

# **Inequality and Health: Is Housing Crowding the Link?\***

**Sholeh A. Maani (The University of Auckland)**

**Rhema Vaithianathan (The University of Auckland)**

**Barbara Wolfe (The University of Wisconsin)**

## **ABSTRACT**

In this study we extend the literature (e.g. Deaton, 2002a; Kennedy and Kawachi, 1996; Wilkinson, 1996) by proposing a new mechanism through which income inequality can influence health. We argue that increased income inequality induces household crowding, which in turn leads to increased rates of infectious diseases. We use data from New Zealand that links hospital discharge rates with community-level characteristics to explore this hypothesis. Our results provide support for a differential effect of income inequality and housing crowding on rates of hospital admissions for infectious diseases among children. Importantly, we find that genetic and non-communicable diseases do not show these joint crowding and inequality effects. The effect of housing on communicable diseases provides a biological foundation for an income inequality gradient.

## **JEL Classification:**

Key words: Housing crowding, child health outcomes, income inequality.

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## 1. Introduction

While the link between income and health is well established at both an individual and a community level (Adler et al, 1994; Case et al, 2002; Deaton, 2002b; Wolfson et al, 1993), the relationship between income inequality and health has a more controversial history (Deaton, 2003; Lynch et al, 2004a, 2004b; ).

There is some evidence that income inequality correlates with health (Wilkinson, 1992), but exactly what this means is debated. If income and individual health have a non-linear relationship, then income inequality will reduce the average health of a population (Preston, 1975; Rodgers, 1979). This is sometimes dismissed as a “statistical artefact” because it will hold true whenever we aggregate individuals—even if these individuals are from separate communities (Gravelle, 1998). However, Deaton (2002a) points out that despite the relationship being a direct result of aggregation, important policy implications flow from the fact that income inequality reduces the average health of a population. Namely, redistribution of income to poor people will result in an overall improvement in health. Other researchers have disputed both Wilkinson’s methodology and the mere fact of a correlation between income inequality and health (e.g. Judge et al, 1998; Mellor and Milyo, 2001).

The “relative income hypothesis” and the “relative position hypothesis” (Wagstaff and van Doorslaer, 2000) propose that income inequality directly contributes to ill health. In the relative income hypothesis, it is the individual’s income relative to a social group that matters, whereas in the relative position hypothesis it is the individual’s position in the income distribution that matters.

As well as arguments about the nature of the findings, there is no consensus on the theoretical mechanism through which inequality influences individual health status. Aside from the “statistical artefact” argument, the two main competing hypotheses for a more direct effect of inequality is the “psychosocial” and the “neo-material” hypotheses.

In the psychosocial hypothesis, individuals and communities become stressed as a result of being in a community with greater inequality and the resulting breakdown of supportive networks, violence etc. (Wilkinson, 2000).

According to the neo-material hypothesis, communities with greater inequality change the material conditions of individuals such as reducing the supply of public health and housing, and so on. This, in turn, leads to poor individual health (Lynch et al, 2004b).

This paper offers a new explanation of how income inequality affects health outcomes, and examines evidence on the role of housing as a link between income inequality and health outcomes. Our hypothesis is, broadly speaking, neo-material as it is based on a link between income inequality, crowding, and disease. Housing crowding is well recognised as an important contributor to health outcomes; however, this paper focuses on the link between income inequality, housing crowding, and health.

Our empirical method is similar to other within-country studies such as Kaplan et al 1996; Kennedy, Kawachi and Prothrow-Stith, 1996; Mellor and Milyo, 2001. In general, within-country studies have found a correlation between income inequality and health (Lynch et al, 2004b). However, according to Deaton (2003) this correlation is due to other factors which are correlated with inequality – rather than being directly attributable to it. For example, Mellor and Milyo (2001) look at country level and State level data on life expectancy and infant mortality. They find that the effect of income inequality is not robust to the time period of the sample nor the inclusion of the secondary school enrolment in State. None of these studies have looked specifically at infections and none that we know of has adjusted for the effect of housing crowding.

We test our model using data from the New Zealand census matched with hospital discharge data for Auckland. New Zealand is very relevant for the study. First, similar to many other countries in recent years, income inequality in New Zealand has increased in the past two decades. For example, between the 1985/6 and 1990/91 census years, there was significant change in New Zealand's income distribution (see Table 1).

