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SOCIOECONOMIC AND ENVIRONMENTAL COVARIATES OF PREMATURE MORTALITY IN ONTARIO

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Abstract—This paper contributes to debates on the broad determinants of health and on the policy shift from curative to preventive and protective interventions. It addresses empirically the relative importance of influences on health with a multiple regression analysis of ecologic data from the 49 counties of Ontario. One model achieved high predictive power (that is, Adj $R^2 > 75\%$, $p < 0.0001$). Educational levels were a strong predictor of population health, showing a consistent inverse relationship with premature mortality ratios for both sexes and it was the strongest predictor for females. A low income variable supplied the strongest prediction for male mortality. This variable displayed a positive association with male mortality. Municipal expenditures on environmental protection exerted a negative effect on male mortality. These findings raise questions about the current directions of health policy in Ontario where the provincial government has reduced funding to social and environmental programs, while promising to maintain health care funding.

Key words—ecologic design, environment, health policy, Ontario, socioeconomic factors

INTRODUCTION

This paper is located in the debates concerning the broad determinants of health at the population level and concerning the policy shift from curative to preventative and protective interventions. It addresses empirically the relative importance of influences on health through an ecologic analysis of the counties in Ontario. Few recent studies have empirically investigated which of these determinants of population health are significant when the influence of the other determinants and related lifestyle variables is controlled through statistical modelling (Feinstein, 1993). In this paper, we incorporate variables representing many of the socioeconomic, environmental, medical care and related lifestyle determinants of health into the same multiple regression model.

Interest in the socioeconomic and environmental determinants of population health emerged in the 19th century with the work of public health pioneers such as Virchow, Villerme, Chadwick and Shatluck. It took until the 20th century, however, for researchers to establish a body of knowledge on these broader determinants of health (Amick *et al.*, 1995). Many studies have documented the importance of socioeconomic determinants of health over the past 20 years, including variables such as income (Kitagawa and Hauser, 1973; Silver, 1973; Pappas *et al.*, 1993), income inequality (Wilkinson, 1992a,b; Kaplan *et al.*, 1996), poverty levels (Hadley, 1982; Menchik, 1993), unemployment rates (Ferrie *et al.*, 1995), education (Kitagawa and Hauser, 1973; Silver, 1973; Weiss *et al.*, 1992; Kunst and Mackenbach, 1994), occupational status and hierarchy (U.K. Department of Health and Social Security, 1980), marital status, family size (Rogers, 1992), social support (Hibbard and Pope, 1992) and interactions among some of these variables (Smith and Waitzman, 1994). In turn, some of these socioeconomic determinants appear to be associated with lifestyle "choices" that affect health. For example, smoking has been linked to lower socioeconomic status and to many health outcomes (Nelson, 1994) and some studies have linked unemployment to alcohol consumption (Brenner, 1987; Catalano *et al.*, 1993). Socioeconomic status could also exert indirect effects that may influence individual choices about the proximity of housing to noxious facilities (Been, 1994) and may result in siting decisions for these facilities that discriminate against the poor and racial minorities (Bullard, 1990; Hamilton, 1995). More generally, people with lower "permanent" or lifetime average incomes have been observed to accept higher health risks from occupational and environmental exposures (Graham *et al.*, 1992).

Evans and Stoddart (1990) provided a convincing and comprehensive statement concerning the determinants of health perspective. In their conceptualiz-

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ation, the determinants are organized into three interrelated categories: (1) genetic endowment, (2) socioeconomic environment and (3) biophysical environment. These broad categories, in turn, condition an individual's behavioural and biological response to external stimuli. While most health experts would agree that these three broad categories influence both individual and population health, considerable disagreement exists over the relative weights to assign to each category. This disagreement magnifies at the definitional and technical levels (Bennett, 1991).

Link and Phelan (1996) refer to "fundamental social causes" to help explain why socioeconomic differences in health outcomes have persisted over time in the face of reductions to specific population risk factors, such as poor public sanitation. These fundamental causes may be measured in the form of, say, income and education levels, but they really represent more basic factors such as power, knowledge, influence and the ability to make choices in support of healthy lifestyles. This conceptualization does much to illuminate potential determinants of health; however, operationalizing predictor variables that represent these causes, without high levels of multicollinearity, remains problematic. Wilkinson (1996) asserts the most important determinant is inequality, as measured by income and by other associated resources. His work suggests that societies with high levels of inequality are most likely to have unhealthy populations. The salient point that arises from Wilkinson's work is that relative levels of disparity exert a larger influence on health than absolute deprivation. His work and the now famous Whitehall studies (Marmot *et al.*, 1995) have heightened interest in equality as a determinant of health. Others have emphasized economic insecurity as a key determinant of health (Catalano, 1991). This insecurity is usually operationalized by statistically exploring the relationship between anticipated unemployment or actual unemployment and some form of health status or behaviour known to affect health status (for example, alcohol consumption). While some equivocal results have appeared, the majority of the insecurity research, including similar studies in Canada (D'Arcy, 1986; Liaw *et al.*, 1989), suggests that both the "anticipation phase" and the actual unemployment experience show significant associations with risky behaviour and negative health outcomes (Catalano *et al.*, 1993; Ferrie *et al.*, 1995).

In addition to these socioeconomic explanations, empirical evidence now links exposure to environmental pollutants and serious health effects such as: reproductive problems (Geschwind *et al.*, 1992; Colborn *et al.*, 1993), increased cancer incidence (Wolff *et al.*, 1993; Davis *et al.*, 1994), acute cardiovascular illness (Burnett *et al.*, 1995; Schwartz and Morris, 1995), cognitive impairment (McKeown-Eyssen and Ruedy, 1983; Harada, 1995), psychosocial stigma (Eyles *et al.*, 1993; Perrolle, 1993), respiratory illness (Burnett *et al.*, 1994; Thurston *et al.*, 1994), infant mortality from pneumonia (Penna and Duchiade, 1991) and total mortality (Schwartz, 1993, 1994; Moolgavkar *et al.*, 1995). Researchers now recognize the importance of including environmental quality variables in population health research (Patrick and Wickizer, 1995).

