the number of ICPs per retailer for each Network Supply Point (NSP) in New Zealand. As each line business controls several NSPs, I have summed the number of ICP per NSP data to each line business. This will then be used for the relative weights of each retailer when constructing a weighted average price for each region and time period.

Age-specific population data (annual, DHB-level) has been obtained from Statistics New Zealand and includes population estimates stratified into five-year age brackets. As this data only goes up to 2008, I have assigned the 2008 population to the observations from 2009. I have merged the age brackets the same way I did with the asthma data and matched the two data sets. This allows me to express my asthma data as a proportion of the population (i.e., asthma rates) rather than as an absolute number. The population data is annual whereas all my other datasets are quarterly. This should not be a significant issue as it is unlikely that there is a large extent of population variation within a DHB/year. I have also obtained ethnic population data from Statistics New Zealand; unfortunately this data is only available for Census years (2001 and 2006). As it would seem inappropriate to extrapolate this data to cover other years, this restricts my sample to only these years in analyses by ethnicity.

As mentioned above, I repeat all of my main models on age and ethnicity subsets. I first use data on total asthma admissions per quarter per DHB region and then repeat my analyses using similar datasets but one broken down into age categories and one stratified by ethnicity.

In an extension of this study, I plan to obtain figures on the smoking prevalence within each DHB region as well as median income figures for each region. I am awaiting data on gas prices and I would also like data on pollution and smoking prevalence in each region.

The New Zealand General Social Survey (NZGSS) provides individual level data on housing conditions, health outcomes, pollution and deprivation for 8,721 individuals within New Zealand (Table 4.) With regards to housing conditions, NZGSS includes questions asking survey respondents whether their house being too damp and too cold is a problem for them. The deprivation data is based on the New Zealand Index of Deprivation based on the 2006 Census (Salmond, Crampton, & Atkinson, 2007). Data on health outcomes is obtained through self-assessed questions about general health and how often health limits the respondents' ability to undertake activities.

5. Method

For an initial check to ascertain whether electricity prices are an appropriate instrumental variable for home heating, I regress the proportion of households using electric heating on electricity prices. As the only available data is for 2001, the analysis is a cross-sectional regression. Since home heating estimates are annual, I use an average of the electricity price over the four quarters of 2001 as the measure of electricity price. In particular, I estimate the following model:

$$Proportion\ of\ households\ using\ electric\ heating_i = \beta_0 + \beta_1 electricity\ price_i + \varepsilon_i$$

where i indexes DHB regions. Next, I regress asthma rates on electricity prices to establish their reduced-form relationship, initially using Ordinary Least Squares (OLS).

$$Asthma\ admissions_{i,t} = \beta_0 + \beta_1 electricity\ price_{i,t} + \beta_2 population_{i,t} + time\ \&\ cross\ sectional\ fixed\ effects + \varepsilon_{i,t}$$

where i indexes DHB regions and t indexes quarters. As long as the dependent variable is the number of admissions (as opposed to the rate of admissions), it is critical that population be included in the regression, as regions with higher populations are likely to have a higher number of admissions, ceteris paribus. The time and regional fixed effects are included to control for time-invariant DHB characteristics and for national time trends and seasonal effects. I have separated the time periods into years and quarters with fixed effects for each in order to separate seasonal effects from an annual trend. I have also weighted the observations by population to give higher importance to regions where a larger share of the population lives and thus to make my results nationally representative. It is likely that different regions will have more variable asthma rates. To account for the fact that some regions have more variable asthma rates than others (heteroskedasticity) , I have applied the white diagonal adjustment (robust standard errors in Stata) in all my analyses.

The above model specification serves as a baseline. In a series of sensitivity analyses, I adjust the functional form and estimation method, including the following checks: transforming the dependent variable to a proportion (admission rate) rather than an absolute value of admissions, transforming the model to log-linear, log-log and linear-log specifications, adding in a lag of the dependent variable as an explanatory variable, and estimating with Panel-Corrected Standard Errors (PCSE). I repeat this process with the dependent variable stratified by age and ethnicity categories with the respective population statistics. With the best fit of the model, I am able to infer from my results if there is a significant relationship between asthma rates and home heating.