**Table 1: Income inequality in New Zealand over time (measured by the Gini coefficient)**

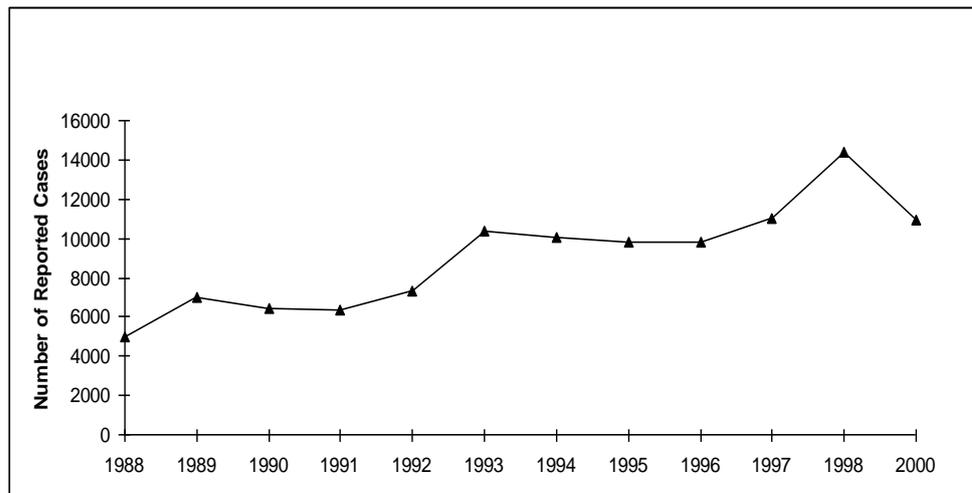
	<b>1981/82</b>	<b>1985/86</b>	<b>1990/91</b>	<b>1995/96</b>
Gini coefficients on household disposable income	0.283	0.278	0.334	0.341

Source: O’Dea (2000).

In addition, in 1991, Government policy changes in New Zealand with respect to housing for poor families meant that families living in subsidised state housing faced large increases in rents. The changes were introduced in 1993, when all housing subsidies were transferred to income support.<sup>1</sup> For example, in 1991 a single-parent beneficiary living in a state house was expected to pay about 24% of their income on rent; by 1999 this figure had risen to 50%.<sup>2</sup> At the same time, welfare payments were reduced.

Also of relevance, infectious diseases during the past decade have shown an upward increase. Figure 1 shows reported infectious diseases. The diseases are restricted to those that have been reported since 1988. The data shows increased infectious diseases during the period.

**Figure 1: Total communicable diseases**



Source: Communicable Diseases Reports<sup>3</sup>, Public Health Surveillance (New Zealand).

The present paper has two objectives. First, we propose a theoretical channel through which income inequality can lead to increased infectious diseases. Our theory is the following. The danger of infection from most diseases is greater from a member of the household than from the community at large. McKendrick (cited in Longini and Koopman, 1982) was one of the earliest to be concerned about the differential effect of household and community infection rates. He concluded that the risk of household to community transmission of the bubonic plague was 200:1.

This implies that every member of a household imposes a negative externality on other members of their household. Therefore, if a person is moved from a smaller household to a larger household (resulting in a mean preserving increase in the variance of occupants per household leads) this leads to a higher overall rate of infection. If the number of cases of infectious disease in a particular community increases, an individual in that community is more likely to catch an infectious disease, so poverty has a negative externality (third-party effects). This implies that reducing inequality (and therefore crowding) may be related to better health outcomes through two channels: the direct effect of crowding (by improving economic means) and a lower externality effect (through third-party effects).

Second, we test our model using a unique data set, which links hospital administrative data with community-level census and municipal information. The theoretical model suggests that income inequality should be particularly associated with infectious diseases and not with non-communicable diseases. Furthermore, we would expect the inclusion of household crowding to reduce the size and significance of income inequality as an explanatory variable in the case of infectious diseases.

Our results provide strong support for both a significant income inequality effect, and housing crowding effects on infectious disease admission rates among children. Moreover, our results suggest that some of the effects of income inequality on health outcomes are through housing crowding. In particular, we find that for each 10% increase in the proportion of children living in crowded households in a particular census area, the rate of infectious disease admissions increases by 1% (after controlling for income and income inequality). Importantly, we also find that genetic and non-communicable diseases do not show the twin effects of crowding and income inequality.