Taken together, these empirical findings and theoretical conceptualizations emphasize the importance of a preventive approach to improving the health of human populations. We stress populations, since improvements in the broad structural determinants of health can never guarantee improvements in the health status of individuals. Even in a society with better social support and a cleaner environment, it is still likely that some individuals would choose to smoke and suffer the consequences, although on a population level, the probability of any given individual smoking might be lower. Likewise, some individuals will always be more susceptible than others to diseases and ill-health (for example, the old and the very young). They may still experience adverse health effects even if they enjoy better socioeconomic and environmental conditions. In addition, some measures used in determinants of health studies, such as the level of income inequality, refer more meaningfully to populations than individuals (Kaplan *et al.*, 1996) or they may exert an effect that differs from that at the individual level. For example, Catalano *et al.* (1993) have found that regional employment exerts a significant effect, independent of an individual's employment experience. Blaxter's (1990) work suggested healthy behaviours delivered greater health benefits in areas where social conditions were better, although Kooiker and Christiansen (1995) questioned the methods used by Blaxter. In their study they found no systematic differences in the association between health and lifestyle among different socioeconomic groups. Where the data permit, multi-level models have supplied interesting and useful findings on the relative importance of individual and population level variables (Jones and Duncan, 1995; Duncan and Jones, 1994).

Spurred by the international and national evidence, Governments in Canada have begun to accept the notion that some or all of the determinants may contribute to improved population health. Consequently, officials have begun to conjecture about how they might modify, through policy intervention, the social and environmental determinants of population health (National Department of Health and Welfare Canada, 1986; Premier's Council on Health Strategy, 1991; Premier's Council on Health, Well-being and Social Justice, 1993; Federal, Provincial and Territorial Advisory Committee on Population Health, 1994, 1996a). Yet one pressing question must be addressed: what policy initiative will achieve the largest health improvements for a given expenditure of societal resources, especially given the limited scope for improvements to population health from medical care (Evans, 1994; Mustard and Frank, 1994)? Should governments, for instance, direct policy intervention toward reducing poverty, improving environmental protection, or some combination of both? Conversely, if a government makes other policy decisions that influence the social or environmental determinants (for example, to promote economic growth at the expense of social equity and environmental protection), are there possible health consequences? This question is germane to the current health care debate in Ontario where the provincial government has severely cut funding to social and environmental programs, while promising to maintain health care funding.

As mentioned earlier, studies that attempt to incorporate variables representing the broad range of possible explanations of population health determinants are relatively rare, although recent studies have used individual level data to test the "cultural/behavioural" and "materialist/structuralist" explanations for socioeconomic inequalities in health (Stronks *et al.*, 1996). The possibility of a dual explanation incorporating both materialist and psychosocial hypotheses is now known as the "soft" approach to health inequalities research, and there is enough empirical evidence to warrant its investigation (Macintyre, 1997). With the intention of informing current policy debates and generating new empirical evidence on the importance of different population health determinants, we employ the soft approach in an ecological model of cross-sectional data from the counties of Ontario. In Section 2 we lay out our methodology in detail. We follow this with a report of the results (Section 3), a discussion of the findings (Section 4) and suggestions for future research (Section 5).

METHODS AND DATA

This study used ecologic data from the 49 census divisions of Ontario, which represent the political regions, counties, and districts of the Province. (For convenience, these census divisions are called "counties".) See Fig. 1 for a map of the study area. Given the ecologic data on which we base our study, our ability to make firm recommendations for policy remains limited. Nevertheless, findings from ecologic studies are still useful for generating hypotheses for future research. Even scholars critical of this method recognize its potential for this use (Piantadosi, 1994). The nearly complete coverage of the population in the study area is another advantage of the ecologic method in the context of population health research (Cohen, 1994). For policy research on *population* health, we assert that the problem of the ecological fallacy is less important than in research focused on assessing the influence of potential health determinants specific subpopulations or individuals. Inferring potentially biased estimates from a population on to individuals within that population is never attempted, although we recognize the utility of balancing ecologic research with multi-level and individual studies that do differentiate among potentially affected subpopulations.

The modifiable areal unit problem presents a more serious challenge for population health research than the ecological fallacy. This problem can occur in any study using aggregate variables because of the size and shape of the spatial units of analysis (Cliff and Ord, 1981; Norcliffe, 1982). Analysis of different units of observation, such as the city or census tract level, could significantly change the results. We regard our study as a first step in understanding the relative importance of determinants of health in Ontario with a specific method (ecologic) and specific spatial unit (census division).

Data for the response variable, mortality in age groups 0–64, range from 1979 to 1988. The models are run with standardized mortality ratios for all causes, respiratory and neoplasms. The data for the predictor variables are from 1991. Although the data come from slightly different times, most of the processes being measured have reasonable stability over this period. While two-stage least squares or some other system of simultaneous equations is the preferred method of estimating models containing income, poverty and medical variables due to the possibility of endogeneity, past studies have shown this method suffers from serious problems when applied to cross-sectional data and a relatively small sample (see, for example, Silver, 1973). We were also prevented from using two-stage estimation by a lack of good instrumental variables to proxy for those variables most likely to be endogenous (that is, supply of doctors and incidence of low income). With these data limitations, we relied on ordinary least squares regression to fit the models. We lay the model out formally below, after which we give detailed rationales for and derivations of the variables.

$$\begin{aligned}\ln Y_{di} = {} & b_o(x_{1i} - \bar{X}_{1i}) + b_2(\ln X_{2i} - \overline{\ln X}_{3i}) \\ & + b_3(\ln X_{3i} - \overline{\ln X}_{3i}) \\ & + b_4(X_{4i}^{4} - \bar{X}_{4i}^{4}) + b_5(\ln X_{5i} - \overline{\ln X}_{5i}) \\ & + b_6(X_{6i} - \bar{X}_{6i}) + b_7(X_{7i} - \bar{X}_{7i}) \\ & + b_8(\ln X_{8i} - \overline{\ln X}_{8i}) + u_i \qquad (1)\end{aligned}$$

where, Y_{di} = standardized mortality rates for cause of death d (i.e. "all causes", neoplasm and respiratory) for ages 0–64 in the ith county; X_{1i} = prevalence of low income, as a percent of the total population over 15, in the ith county;