In an extension of this paper, I will implement the more comprehensive definition of electricity prices and see if my initial results are sensitive to the change in definition. I will also include additional variables (as they become available) on smoking, pollution, and alternative fuel prices. I will estimate similar regressions including the new independent/explanatory variables and perform the same best fit heuristic process. I will also be aware to note if the results are unduly sensitive to functional form.

For a "straw man" robustness check, I will consult the literature to find a disease - with data available from the Ministry of Health - which is in no way caused by (or related to) home heating and I will check whether the methodology I used for asthma gives a significant relationship between home heating and this disease, pointing to a spurious correlation in my asthma findings.

As another way to corroborate my findings, I have used data from the New Zealand General Social Survey to see if there is a relationship between home heating and general health outcomes, independent of wealth. As the responses are grouped into ordered categories I used ordinal logit regressions with the following specification:

$$\begin{aligned} Health\ Outcome_i &= \beta_0 + \beta_1 Damp_i + \beta_2 Cold_i \\ &+ \beta_3 Pollution_i \\ &+ \beta_4 Deprivation_i + \varepsilon_i \end{aligned}$$

Where *i* indexes the respondent.

6. Results

As expected, electricity price is significantly negatively correlated with households' use of electric heating. Where electricity price had a coefficient of -0.061 (significant at the 1% confidence level), indicating that when electricity price increases by one cent per kilowatt, the proportion of households using electric heating decreases by 6.1 percentage points. Even though there were only 20 DHB-level observations (for year 2001) for this model, it seems safe to assume from these results (and economic theory) that households do respond to electricity price when consuming electric power for home heating. This, combined with the fact that electricity prices do not affect asthma in any way other than through heating use, indicates that electricity prices are a good proxy/instrument for home heating.

As hypothesised, the effect of electricity prices on asthma admissions is positive and highly significant in my baseline specification (Table 3.), indicating that if the price of electricity increases by one cent per kilowatt, holding population constant, the number of hospital admissions for asthma will increase by around 7 people on average in any quarter in any region. This result withstands most robustness checks (Table 3.). For example, adding a lag of the dependent variable does not substantially affect the magnitude or significance of the coefficient on price. Similarly, various log transformations of the dependent and independent variables do not greatly affect the significance of the price (or log(price)) coefficient. When admissions are in log format the price coefficient is less significant than otherwise but still comes under the 10% threshold. Applying the coefficients to an average region and time quarter produces similar magnitudes of effect as the linear model (roughly six additional admissions for every one cent increase). However, converting the dependent variable to the form of rates eliminates the significance of the price coefficient regardless of whether population and the lagged dependent variable are included as explanatory variables. It is plausible that this result is due to the fact that population numbers are annual rather than seasonal and hence produces inaccuracies in the measurement of rates.

The coefficients on the year dummy variables become increasingly negative for later years (where the first year was the omitted dummy variable), confirming that asthma admissions has been decreasing throughout time. The coefficients on the quarterly dummies indicate that asthma admissions are highest in the first quarter of the year (January to March) and lowest in the third (July to September) indicating that asthma is a bigger problem in the warmer months than the colder ones. Coefficients on the regional dummies suggest that South Canterbury has consistently the highest asthma admissions and Waitemata and Auckland have the lowest, holding all else constant.

To summarise, the initial specification produces a positive and highly significant coefficient on electricity price, suggesting increasing electricity price by one cent per kilowatt in any quarterly time period will increase asthma hospital admissions(through reduced home heating) by about seven people within a DHB region for that particular quarter. The probability that this relationship was found by chance is less than 0.1%. This relationship is robust to estimation through random effects and PCSE estimation as long as time and population has been controlled for. It is not robust when time has not been controlled for, but this is as expected since electricity price has increased throughout the time period of my sample whereas asthma admissions have decreased. These results are not robust to the dependent variable being expressed in rates rather than absolute values, but are (fairly) robust to log transformations.