The paper is organised as follows: section 2 provides a theoretical and related empirical model. Section 3 outlines the data, while results are discussed in section 4. A discussion and conclusions are presented in section 5.

## 2. Model

Longini and Koopman (1982) model a communicable disease that is spread through individual contact. An individual has two sources of infection: the general community and fellow household members. Consider a community of  $n$  children. Over a period of 1 year, child  $i$  may be infected by household members with probability  $p_i^f$  and by a member of the community with probability  $p_i^c$ . The probability of infection from the household is higher than from the community at large ( $p^f > p^c$ ). We assume that family size differs and let  $F_i$  be the number of members in the child's household.

To simplify, we assume independence of contagion from the family and community sources. Therefore, the probability that the child will *not* be infected by a family member or by a member of their community is  $(1 - p_i^f)^{F_i-1} (1 - p_i^c)^{n-F_i}$ . A general expression for  $X_T$ , the total number of children who contract a disease at the end of the period, is given by:

$$X_T = \sum_{i=1}^n \left[ (1 - (1 - p_i^c)^{n-F_i} (1 - p_i^f)^{F_i-1}) \right]$$

This general expression suggests that  $X_T$  is increasing in the inequality in the distribution of children across households (that is, as inequality increases, total disease propensity increases). For example, if there are 10 households and 20 children,  $p_i^c = 0.1$  and  $p_i^f = 0.5$ . If the children are spread across all households evenly, the expected number who would be infected is 18.5. If, however, 9 households have 1 child each with the 10th household having 11 children, the expected number infected is 18.8. If all 20 children lived in one house, the expected number would be 19.9. If inequality in housing consumption is related to inequality in income, then we have proposed a direct link between income inequality and health.<sup>4</sup>

However, so far, all we have argued is that through the housing crowding mechanism, there is a negative relationship between health per household member and the number of people in a household. This does not necessarily imply that a child, whose own housing does not change, would experience a worse health outcome because of the change in inequality of those in the child's community.

To take this next step, we argue that  $p_i^c$  (the rate of infection from the community) depends on whether a person is at an increasing risk of being infected because the community in which that person lives now has a higher disease rate. It is not controversial to argue that through being in contact with a community where the average rate of disease is higher, each individual suffers from a higher probability of disease.

The final link in our argument is to observe that, as long as housing is a normal good (such that demand for housing increases with income), with relatively inelastic supply, increased income inequality will lead to household crowding. Matlack and Vigdor (2006) present the most robust empirical evidence of this link. They show that increasing income inequality is associated with an increase in the level of crowding among the poor.

Before turning to the empirical specification, let us summarise the arguments presented above. If the probability of contracting a disease from a member of one's own household is higher than from members of the wider community, then an increase in the inequality of housing consumption increases the average incidence of infectious diseases. To the extent that increased income inequality leads to inequality of housing consumption, we argue that increased income inequality leads to increased rates of infectious diseases. Moreover, the remaining, or residual effect of income inequality should be less (or even disappear) once household crowding is taken into account.

We now turn to our empirical model to explore the theoretical arguments proposed above. One of the problems with empirical analysis of the socio-economic determinants of health is that health stock is accumulated over the life of the individual (e.g. Blakely et al, 2000). Therefore, the individual's circumstances at a given time are the result of their lifetime exposure to risk factors—including (if our hypothesis is correct) the level of inequality of the society in which they lived all their lives. For this reason, we focus on health outcomes for the young (those aged under 5 years old) and acute infectious diseases that are more sensitive to the immediate conditions of the person.

The empirical model we estimate is:

$$P_{ijt} = a + b_1 Y_{ijt} + b_2 Y_{ijt}^2 + C_1 Inequal_{kt} + C_2 HsCrowding_{kt} + u_{ijt}$$

$P_{ij}$  is the infectious disease discharge rate for age group  $i$ , living in census area unit (CAU)  $j$ . ( $P_{ij} = p_{ij}^c + p_{ij}^f$ ). Subscript  $t$  stands for time. The discharge rate is defined as the number of hospital admissions for infectious diseases for children in group  $i$  living in area  $j$  observed in year  $t$  divided by the number of children in the group at the time of the census of year  $t$ .  $Y_{ij}$  represents the average annual income of families with children under the age of 5 (age group  $i$ ) living in CAU  $j$ .  $HsCrowding_{kt}$  represents housing crowding of the surrounding neighbourhood (or community) of families with children under the age of 5 living in CAU  $j$ . Coefficients  $b_1$  and  $b_2$  capture the standard “absolute income” effect of poverty on group infectious disease discharge rates, and  $C_2$  captures the housing effect.