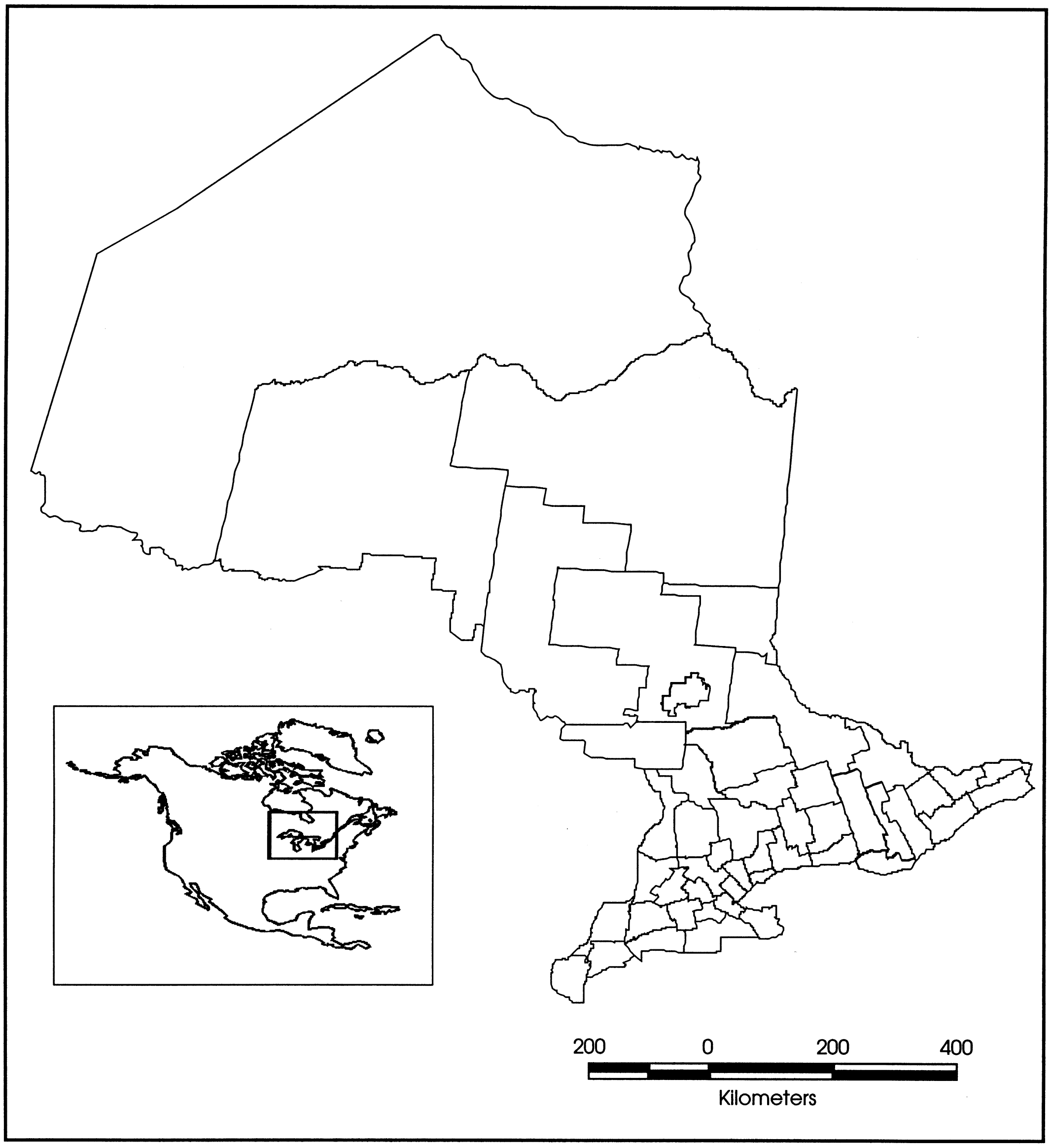

Fig. 1. Study area.

X_{2i} = educational location quotient of all persons in the ith county; X_{3i} = municipal defensive expenditures per person, in 1991 Canadian dollars, in the ith county; X_{4i} = smoking prevalence, as a percentage of total population more than 12 years of age, in the ith county; X_{5i} = primary industry employment location quotient of all persons in the ith county; X_{6i} = manufacturing employment location quotient of all persons for the ith county; X_{7i} = location quotient of general practitioners and family physicians for all persons in the ith county; X_{8i} = location quotient of First Nations population for all persons the ith county; and u_i = disturbance term in the ith county.

All variables were transformed to the closest approximation of the Gaussian or normal distribution before being entered into the regression models to improve the fit and to reduce the possibility of other statistical problems brought on by running models with skewed or kurtotic variables.

Response variables

Standardized mortality ratios (SMRs) that conform with the International Classification of Diseases (ICD) categories were used as the response variables. Mortality data were supplied by the Ontario Ministry of Health. SMRs were calculated for an earlier study (Birch and Chambers, 1993) and were supplied to us by the authors (Birch and Chambers, 1995, personal communication). The SMR data are based on a ten year sequence from 1979 to 1988 to ensure meaningful and stable results. The formula used to calculate the SMR is given below:

$$\frac{\sum_{i=0}^{64} m_i p_i}{\sum_{i=0}^{64} M_i p_i} = \frac{\sum_{i=0}^{64} d_i}{\sum_{i=0}^{64} D_i} \tag{2}$$

where, m_i = county age-specific death rate, p_i = county population in age group i, M_i = standard (provincial) age-specific death rate, d_i = actual deaths in age group i and D_i = expected deaths in age group i.

This ratio summarizes the differences between county and standard population (i.e. provincial) age-specific death rates (adapted from Palmer *et al.*, 1979). The SMRs were calculated for both males and females, with age groups in 5 year intervals ranging from 0–64, thus providing a measure of premature mortality, given the total life expectancy for a person born in Ontario in 1991 is 77.7 years (Federal, Provincial and Territorial Advisory Committee on Population Health, 1996b). Gender-based measures were used to control for both potential biological and social distinctions between males and females, which often provide important clues about the determinants of health (Walsh *et al.*, 1995).

Predictor variables

All predictor variables underwent a deviation from the mean or "centering" transformation to overcome the problem of multicollinearity with the constant term [see Montgomery and Peck (1982) for discussion of this transformation technique]. The variables are described in different levels of detail. Variables that regularly appear in other studies receive only a brief description, while those developed specifically for this study receive a more detailed treatment.