Next, I apply the baseline specification to the separate age and ethnicity categories (Table 4.) The effect of electricity price on asthma admissions is positive and highly significant for infants but not for children or adults. This suggests that the main effect of home heating on asthma is through the effect on infants; which makes intuitive sense firstly because infants are by far the most likely to be admitted to hospital for asthma and also because infants probably spend a lot more time at home than any other age group, so would be affected the most by housing conditions. The results for infants are very robust to functional form changes and different estimation techniques, even when the dependent variable is expressed as the admissions rate as opposed to the absolute number of admissions. The results for children remain insignificant with all functional form and estimation technique adjustments, this may be because children tend to suffer from asthma attacks at school rather than at home, however more analysis is needed before any reliable conclusions can be made from these results. The results for adults tend to produce positive but not quite significant coefficients on price for different functional forms. Since the results are insignificant it would not be reliable to conclude that there is a positive effect of price on adult admissions but it seems reasonable to assume at least for the time being that this is more likely than not. The results from the ethnicity specific regressions show only the 'other ethnicity' category to have a positive and significant coefficient on price. The most likely reason for this is the lack of observations available due to ethnic population figures only being measured in Census years.

In preliminary analyses using the NZGSS data (Table 5.), all coefficients have the expected signs, suggesting that increasing household dampness, household cold, pollution and deprivation worsens self-reported general health and increases the amount of time the individual has been limited in their ability to work or accomplish tasks in the past four weeks (see Table 2. for definitions of the variables). From these results, I can infer that household dampness and cold worsen health outcomes. Although these conditions would affect more health problems than just asthma, it is not unreasonable to assume that asthma would be a significant contributor to these findings. Hence, there appears to be some evidence from the NZGSS to back up my findings that home heating can reduce asthma prevalence and/or severity.

7. Discussion & Conclusion

As this is still a work in progress, there are other avenues I would like to explore to further explain the relationship between home heating and asthma. Firstly, I plan on producing a more accurate measure of electricity price, using a weighted average for all retailers in each region as well as adjusting for inflation using the Consumer Price Index. With this measure of price, I will rerun my main regressions to see if my results are sensitive to the different definition. I also plan on obtaining data on gas prices, smoking prevalence, and deprivation measures to incorporate into my regressions for a fuller explanation of the effect home heating has on asthma. I will also rerun my main regression using a two-stage instrumental variable estimation technique for the two years of the Census to see if my results still hold. I plan on running a 'straw-man' analysis with data for another disease unrelated to home heating to check that my results are not merely spurious. If I can get substantial data, I will attempt a cost-benefit analysis of home heating to reduce asthma.

Although this is still work in progress, preliminary results strongly suggest that there is a highly significant positive relationship between home heating and asthma hospital admissions as would be expected. This relationship is uninfluenced by expected unobservable factors like income. Since asthma is such a large problem in New Zealand, this is an important result which may have implications for public health policy.

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Figure 1. Asthma Admissions by Five-Year Age Bracket in the Sample