If the inclusion of housing crowding reduces  $C_1$ , then this suggests that the way that income inequality affects infectious diseases is by its effect on household crowding. The specification of housing crowding used in this paper is the Canadian national crowding index (Canadian National Occupancy Standard). This index identifies the number of additional bedrooms that are required but lacking.

One of the well-recognised problems in studying the effect of neighbourhoods on individuals is that neighbourhood characteristics are chosen by individuals who decide to locate in a particular area. Families who locate in areas where the schools have lower rates of infectious disease might also engage in other unobservable activity that promotes good health (frequent visits to the doctor, good diet, and so on).

One of the ways that other researchers have dealt with this is to look at outcomes for children, arguing that children do not choose their neighbourhoods (e.g. Cutler and Glaeser, 1997). However, it is conceivable that parents who locate in areas surrounded by poor neighbourhoods may have some unobserved characteristic that also makes them negligent of their children’s health.

While it is clear that parents may move to areas for their income characteristics, it is less likely that they would move for income inequality characteristics. For one thing, income inequality is not readily observed. For another, the area units are somewhat

larger than a neighbourhood—they are CAUs. Although people choose the immediate neighbourhood, they are less likely to choose the CAU.

In addition, we also check our results against an alternative specification for “neighbourhoods”, defined as “school zones”. Public schooling in New Zealand is operated on the basis of a geographical zone that determines which public school a child will attend. We construct a school zone inequality variable that excludes the immediate neighbourhood of the children, and simply measures the inequality of the larger area that feeds into the school zone. While this does not perfectly control for the endogeneity of the income inequality and housing crowding variables, as we are excluding the immediate neighbourhood, we are to some extent testing the robustness of the estimates.

### **3. Data**

We focus on the population of the Auckland Region, which has close to 1.4 million people—the largest metropolitan area in New Zealand. The region includes both a major urban area and the surrounding areas of Auckland, which are more sparsely populated. In addition, it includes a range of income levels and housing prices across areas. Moreover, the data is from two periods (1991 and 1996), during which both population and state housing prices (government housing for welfare recipients) increased significantly due to policy changes. Therefore, the regional nature of the data, along with coverage of two census periods provides relevant variation in income, housing costs, and crowding.

In Auckland there are three publicly funded hospitals from which the data were derived: Auckland City Hospital, Waitemata, and South Auckland Health. These hospitals together serve the wider Auckland region.

The data for this study were derived from matching information from four sources: (1) the New Zealand Census of Population; (2) the New Zealand Census of Dwellings; (3) Health Council hospital discharge data; and (4) Ministry of Education school zone data.

Our neighbourhood is defined as a CAU classification, and we use a pooled sample from the 1991 and 1996 censuses.

The hospital admission data has records of discharges at an individual level, and record the age, sex, ethnicity, and CAU of residence of the patient. This data is particularly rich in the details of the types of disease. The admission data, however, does not record any information on family income, education of parents, and household crowding based on this data set. Therefore, we match our hospital discharge data with average group level characteristics derived from the New Zealand Census of Population and Dwellings.

The unit of observation is the CAU. Table 2 describes the data. There are 467 observations composed of 154 in 1991 and 313 CAUs in 1996. Statistics New Zealand changed the definition of CAUs between these two periods, so the CAUs are not exactly matched between years.

**[Table 2 about here]**

The average number of children aged under 5 in a CAU is 255. Family income is defined as the average income of all families in the CAU who have children under 5 years old. The average family income is \$45,495 and the mean of the variance is \$65,610. The mean of the variance is calculated as the income variance of family income in the CAU.