In selecting our variables, we attempted to use those that could test some of the leading hypotheses about the determinants of health. Evans and Stoddart (1990) supplied our broad organizing framework, thus indicating the need to operationalize variables representing the socioeconomic environment, biophysical environment and genetic endowment. Within this broader framework, we have attempted to select variables that might proxy for the fundamental social causes (Link and Phelan, 1996), for inequality (Marmot *et al.*, 1995; Wilkinson, 1996), for economic insecurity (Catalano, 1991) and for environmental quality (Patrick and Wickizer, 1995). We have also incorporated variables to control for county differences in lifestyle, medical care and First Nations or aboriginal populations. The cross-sectional nature of the data make it impossible to test important temporally-oriented hypotheses, such as the stages of life emphasized by Macintyre (1994). Most data for the predictor variables were extracted from the Profile 2B File of the 1991 Census of Canada.

Socioeconomic variables: Low income, education and employment structures

Prevalence of low income provides a general indicator of poverty levels within the population. Statistics Canada defines a low income person as one who spends 20% more on food and shelter as a proportion of total income than the amount spent by the average person in the population. For example, if the average individual spends 37% of their total income on basic necessities such as food and shelter, then a person would be classified as "low income" if they spend 37 + 20% or 57% of their income on these necessities. In other words, *relative* to the mean reference category, people in the low income category are materially deprived. The low income cutoffs are also adjusted for the size of settlement to account for differences in the cost of living (Statistics Canada, 1992). The formation of the low income variable makes it a measure of *relative* deprivation, hence making it useful for testing the inequality hypothesis. If previous findings on income inequality hold (for example Wilkinson, 1996), we expect this variable to relate positively to the mortality variables.

Educational levels are represented by an education location quotient defined elsewhere (Jerrett *et al.*, 1997) as follows:

$$\mathrm{EdLQ}_i^{\mathrm{c}} = \frac{\left(\sum_{i=13}^{I} \mathrm{Ed}_i^{\mathrm{c}} | \sum_{i=0}^{I} \mathrm{Ed}_i^{\mathrm{c}}\right)}{\left(\sum_{i=13}^{I} \mathrm{Ed}_i^{\mathrm{p}} | \sum_{i=0}^{I} \mathrm{Ed}_i^{\mathrm{p}}\right)} \tag{3}$$

where, $\mathrm{EdLQ}_i^{\mathrm{c}}$ = educational location quotient of a county, $\mathrm{Ed}_i^{\mathrm{c}}$ = persons with grade level i in the county, $\mathrm{Ed}_i^{\mathrm{p}}$ = persons with grade level i in the province and I = total number of educational grades.

We have used grade 13 or higher as the cutoff indicating higher education. Grade 13 was chosen because it represents the preparation year for attendance at university. Using grade 13 also has the desirable effect of capturing all students enrolled in community college programs and other post-secondary institutions. Values greater than one indicate a county has a higher proportion of persons with grade 13 or higher than in the entire province. Values below one indicate the opposite. We view education as a gateway to other fundamental social resources such as knowledge, power, and influence. Following the Link and Phelan (1996) "fundamental social causes" hypothesis, we expect this variable to relate negatively to mortality.

Similar to the educational variable, we used location quotients to derive the employment variables. The general formula used to derive the location quotients is given as follows:

$$\mathrm{EmLQ}_i^{\mathrm{c}} = \frac{\left(E_i^{\mathrm{c}} | \sum_{i=1}^{I} E_i^{\mathrm{c}}\right)}{\left(E_i^{\mathrm{p}} | \sum_{i=1}^{I} E_i^{\mathrm{p}}\right)} \quad (4)$$

where, $\mathrm{EmLQ}_i^{\mathrm{c}}$ = employment location quotient of a county for sector I, E_i^{p} = number of persons employed in sector I in the entire province, E_i^{c} = number of persons employed in sector I in a county and I = number of sectors.

Similar to the educational location quotients, values greater than one indicate the county has a proportion of employment in that sector which exceeds the proportion of employment in the same sector for the province. Values below 1 indicate the converse (Filion, 1991).

For the manufacturing employment location quotient, we used the 1991 census category, "manufacturing", to represent this sector. This variable is included as a general indicator of relatively stable, well-paid employment. Using this formulation, it is expected that the variable will relate negatively to the mortality variables.

For the primary industry quotient, we summed employment in the categories "logging" and "mining" to represent the primary sector. Primary industry employment serves as a general indicator of unstable and dangerous work. The boom-bust cycle of resource development in Canada has long been associated with socially damaging behaviour and economic insecurity (Nelles, 1974). As well, Marshall (1996) has shown that the mining and logging industries have the second and third highest fatality rate of any sector, led only by fishing and trapping. (Fishing and trapping were excluded because these sectors account for extremely low proportions of total employment in Ontario.) The hazard of occupational injury potentially adds to the level of insecurity associated with working in this sector. Building on the economic insecurity hypothesis (Catalano, 1991), we expect employment in primary industry to display a positive association with the mortality variables. Our formulation here differs from that of other researchers in that we are attempting to compare the relative insecurity present in different employment sectors as opposed to testing a hypotheses based on unemployment (see, for example, Catalano, 1991; Catalano *et al.*, 1993; Dooley *et al.*, 1996; Ferrie *et al.*, 1995). By so doing, we hope to extend current knowledge and add support to the economic insecurity argument.

Biophysical environment: Defensive expenditures

Ideally, we would like to represent the biophysical environment with a multi-criteria ranking of key aspects of environmental quality of the kind suggested by Maclaren (1996). Such data, however, are currently unavailable at the county level in Ontario. Some municipalities have developed their own state of the environment reports (for example, Metro Toronto and Waterloo). But most jurisdictions have not developed comprehensive measures. Jerrett *et al.* (1997) have aggregated data on gross pollution emissions per county, using Environment Canada's National Pollutant Release Inventory (Environment Canada, 1995). The aggregate nature of the pollution variable and our inability to control for potential exposures due to differences in meteorological conditions and social-spatial patterns led to concerns about validity of the pollution measure. We tested the pollution variable for exploratory purposes in initial screening analyses for the regression models, but no significant associations were found. This negative finding and our concerns about the validity of the variable led to its exclusion from the final model.

The human response to environmental degradation in the form of defensive expenditures may influence population health if these expenditures are seen to affect the supply of environmental services valued and needed by humans (Hueting and Bosch, 1991). Therefore, defensive expenditures made in a county could proxy environmental conditions. For the purpose of this analysis, defensive expenditures are defined as the actual environmental protection costs of preventing or neutralizing a decrease in environmental quality thought to be caused by human activities and the actual expenditures needed to compensate for or repair the negative impacts that human activities are thought to have exerted on the environment [adapted from UN (1993)]. A broad categorization of these impacts includes those that adversely affect resources supply, waste assimilation and spiritual and recreational fulfilment (Pearce and Turner, 1990).