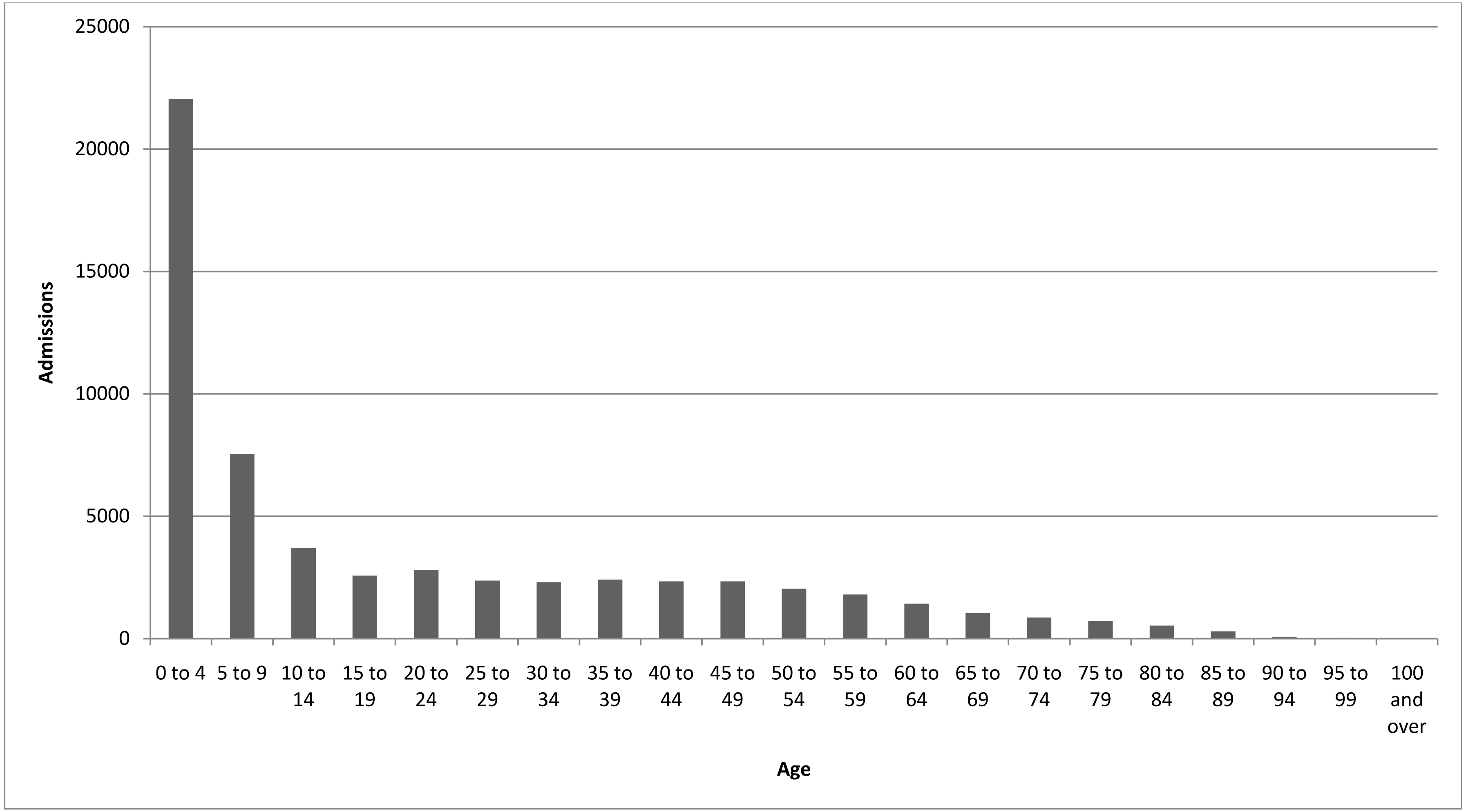

Figure 2. Asthma Admissions by Ethnicity vs. Population by Ethnicity in the Sample