While the child's immediate CAUs are small neighbourhoods covering about 3,000 to 5,000 individuals, school zones are much larger and cover several CAUs. We use an alternative definition of neighbourhood, which includes the school zone community but excludes the child's own home CAU. This definition provides a good approximation of the community met by families and their children through school and other out-of-school activities of older siblings. Our school zone community encompasses primary and secondary schools.<sup>5</sup> The variance of family income using this alternative definition is \$999.52, which is larger than when only the neighbouring CAU is used.

The crowding variable pertains to the average experienced by members of their group (of families with children under the age of 5). The main variable for housing crowding in our study is the proportion of children under the age of 5 living in crowded housing, based on the Canadian crowding index. The Canadian crowding index measures the number of bedrooms required but lacking. We find quite a high proportion of crowded families by this standard, with an average of 20% of children under 5 years living in households requiring an extra bedroom. A similar proportion is crowded in the larger school zone community.

A second measure of crowding used was the ratio of the number of household members to bedrooms. On average there are 1.54 people per bedroom. The two measures show very comparable results.

Infectious diseases are defined using the disease code recorded when the patient is admitted to the hospital. We made a judgement on what constituted infectious disease using three-digit disease codes. Detail on the diseases included is shown in Appendix A. On average, 5 per 100 children under 5 years old in the CAU were admitted for infectious diseases.

## 4. Results

Table 3 reports the regression results for the full sample. All regressions include a year dummy variable adjusting for the two census years. Specification 1 (Column 1) is simply the gradient effect between income and hospitalisation rate for infectious diseases, and demonstrates a quadratic relationship. Both family income and its squared term are significant.

Specification 2 (Column 2) verifies that income inequality has additional explanatory power in explaining health outcomes. Variance of income in the immediate CAU is statistically significant at a 0.001 level. The inclusion of the variance increases the gradient effect.

In specification 3 (Column 3), we incorporate the crowding ratio of the CAU (the ratio of usual household members to the number of bedrooms), which is significant and positive. Including the crowding variable reduces the significance of the income and the squared term, but the income variance continues to be significant (t-ratio of 2.842). Specification 4 (Column 4) replaces the crowding ratio with the Canadian crowding index, which is also significant (t-ratio of 2.88).

As hypothesised, the estimated coefficient of income inequality ( $C_1$ ) decreases significantly when a crowding variable is also included in the model. Comparing specification 2 and specification 4 in Table 3, the income inequality coefficient decreases from 0.048 to 0.033—a decrease of 31%, which is statistically significant at better than a 0.001 level, based on the Wald test. In addition, the test of restrictions for the inclusion of the crowding variable in specification 4 (compared to specification 2) results in significance of the crowding variable at a 0.001 level. These results support our hypothesised impact of income inequality and housing crowding on health outcomes. That is, including crowding partially mitigates the inequality gradient.

**[Table 3 about here]**

Specification 5 (Column 5) includes income variance and housing crowding, when the community is defined as the wider surrounding community based on the common school zone. The crowding of the surrounding community continues to be a significant predictor of infectious diseases. Comparing the results of specification 4 and specification 5 shows that the income inequality of the immediate community and the crowding of both the immediate and surrounding communities show significant association with health outcomes. Moreover, our results suggest that these associations are causal, because people's decisions about where to live are based more on the immediate CAU than on the surrounding community.

Now we turn to checking whether the pattern observed for infectious diseases is also observed for other diseases. To check this we estimate specification 4 on selected diseases as classified by the one-digit medical diagnostic code. In these cases, the dependent variable is the percentage of children who have been hospitalised for a disease that is recorded as belonging to a specific broad disease classification (Table 4).

**[Table 4 about here]**

Respiratory diseases, which have strong infectious components, demonstrate the same pattern as infectious diseases. Respiratory diseases are the most common cause of hospitalisation with the majority being for bronchitis and pneumonia, which make up a large part of the infectious diseases as defined in our main results. The same pattern as observed in the main results is also found with respiratory diseases, in that the coefficient of income inequality ( $C_1$ ) decreases significantly when the crowding variable is included in the model (a decrease in the coefficient  $C_1$  from 0.044 to 0.024). The t-ratio falls from 3.81 to 1.73.

Diseases and disorders of the ear, nose, mouth, and throat (which are only partly affected by infectious diseases) show a significant negative relationship with income, and a positive and significant relationship with income inequality. Crowding is insignificant.