From a detailed environmental content analysis of functional accounting categories used in the Ontario Municipal Financial Information Database (OMMA, 1993), it is possible to formalize a defensive expenditures account. Most of the expenditures included in this accounting definition conform with those suggested by the UN (1993, 1994) for defensive expenditures and for environmental protection expenditures. Defining defensive expenditures nevertheless entails value judgements about what to include or exclude. The percentages for inclusion were derived from an extended analysis (Jerrett, 1996), which is summarized in Appendix A. We applied the accounting from Appendix A to the operating and capital expenditures of all 832 lower and upper tier municipalities for the 1991 budget year to derive 49 county estimates as follows:

$$\mathrm{DETot}_i = \frac{\sum \mathrm{DECap}_i + \sum \mathrm{DEOp}_i}{N_i} \quad (5)$$

where, DETot_i = per capita defensive expenditures in county i, DECap_i = total capital expenditure on defensive programs in county i, DEOp_i = total operating expenditure on defensive programs in county i and N_i = total population in county i.

Data on provincial and federal expenditures are not available on a county scale, so we are unable to include these in the statistical model. Given the role of these expenditures in maintaining environmental quality and in protecting public health through the provision of sanitation and related services, we expect these expenditures to display a negative relationship with mortality. Although some components of this variable may appear to have only ephemeral links to population health, we view all components as contributors to broadly based environmental quality and hence capable of influencing health.

Control variables: First Nations, smoking and physicians

At this scale of analysis, it is difficult to operationalize a variable representing genetic endowment. Nonetheless, it still appears necessary to control for significant subpopulations that are known to experience different health outcomes. Some counties of Ontario contain high proportions of First Nations or aboriginal peoples (i.e. >20%). Many First Nations reserves have inadequate housing and public sanitation. These problems, in association with other lifestyle differences, have resulted in mortality rates for First Nations persons that are much higher than those of the general population [see Eyles *et al.* (1994) for a survey of the literature on First Nations health status and Mao *et al.* (1986) for specific data on First Nations mortality rates in Canada]. The First Nations population location quotients were derived using the following formula:

$$\mathrm{NatLQ}_i^{\mathrm{c}} = \frac{N_i^{\mathrm{nc}}/N_i^{\mathrm{c}}}{N^{\mathrm{np}}/N^{\mathrm{p}}} \tag{6}$$

where, $\mathrm{NatLQ}_i^{\mathrm{c}}$ = First Nations location quotient of all persons in a county, N_i^{nc} = number of First Nations persons in a county, N_i^{c} = total number of persons in a county, N^{np} = total number of First Nations persons in the province and N^{p} = total number of persons in the province.

The reporting of First Nations populations to the Census is not always complete; therefore, this variable might under-represent First Nations populations, especially in urban areas and on reserves that refuse to participate in the Census. Despite these problems, the variable appears to provide a rough estimate of areas with high First Nations populations. Thus, we expect it to relate positively to mortality variables.

Data on lifestyle variables were collected as part of the Ontario Health Survey (OHS) and were supplied to us at county level aggregation by the Addiction Research Foundation. The data were extracted from a survey based on a randomly selected 1990 stratified sample of 49,000 Ontarians (Ontario Ministry of Health, 1992). Due to geographic incompatibilities, in that the OHS data uses public health units as its spatial reference which are not always coterminous with counties, data were available for only 38 counties. All subsequent results for models containing the smoking variable are based on a smaller sub-sample of 38 counties (i.e. N = 38). The excluded counties appear to be evenly distributed throughout the province, both geographically and in the type of county (that is, urbanized regions, rural agrarian counties, and northern resource-based districts). For this variable, the percentages of persons who reported that they smoked regularly or occasionally are summed to obtain a smoking prevalence estimate for each county. Accordingly, this variable is expected to relate positively to the mortality indices.

Recent research suggests medical care increases both the duration and quality of life (Bunker *et al.*, 1995). While some have questioned the importance of medical care (McKeown, 1979), it still appears necessary to control for its potential effect. We have used primary care physician availability as an indicator of access to medical care. Primary care physicians were chosen because they are the "gate keepers" of the medical care system (Abelson and Hutchinson, 1994). Therefore, it can reasonably be expected that counties deficient in primary care physicians relative to the provincial standard would have reduced access to all types of medical care and increased mortality. Data on the number of family physicians and general practitioners is available on a county level of aggregation for 1992 (Clements and Johnston, 1992). Using these data, we defined a primary care physician location quotient as follows:

$$\mathrm{DocLQ}_i^{\mathrm{c}} = \frac{N_i^{\mathrm{dc}}/N_i^{\mathrm{c}}}{N^{\mathrm{dp}}N^{\mathrm{p}}} \tag{7}$$

where, $\mathrm{DocLQ}_i^{\mathrm{c}}$ = location quotient for family physicians and general practitioners of all persons in a county, N_i^{dc} = number of physicians and practitioners in a county, N_i^{c} = total number of persons in a county, N^{dp} = total number of physicians and practitioners in the province and N^{p} = total number of persons in the province.

It is expected this "doctors" variable will relate negatively to the mortality variables given the findings of recent U.S. research (Shi, 1994).

Model selection process

There were two steps in the model selection process. First, we ran a best subsets procedure on a model that included socioeconomic and environmental variables (N = 49). Second, we selected the variables that had shown statistical significance in these models and combined them with the smoking variable. We then ran a best subsets procedure with the combined set of variables (N = 38). We recognize that it would be desirable to add the smoking variable to the full array of other variables. The smaller sample size for the smoking variable, however, would not permit this. Regression requires a minimum ratio of five cases to each predictor variable (Tabachnick and Fidell, 1989). Mallow's Cp statistics, adjusted R^2, the standard error of model prediction, multicollinearity diagnostics and analysis of the residuals for conformity with the assumptions of the regression model were used to select the preferred models. Models with higher numbers of variables were tested first, since all variables had a theoretical justification for inclusion.