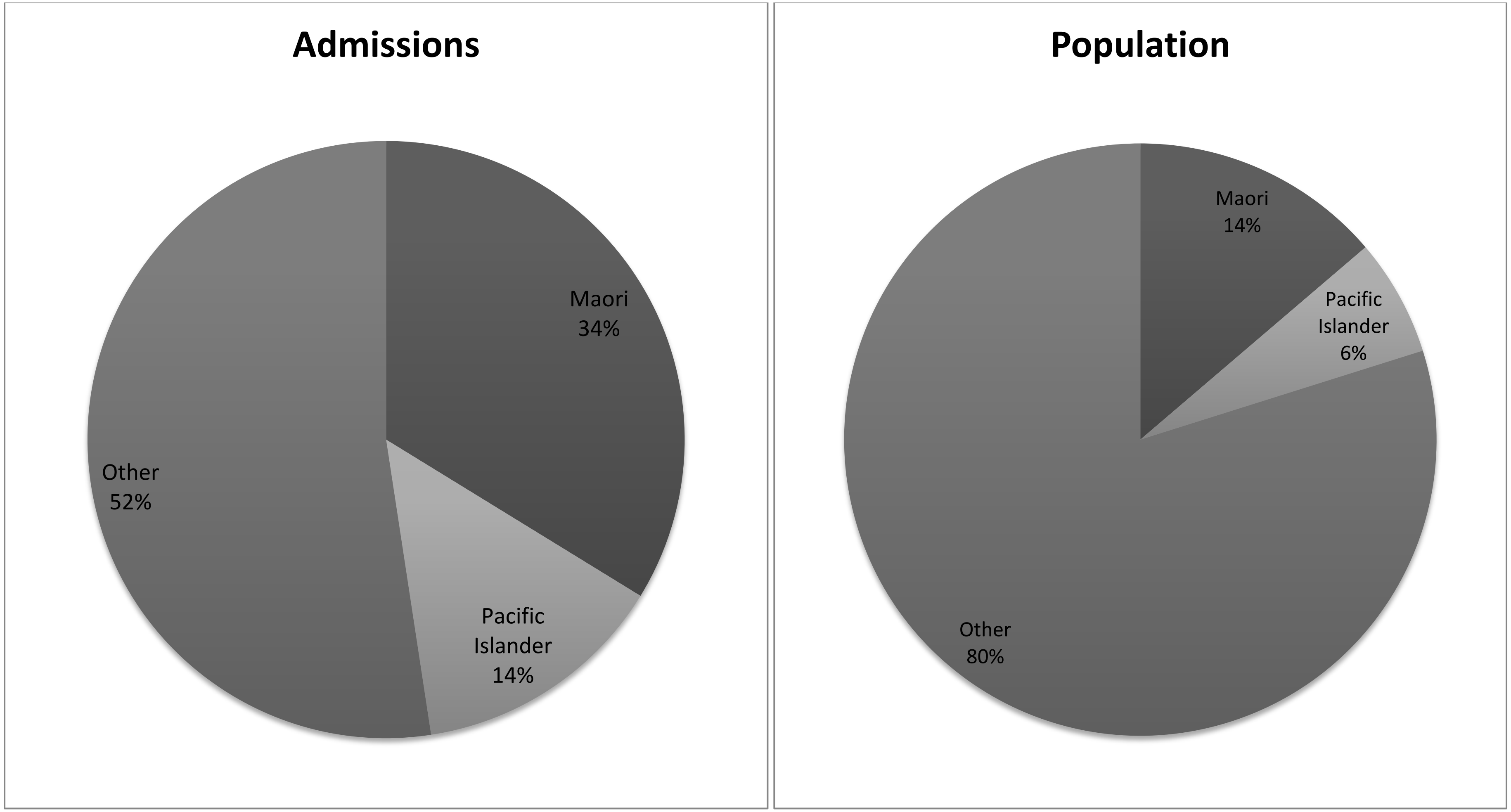

Figure 3. Total Asthma Admissions per Year in the Sample

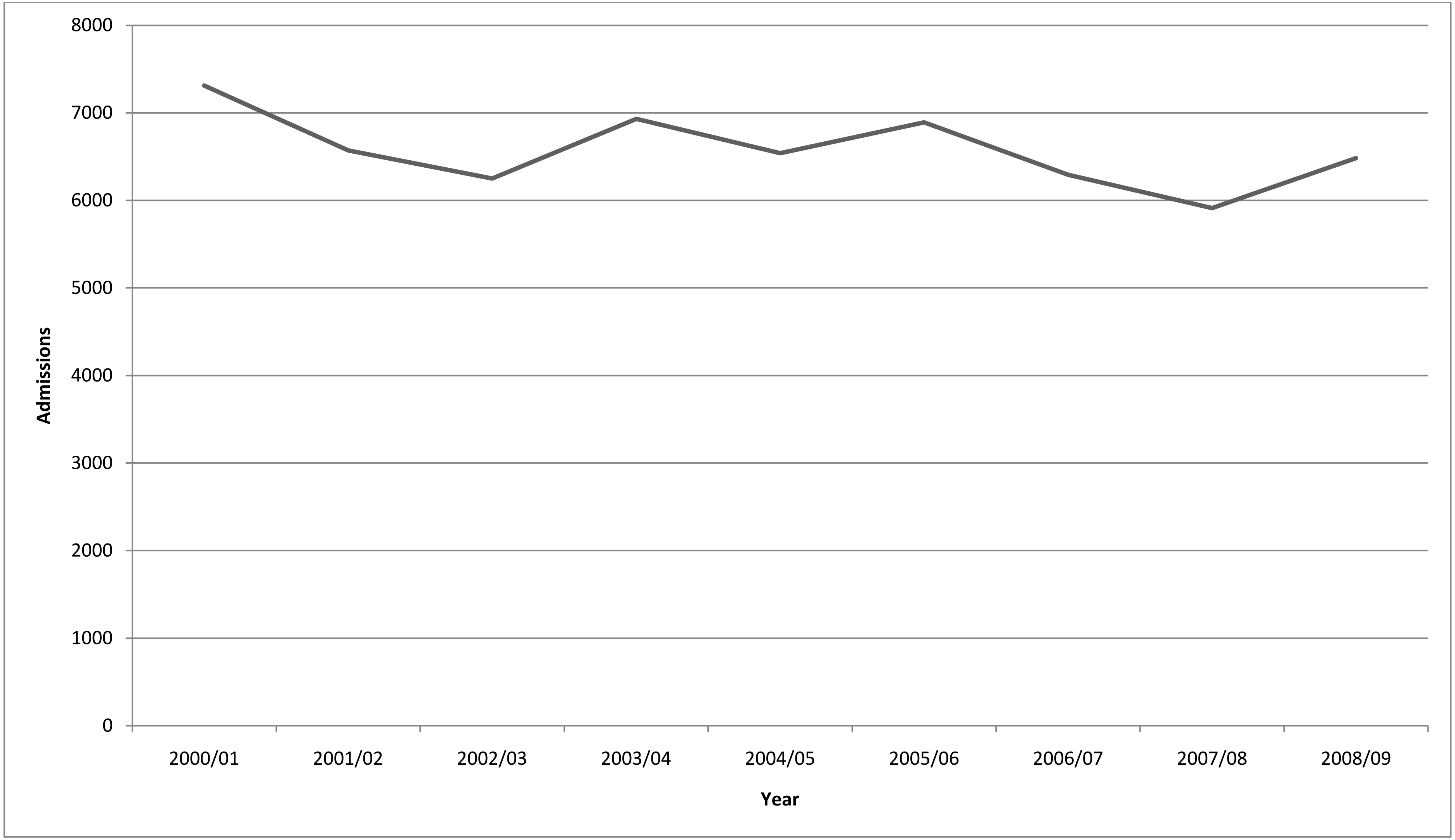

Table 1. Mapping of Line Businesses to DHB Region

DHB Domicile Code	DHB Name	Line Business
11	Northland	Top Energy Northpower
21	Waitemata	UnitedNetworks (Waitemata)
22	Auckland	Vector
23	Counties Manukau	Counties Power
31	Waikato	Waipa Networks WEL Networks Powerco (Thames Valley) The Lines Company (Waitomo) The Lines Company (King Country)
42	Lakes	Unison (Rotorua) Unison (Taupo)
47	Bay of Plenty	Horizon Energy Distribution Powerco (Tauranga)
51	Tairawhiti	Eastland Network (Eastland) Eastland Network (Wairoa)
71	Taranaki	Powerco (Hawera) Powerco (New Plymouth) Powerco (Stratford)
61	Hawke's Bay	Unison (Hawke's Bay) Centralines
81	Mid Central	Scanpower Electra Powerco (Manawatu)
82	Whanganui	Powerco (Wanganui)
91&92	Capital and Coast + Hutt Valley	Wellington Electricity Lines (North) Wellington Electricity Lines (South)
93	Wairarapa	Powerco (Wairarapa)
101	Nelson Marlborough	Marlborough Lines Nelson Electricity Network Tasman
111	West Coast	Westpower Buller Electricity
121	Canterbury	Orion NZ MainPower MainPower (Kaiapoi)

		Electricity Ashburton
123	South Canterbury	Alpine Energy
131	Otago	OtagoNet Network Waitaki Aurora Energy (Central Otago Clyde/Crom) Aurora Energy (Dunedin) Aurora Energy (Queenstown)
141	Southland	Electricity Invercargill The Power Company