Injuries and poisoning (which are non-communicable) are also significant in relation to income inequality, but not crowding, which further supports our hypothesis regarding communicable diseases.<sup>6</sup> Indeed, there is very little evidence that crowding or income inequality matters to non-communicable diseases. Burns, in contrast, are positively associated with crowding but not income inequality or mean income.

For further tests of robustness, we extend specification 4 to control for ethnicity (Table 5). The question of ethnicity is of potential interest, as the incidence of infectious disease is generally higher among Māori and Pacific Island populations, compared to European and other populations. In addition, Māori and Pacific Island families may tend to live in more crowded circumstances because they have larger families. Simple regression models, including child ethnicity only, confirm this effect for the Pacific Island population at statistically significant levels (1% or better). Therefore, we have re-estimated our model by controlling for child Māori or Pacific Island ethnicity, to check that our results are not merely reflecting specific ethnicity effects.

**[Table 5 about here]**

We find that the inclusion of ethnicity in our model does not alter the results we have reported on the tie between income inequality and housing crowding on health outcomes. That is, the addition of Māori or Pacific Island ethnicity to Model 4 (in Column 3, Table 5, compared to our main specification, in Column 4, Table 3) fails all restriction tests—with statistically insignificant coefficients for ethnicity, while the estimated effects of housing crowding and income inequality remain intact.

These results further support the hypothesis that income inequality and housing crowding are tied to increased risk of infectious diseases and are robust across ethnic groups.

## **5. Discussion**

Our results (as supported by tests of restrictions) provide strong support for the effect of income inequality as measured by income variance on infectious disease discharge rates. Moreover, there is evidence of an additional and independent effect of crowding across all specifications. This suggests that for infectious diseases, housing crowding is a significant link in the transmission of inequality on health. Importantly, we also found that genetic and non-communicable diseases do not show this relationship—supporting the biological disease transmission hypothesis in this case.

Our estimates of the influence of crowding and of income inequality on infectious disease discharge rates suggest that the influence is sizeable. In Table 6 we report the expected change in discharges as each of our various measures of income inequality and crowding is increased by one standard deviation moving from the mean rate of such discharges. A one standard deviation increase in the Variance of Family Income in the community is expected to increase the rate of infectious disease discharges by more than 40 percent or nearly two per hundred children. A one standard deviation change in crowding in the area (using the Canadian index) is expected to lead to an even larger increase in this rate—nearly a fifty percent increase or about 2.25 per hundred, even while controlling for the variance of family income. The combination of a one standard deviation increase in both the ratio of crowded housing and income variance in the area is expected to increase the rate of infectious disease discharges by nearly three or by more than 60 percent; similar changes at the school feeder area are expected to increase the rate by more than two and a half or more than 55 percent. In nearly every simulation then, moving from one standard deviation in crowding and income inequality to one standard deviation above the mean would nearly double the rate of infectious disease discharges and in some cases, more than double the rate.

**[Table 6 about here]**

Beyond the sheer magnitude, the results are interesting for additional reasons. First, they suggest that the effect of housing is truly exogenous—an omitted variable, as there is no reason to believe that unobserved effects are more likely to play a role in infectious diseases than in other diseases. Second, the effect of housing on communicable diseases provides a biological foundation for the income inequality effect.

The effects observed in our data suggests that some of the rise in infectious disease experienced in New Zealand may be directly attributed to the increase in income inequality, and the increase in housing costs. If so, then there is certainly a suggestion that policies that promote less poverty and inequality, and better housing for low income families might improve the health of the whole community. This link is of interest both for lower income countries, where infectious diseases are more prevalent, and for higher income countries, with increasing income inequality. It also suggests that when income inequality increases, housing policies are important and relevant to overall health outcomes.

The evidence in this paper provides new mechanisms and evidence, which are robust at the community level. Future research is needed to examine whether our results are robust when a richer set of individual level data is included.