Other variables representing unemployment and alcohol consumption were tested in the initial regression screening. Neither of these variables showed significant associations with the mortality variables when the effect of other variables was taken into account. In addition our major interest lies in assessing relative insecurity among employment sectors as opposed to the influence of the unemployment per se because it has already been investigated by others (Catalano *et al.*, 1993; Ferrie *et al.*, 1995). The drinking variable was derived from the question that asked how often the person drank alcohol: daily, weekly, monthly, or less than monthly. Preliminary analyses of these data indicated that counties with larger immigrant populations, such as Metropolitan Toronto, had higher proportions of people who drank daily. This finding might represent cultural differences where members of some ethnic groups may consume moderate amounts of wine with meals, instead of representing those who consume excessive amounts, and this type of consumption may produce health benefits (cf. Calkins, 1987; Poikalainen *et al.*, 1996). Thus the alcohol variable lacked face validity. Given the constraints imposed by the relatively small sample size as well as the conceptual and measurement problems with these variables, both were excluded from further analysis.

RESULTS

Tables 1 and 2 summarize the zero-order Pearson product moment correlation coefficients for the female and male models, respectively. Although we are primarily interested in the regression results, the correlation coefficients supply interesting information about possible patterns of relationship among the variables.

Not surprisingly, significant correlations exist among the mortality variables. These are small enough, however, to warrant separate analyses of the three SMRs (i.e. all causes, neoplasm, respiratory). In preliminary analyses, we investigated relationships with SMR for circulatory and injuries and poisoning causes. For both females and males, the all causes SMRs relate strongly to the circulatory and the injuries and poisoning SMRs ($r > 0.84$, $p < 0.05$). These strong relationships are expected because the circulatory and injuries and poisoning SMRs are among the most important causes of death in Canada (Wilkens and Mark, 1992) and Ontario. Hence, these variables were excluded from the analysis due to redundancy with the all causes SMR.

Some predictor variables also show significant correlations with the SMR variables. For females, low income relates significantly with the all causes SMRs, education with two SMRs, defensive expenditures with none, smoking with three, primary industry with one, manufacturing with one, doctors with none and First Nations with two. All significant relationships take the expected direction. The highest significant correlations for the female all causes SMR occur with education ($r = -0.6265$), primary industry (r = 0.7122) and First Nations populations (r = 0.6822).

For males, low income relates significantly to two of the SMRs, education with three, defensive expenditures with none, smoking with two, primary industry with two, manufacturing with one, doctors with none and First Nations with two. Similar to the female results, the significant relationships take the expected direction. The highest significant corre-

Table 1. Zero-order correlations for all variables in the female models

	Y_1	Y_2	Y_3	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y_1	–	0.5145*	0.4055*	0.1861*	−0.6265*	−0.0433	0.3585*	0.7122*	−0.4069*	0.0885	0.6822*
Y_2		–	0.3875*	0.1336	−0.2611	0.0353	0.4119*	0.2456	−0.1911	0.2728	0.1964
Y_3			–	−0.0060	−0.4036*	−0.0679	0.4399*	0.2257	0.0139	−0.0304	0.3102*
X_1				–	0.0822	0.0599	0.0936	0.1709	−0.1683	0.2244	0.2468
X_2					–	−0.2751	−0.2593	−0.5605*	0.0820	0.3390*	−0.4520*
X_3						–	0.0901	0.0369	−0.1326	0.2356	0.2418
X_4							–	0.3795*	−0.1600	−0.0180	0.4959*
X_5								–	−0.4802*	−0.0755	0.7068*
X_6									–	0.4158*	−0.4751*
X_7										–	−0.0188

Variable descriptions: Y_1, SMR all causes; Y_2, SMR neoplasm; Y_3, SMR respiratory; X_1, low income; X_2, education; X_3, defensive expenditures; X_4, smoking (N = 38); X_5, primary industry; X_6, manufacturing; X_7, doctors; X_8, First Nations

N = 49 for all variables except smoking where N = 38.

*Two-tailed $p < 0.05$.

Table 2. Zero-order correlations for all variables in the male models

	Y_1	Y_2	Y_3	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y_1	–	0.6614*	0.6794*	0.2664	–0.6796*	–0.1415	0.4495*	0.6720*	–0.4458*	0.0047	0.7500*
Y_2		–	0.5208*	0.4155*	–0.3446*	–0.2283	0.4901*	0.3717*	–0.1789	–0.0321	0.4255*
Y_3			–	0.1382*	–0.6075*	–0.2640	0.2825	0.2588	–0.1966	0.0116	0.2694
X_1				–	0.0822	0.0599	0.0936	0.1709	–0.1683	0.2244	0.2468
X_2					–	0.2751	–0.2593	–0.5605*	0.0820	0.3390*	–0.4520*
X_3						–	0.0901	0.0369	–0.1326	0.2356	0.2418
X_4							–	0.3795*	–0.1600	–0.0180	0.4959*
X_5								–	–0.4802*	–0.0755	0.7068*
X_6									–	0.4158*	–0.4751*
X_7										–	–0.0188*

Variable descriptions: Y_1, SMR all causes; Y_2, SMR neoplasm; Y_3, SMR respiratory; X_1, low income; X_2, education; X_3, defensive expenditures; X_4, smoking ($N = 38$); X_5, primary industry; X_6, manufacturing; X_7, doctors; X_8, First Nations.
$N = 49$ for all variables except smoking where $N = 38$.
*Two-tailed $p < 0.05$.

lations for the male all causes SMR occur with the same variables as in the female models.

The relationships among the predictor variables are the same for the female and male models. Among the predictor variables, a strong correlation exists between primary industry and First Nations ($r = 0.7068$). This multicollinearity will make it difficult to discern the specific effects for each of the variables in the same model. Surprisingly the low income and education variables show no significant association. In other recent studies on the counties of Ontario, median household income and education showed significant positive association (Jerrett *et al.*, 1997). The insignificant result here probably arises due to the formulation of the low income variable as a measure of relative deprivation. Other European studies have found that education tends to distinguish different social classes more effectively among higher status groups than among lower status groups (Marmot *et al.*, 1995). Some counties could still have a relatively high number of individuals with less than high school education who are not classed as low income. Likewise, counties with relatively high levels of low income may simply have many individuals who are attending post secondary education institutions, which would give them both a low income and a high educational level.

Table 3 summarizes the results for the female models. The results of the male models appear in Table 4. A brief commentary on the results from the all causes models is given below to demonstrate how these are interpreted.