Table 2. NZGSS Questions Regarding Health, Housing Conditions, Pollution and Deprivation

Code	Question	Responses
HEAQ01	In general, would you say your health is excellent, very good, good, fair or poor?	11- excellent 12- very good 13- good 14- fair 15- poor
HEAQ02a	During a typical day, does your health limit you when doing moderate activities such as moving a table, pushing a vacuum cleaner, bowling, or playing golf?	11- yes, limited a lot 12- yes, limited a little 13- no, not limited at all
HEAQ02b	During a typical day, does your health limit you climbing several flights of stairs?	11- yes, limited a lot 12- yes, limited a little 13- no, not limited at all
HEAQ03	During the past four weeks, how much of the time have you accomplished less than you would like as a result of your physical health?	11- all of the time 12- most of the time 13- some of the time 14- a little of the time 15- none of the time
HEAQ04	During the past four weeks, how much of the time were you limited in the kind of work or other regular daily activities you do as a result of your physical health?	11- all of the time 12- most of the time 13- some of the time 14- a little of the time 15- none of the time
HOUQ04_15	Air pollution from traffic fumes, industry or other smoke is a major problem with the person's street/neighbourhood	0. No 1. Yes
HOUQ03_14	Being damp is a major problem with the person's house/flat	0. No 1. Yes

HOUQ03_15	Being too cold, or difficult to heat/keep warm is a major problem with the person's house/flat	0. No 1. Yes
NZDep	Socio-economic Deprivation in New Zealand	0. (missing) 1. Least deprived : : : : 10. Most deprived

Table 3. Alternative Specification Results – Full Sample[1]

	Admissions	Admissions	Admissions per 10,000 population	Admissions per 10,000 population	Admissions per 10,000 population	Admissions	Log(admissions)	Log(admissions)
Electricity Price	6.58*** (0.00)	6.21*** (0.00)	0.0086 (0.86)	-0.0066 (0.90)	0.011 (0.82)	-	-	0.022* (0.07)
Log(electricity price)	-	-	-	-	-	110.65*** (0.00)	0.42* (0.06)	-
Population	0.00063*** (0.00)	0.00058*** (0.00)	-	-	0.00013*** (0.00)	0.00059*** (0.00)	0.0000052*** (0.00)	0.0000053 *** (0.00)
Lagged Dependent Variable	-	0.023 (0.66)	-	0.15*** (0.00)	0.11*** (0.00)	-	-	-

[1] P-values reported in parentheses, calculated with white diagonal robust standard errors
*significant at 10 per cent; **significant at 5 per cent,*** significant at 1 per cent

Table 4. Results for Age and Ethnicity Specifications[2]

	Infant Admissions	Child Admissions	Adult Admissions	Maori admissions	Pacific Islander Admissions	Other ethnicity admissions
Electricity Price	3.74*** (0.00)	-0.127 (0.81)	1.07 (0.21)	-1.39 (0.28)	-0.013 (0.99)	6.21*** (0.00)
Population	0.0019** (0.05)	0.00058*** (0.00)	0.00023*** (0.00)	0.0029*** (0.00)	0.0018*** (0.00)	0.00025 (0.18)

[2] P-values reported in parentheses, calculated with white diagonal robust standard errors
*significant at 10 per cent; **significant at 5 per cent,*** significant at 1 per cent

Table 5. NZGSS Ordered Logit Results[3]

	Heaq01	**Heaq03**	**Heaq04**
Housing Dampness (Houq03_14)	0.31*** (0.00)	-0.19** (0.01)	-0.13* (0.08)
Housing Coldness (Houq03_15)	0.23*** (0.00)	-0.12* (0.05)	-0.20*** (0.00)
Pollution (Houq04_15)	0.20** (0.03)	-0.31*** (0.00)	-0.33*** (0.00)
Deprivation (NZDep)	0.08*** (0.00)	-0.06*** (0.00)	-0.07*** (0.00)

[3] P-values reported in parentheses
*significant at 10 per cent; **significant at 5 per cent,*** significant at 1 per cent

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