**Table 2: Descriptive statistics**

Variables	Mean (S.D.)
Family income (‘000\$)	46.954 (17.30)
Variance of family income within CAU* (‘000\$)	69.968 (40.26)
Variance of family income across school zone excluding home CAU (‘000\$)	1038.35 (406.58)
Proportion crowded in CAU (Canadian index)	0.209 (0.152)
Proportion crowded in school zone excluding home CAU (Canadian index)	0.221 (0.134)
Average number of people in a house divided by the number of bedrooms (crowding ratio)	1.54 (0.234)
Infectious diseases prevalence in CAU (per 100)	4.67
Proportion in CAU Māori or Pacific Islander	0.275
Number of Observations	467

\*Note: CAU= Census Area Unit

**Table 3: Hospital discharges of infectious diseases  
per population of children in age group (per 100 children)**

**Alternative specifications: 1-5**

Explanatory variables	1	2	3	4	5
Intercept	14.49*** (4.02)	16.83*** (4.66)	1.19 (-0.22)	2.02 (0.53)	5.61 (1.46)
Mean family income	-0.27*** (-2.34)	-0.42*** (-3.62)	-0.14 (-1.32)	0.017 (0.14)	-0.12 (-1.09)
Mean family income <sup>2</sup>	0.002** (1.95)	0.0024*** (2.62)	0.006 (0.82)	-0.0004 (-0.52)	0.0006 (0.67)
Income inequality (income variance)		0.048*** (3.58)	0.033** (2.42)	0.024 (1.63)	NO
Crowding ratio			6.69 ** (2.79)	-	-
Proportion in crowded housing (Canadian index)		-	-	14.66*** (2.88)	NO
Surrounding school zone community— income inequality (income variance)		-	-		0.002** (2.16)
Surrounding school zone community— proportion in crowded housing (Canadian index)		-	-		13.22*** (4.01)
Year	Yes	Yes	Yes	Yes	Yes
F-significance level	0.0000	0.0000	0.0000	0.0000	0.0000
<b>R<sup>2</sup></b>	0.0758	0.0980	0.115	0.130	0.111

Note: Sample size, 467; all specifications control for year (dummy = year 1996); income is measured in thousand dollars per year.

\*\*\*1%, \*\*5%, significance level; t-ratios, based on White consistent standard errors, in parentheses.

**Table 4: Child hospital discharges by selected disease categories**  
**(Medical Diagnostic Code)**  
**per population of children in age group (per 100 children)**

<b>Diseases and disorders</b>	<b>Income</b>	<b>Variance of income</b>	<b>Crowding</b>
Eye (Dis_02)	-0.003 (-0.20)	0.004 (1.54)	- 0.012 (- 0.03)
<b>Ear, nose, throat (Dis_03)</b>	-0.201** (-2.02)	<b>0.038***</b> <b>(2.86)</b>	-1.905 (-0.61)
<b>Respiratory (Dis_04)</b>	-0.409 (-3.70)	<b>0.044***</b> <b>(3.81)</b>	<b>NO</b>
	-0.032 (-0.27)	<b>0.024</b> <b>(1.73)</b>	<b>12.570***</b> <b>(2.55)</b>
Circulatory system (Dis_05)	0.022 (1.70)	-0.001 (-1.62)	0.555 (1.69)
Digestive (Dis_06)	-0.065 (- 0.76)	0.024 (1.80)	0.141 (0.06)
Hepatobiliary (liver) (Dis_07)	-0.007 (-1.26)	0.001 (1.21)	-0.088 (-0.49)
Musculoskeletal (Dis_08)	-0.069 (-0.98)	0.016 (1.68)	-0.252 (-0.15)
Skin (Dis_09)	-0.023 (-0.73)	-0.0001 (-0.03)	2.288 (1.72)
Male reproductive system (Dis_12)	-0.022	0.005	-0.304

	(-0.89)	(1.58)	(-0.51)
Female reproductive system (Dis_13)	0.003 (1.11)	-0.0004 (-1.55)	0.017 (0.33)
Injuries, poisoning, and toxic effects of drugs (Dis-21)	-0.022 (-0.83)	<b>0.008***</b> <b>(2.41)</b>	0.326 (0.45)
Burns (Dis_22)	-0.026** (-2.01)	0.005 (1.51)	NO
	0.004 (0.39)	0.004 (1.13)	<b>1.022***</b> <b>(2.85)</b>

Note: Selected regression coefficients reported, using specification 4 where we control for mean income and mean squared, and variance of income; crowding variable is the Canadian crowding index; sample size, 467; all specifications control for year (dummy = year 1996); income is measured in thousand dollars per year. Disease category and coefficients in bold represent income inequality or housing crowding effects of special interest, relating to our model.

\*\*\*1%, \*\*5%, significance level; t-ratios, based on White consistent standard errors, in parentheses.