Female all causes SMR (determinants model: N = 49)

This model accounts for about 66% of the variation in the SMR. Four variables display a significant relationship with this SMR: education (negative), First Nations (positive), doctors (positive) and primary industry (positive). The diagnostics show that some multicollinearity is present, with a variance inflation factor (VIF) of 2.1 on the education variable, although this is still within the acceptable range. Bias, as measured by the Mallow's Cp, is low, with a value of 3 for a 4 variable model. Since most coefficients in this model are log–log, they can be interpreted as percentage changes (Gujarati, 1995). Thus, every 10% increase above the mean of the education variable is associated, on average, with a 4.9% decrease in the all causes SMR. For the primary industry and First Nations variables, every 10% increase is associated with a 0.3% increase in the SMR. Interpretation of the doctors variable is slightly different. To interpret the influence of this variable, we use the regression coefficient as the exponent of the base of the natu-

Table 3. Predictors with statistically significant regression coefficients ($p < 0.05$) and standard errors for the female models

Predictor variables/ SMRs	All causes (1)	All causes (2)	Neoplasm (1)	Neoplasm (2)	Respiratory (1)	Respiratory (2)
Intercept	0.07846 (0.01141)		0.02675 (0.01138)	0.03296 (0.01071)	0.13191 (0.04348)	0.11109 (0.04767)
Low income						
Education	–0.4907 (0.1301)			–0.3503 (0.1007)	–1.1480 (0.3796)	–0.9895 (0.4008)
Defensive expenditures						
Smoking				5.400 (2.334)		24.75 (10.35)
Primary industry	0.03294 (0.01407)		0.02675* (0.01138)			
Manufacturing						
Doctors	0.15585 (0.05782)		0.11419 (0.05324)	0.23497 (0.05433)		
First Nations	0.02869 (0.01263)					
Adj R^2	65.7%		10.8%	44.8%	14.5%	27.4%
MSE	0.00637		0.006343	0.03174	0.09265	0.08517
Cp	3		2.6	0.08	–0.2	2.7

Models labelled (1) have no control for smoking ($N = 49$). Models labelled (2) include the smoking variable ($N = 38$). Blank columns represent models with no significant variables or that were deemed inadequate based on the regression diagnostics.
*$p \leq 0.056$.

Table 4. Predictors with statistically significant regression ($p < 0.05$) coefficients in the male models

Predictor variables/ SMRs	All causes (1)	All causes (2)	Neoplasm (1)	Neoplasm (2)	Respiratory (1)	Respiratory (2)
Intercept	0.09916 (0.01234)		0.02836 (0.01256)	0.02443 (0.01165)	0.14257 (0.03769)	
Low income	0.010308 (0.004755)		0.013007 (0.004685)	0.015092 (0.004180)	0.02757* (0.01418)	
Education	−0.6329 (0.1413)				−2.4269 (0.4193)	
Defensive expenditures	−0.15954 (0.07255)		−0.19400 (0.06560)	−0.18292 (0.06276)		
Smoking				7.808 (2.780)		
Primary industry					−0.09939 (0.04405)	
Manufacturing	−0.09661 (0.04355)				−0.2796 (0.1359)	
Doctors						
First Nations	0.06558 (0.01402)		0.03599 (0.01028)	0.02497 (00.1216)		
Adj R^2	76.5%		36.0%	57.7%	43.1%	
MSE	0.00747		0.007732	0.064892	0.06959	
Cp	5.3		1.3	3.7	4	

Models labelled (1) have no control for smoking ($N = 49$). Models labelled (2) include the smoking variable ($N = 38$). Blank columns represent models with no significant variables or that were deemed inadequate based on the regression diagnostics.

ral log (i.e. $e^{b(\Delta X - \Delta \bar{X})}$). The resulting coefficient indicates that a 1 unit increase in the physicians variable is associated with an average increase of the SMR by 1.168 times any given Y. By assuming a 1 unit increase in X above its mean, this estimate can be translated into a percentage change in Y as follows: $100(e^{b(\Delta X - \Delta \bar{X})}-1) = 16.8\%$. This suggests a 1 unit increase above the mean of the physicians variable is, on average, associated with an increase in the SMR of about 16.8%. A smaller increase of 0.1 in this location quotient is associated with an increase of 1.57% in the SMR.

Male all causes SMR (determinants model: $N = 49$)

This model accounts for about 76.5% of the variation in this SMR, with five variables showing a significant relationship: low income (positive), education (negative), defensive expenditures (negative), manufacturing (negative) and First Nations (positive). Multicollinearity is moderate with the highest VIF of 2.2 occurring on the First Nations variable, and there is some indication of bias in the Cp statistic (5.3 with 5 variables). The regression coefficient indicates that every 10% increase in the First Nations variable above its mean value is associated with a 0.7% increase in the SMR. For the other log variables, the equivalent decreases are 6.3% for education and 1.6% for defensive expenditures. The low income and manufacturing variables are interpreted in the same way as the doctors variable. This interpretation suggests a 10% increase in the low income variable above its mean value is associated with a 10.36% increase in the SMR. (This variable can be interpreted as a percentage increase because the low income variable is expressed as a percentage variable.) Every 0.1 unit increase in the manufacturing location quotient is associated with a decrease of 0.92% in the SMR.

Female and male all causes SMR (secondary control model: $N = 38$)

The smoking variable did not achieve significance in either the male or female all causes models. The results for the other models can be interpreted in a similar manner, with the exception of the smoking variable. This variable is difficult to interpret because it was raised to a power of 4 to approximate a Gaussian distribution. For example, with the female respiratory model in Table 3, a one unit increase above the mean in the percentage of smokers in a population raised to the power of 4 is associated with a 10.63 unit increase in the respiratory SMR. All that can be said is that increases in smoking at the population level are, on average, associated with increases in the SMRs of interest. In lifestyle models with no results reported, the smoking variable did not add significantly to the model and therefore the entire model was excluded from the analysis.

DISCUSSION

What do the combined results of these ecologic models tell us about population health in Ontario? While our findings lack the certainty necessary for policy action, we proceed with an analysis of the findings to highlight hypotheses for future research and to conjecture about potential policy implications.

For females, education, smoking, primary industry and the supply of primary care physicians all exert consistent effects on two or more mortality variables. The coefficients on the education variable exert the largest effect. When the smoking variable achieves statistical significance, the "lifestyle" models generally account for a greater percentage of the variance in the SMRs.