**Table 5: Controlling for ethnicity**

**Child hospital discharges by selected disease categories  
(Medical Diagnostic Code)  
per population of children in age group (per 100 children)**

Explanatory variables	1	1	2
Intercept	4.568*** (6.55)	7.086 (1.82)	2.835 (0.70)
Mean family income	—	-0.136 (-1.09)	-0.007 (-0.05)
Mean family income <sup>2</sup>	—	0.0005 (0.58)	-0.0002 (-0.31)
Income inequality (income variance)		0.039*** (2.59)	0.023 (1.63)
Proportion in crowded housing (Canadian index)			16.731*** (2.52)
Ethnicity Māori or Pacific Island	7.046 (3.59)	6.244 (2.12)	-1.860 (-0.52)
Year	Yes	Yes	Yes
F-significance level	0.0009	0.0000	0.0001
R <sup>2</sup>	0.1001	0.1114	0.1307

Note: Sample size, 467; all specifications control for year (dummy = year 1996); income is measured in thousand dollars per year.

\*\*\*1%, \*\*5%, significance level; t-ratios, based on White consistent standard errors, in parentheses.

**Table 6: Simulations of influence of crowding and inequality of income on rate of infectious diseases**

Base infectious disease rate = Mean: 4.67, per hundred children in age group

Simulation	Change in rate	Percentage change in rate
Base disease rate = 4.67		
+1 S.D. in income inequality <sup>1</sup>	1.93	41.4%
+1 S.D. change in proportion crowded housing (Canadian index) + 1 S.D. change in income inequality <sup>2</sup>	2.23 0.97 Total: 3.2	47.8% 20.7% Total: 68.5%
+1 S.D. change in income inequality + 1 S.D. change in crowding ratio <sup>3</sup>	1.33 1.56 Total: 2.89	28.4% 33.5% Total: 61.9%
+1 S.D. change in school income inequality + 1 S.D. change in school zone proportion in crowded housing <sup>4</sup>	0.81 1.77 Total: 2.58	17.4% 37.9% Total: 55.3%

Note: The following notes refer to the model specification columns in Table 3 that are the basis for coefficients in these calculations:

1. Column (2);      2. Column (4);      3. Column (3); 4. Column (5).

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## **Appendix A**

### **Specifics of infectious diseases and crowding variables**

#### **Infectious diseases included in the infectious diseases variable**

Infectious diseases included in the infectious diseases variable, based on the three-digit New Zealand Health Council classifications are: viral meningitis, respiratory infections or inflammations, pneumothorax with complications, whooping cough and acute bronchiolitis, acute and major infections of the eye, skin ulcers, HIV-related infection, viral illnesses, fever of unknown origin, and other infectious and parasitic diseases.

#### **The Canadian housing crowding index**

The Canadian crowding index is based on the Canadian National Occupancy Standard. This index identifies the number of additional bedrooms that are required but lacking, based on the number of occupants, their age, and the gender of siblings. A child is identified as living in crowded housing if, based on the index, one or more bedrooms are required but lacking.

#### **Crowding ratio**

The crowding ratio measures the ratio of the number of household members in each dwelling, to the number of bedrooms. At the census area unit level, the variable measures the mean of household crowding ratios.

## Endnotes

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- <sup>1</sup> See for example, Howden-Chapman and Wilson (2000).
- <sup>2</sup> NZ Council of Christian Social Service (1999).
- <sup>3</sup> Total reported cases of AIDS, campylobacter, cholera, diphtheria, hepatitis A, hepatitis B, hydatid disease, legionellosis, leprosy, leptospirosis, listeriosis, malaria, paratyphoid, poliomyelitis, rheumatic fever (initial attack), salmonellosis, shigellosis, tetanus, and typhoid.
- <sup>4</sup> Note that this model can be applied to any transmission mechanism where contagion from household members is greater than from the community as a whole. For example, domestic violence could also be modelled in this manner—although we do not directly deal with this issue.
- <sup>5</sup> In our data, for the region, the mean number of households with children under the age of 5 years in each Census Area Unit (CAU) is 246 households, compared to 4674 households at the school zone level.
- <sup>6</sup> This non-communicable effect of inequality may reflect other effects such as poor housing, heating, bedding, clothing, or exercise.