For the male models, the low income variable exerts an effect in almost every model, with substantively large coefficients. In the context of regression modelling, it is possible to witness effects that are statistically significant, but where the relative change in the response variable associated with the change in the predictor variable is quite small. In such an instance, the relationship might be statistically significant, but substantively insignificant, hence the term "substantive" significance (Achen, 1982). Education, defensive expenditures, smoking, primary industry, manufacturing industry and First Nations variables exert effects in two or more of the models. As with the female models, the education variable exerts large effects, although defensive expenditures and manufacturing also have substantively large coefficients.

The proportion of explained variance is generally higher in the male than in the female models. This finding suggests a few avenues for future research. First, variables that are particularly significant determinants of female population health might be missing from the models (for example, dietary variables). Second, some of the relationships between the variables in the female models and the SMRs might be non-linear and, therefore, not amenable to linear regression modelling. Third, genetic inheritance might be a more important determinant of population health for females than for males. The gender differences in the findings, especially the lower explanatory power for the female models, suggest that future research should focus on other variables that might determine the health of female populations and on explaining gender differences in the determinants. Gender provides unique opportunities for assessing the importance of social determinants for health because it is simultaneously a biological distinction (called *sex*) and a social one (called *gender*) (Walsh *et al*., 1995).

One significant difference between the female and male findings occurs with the environmental variable. Defensive expenditures showed no relation to the female mortality indices, while showing significant and substantively large associations with the all causes and neoplasm SMRs for males. This association remained significant, even after controlling for lifestyle variables such as smoking. The policy implications of this finding is that increases in defensive expenditures could exert a negative influence on cancer and all causes mortality for males. The opposite is also possible and important in the context of current provincial reductions in environmental spending and in environmental grants to municipalities. Savings gained from cuts to environmental programs may eventually cycle through to higher expenditures on medical care. A possible explanation for the difference between the male and female coefficients is the different occupational structures. Possibly males were more likely to benefit from defensive expenditures due to higher exposures around polluted workplaces such as industrial and primary processing areas.

The most significant difference between the female and male models is with the low income variable. This variable showed no significant relationships with any of the female SMRs, while showing significant relationships with every male mortality variable. This may indicate that income is a relatively more important marker of social status for males than for females. Future research using qualitative surveys could probe this question more thoroughly.

The results suggest education exerts a large influence on many of the female and male SMRs. Whether the influence of education exerts a direct effect, or one mediated through lifestyle, environmental, economic, or health care variables, is a question that goes beyond this type of analysis. What can be said is that education is significantly and positively associated with the supply of doctors ($r = 0.339$, $p < 0.05$) (see Table 1). Other recent studies on the counties of Ontario have also shown education is significantly and positively associated with average household income ($r = 0.667$, $p < 0.05$) and dwelling value ($r = 0.724$, $p < 0.05$). In turn, dwelling value is significantly and negatively related to pollution output (Jerrett *et al*., 1997). These associations suggest that education might be capturing the effects of better medical care through the supply of doctors, better nutrition through higher income, and lower exposure to pollution through higher dwelling values. All of these material relationships may reflect position in the social hierarchy. Yet, increased education may also result in a greater knowledge about potential health threats and about how to gain access to better medical care. This knowledge could lead to "defensive" behaviours that reduce one's chance of premature mortality. In essence, it appears that education acts as a gateway to many fundamental social resources that enable populations to respond and adapt, effectively, to existing and new risk factors. Regardless of the explanation, the policy implications are clear: education is a crucial variable in understanding premature mortality and reductions in educational spending may increase health expenditures in the future or, at the very least, widen disparities between groups.

The employment variables provide some policy guidance on the determinants of health. For women, primary industry is significantly and positively associated with two SMRs, indicating that as the amount of employment in primary industry in a county increases in relation to the rest of the province, the SMRs for all causes and neoplasm will, on average, also increase. This raises the question of what variable or group of variables primary industry might represent or proxy for women. Primary industry shows a moderately strong, negative association with education and a strong positive association with the First Nations variable. It is possible that primary industry is capturing some of the influence of these other variables.

In the male respiratory model, the primary industry variable takes the opposite direction than expected because it shows a negative association with this SMR. There are four statistical possibilities when a regression coefficient takes the "wrong" sign: (1) the range of some variables is too small, (2) important variables have been excluded, (3) multicollinearity is present and (4) computational errors have occurred (Montgomery and Peck, 1982). Explanations (3) and (4) appear unlikely. Explanation (1) is always possible, but can only be tested through experimental control that cannot be applied here. Explanation (2) appears most likely, but it is uncertain which variables are missing. Future research could explore variables that potentially show a strong positive association with primary industry and a strong negative association with respiratory illness. Drawing on the economic insecurity argument, this unusual result could occur because of the context in which males who work in the primary sector find themselves. Most of the primary industry is located in remote locations with relatively high unemployment rates (Bourne and Olvet, 1995). In these places, workers in primary industries might view their economic situation as relatively stable when compared to fellow community members experiencing unemployment. The relatively large negative coefficients on manufacturing support this interpretation.

The manufacturing variable is significant for the male all causes and respiratory SMRs. In both cases, the coefficients take the expected direction. This suggests another possible determinant of health. Manufacturing generally provides a more stable base of employment than primary industry because primary industry suffers greater exposure to the vagaries of international commodity markets (Randall and Ironside, 1996). It might be that the uncertainty in terms of continued and future employment associated with primary industry or conversely the greater certainty associated with manufacturing influences health. Recent studies on urban and regional development in Canada suggest that regions based on primary industry have suffered the worst employment losses compared with regions where employment is based on the manufacturing and service sectors (Bourne and Olvet, 1995). These findings link with those of earlier British studies where level in the workplace hierarchy and relative sense of control over work were found to influence health (U.K. Department of Health and Social Security, 1980; Marmot *et al.*, 1995). It is possible that the adverse effects of lack of control in the workplace extend to employment insecurity in broader sectors of the economy. The most recent studies on longitudinal data from the British civil service have shown the "anticipation phase" prior to actual unemployment probably exerts an adverse effect on health (Ferrie *et al.*, 1995). Extending this reasoning would infer those populations who live in areas dominated by primary sector employment suffer from prolonged anticipation phase effects, while populations in manufacturing areas experience a relatively high sense of security.

The positive regression coefficient on the supply of doctors variable in some of the female models suggests a possible specification error in the direction of causality. It seems unlikely that a greater supply of physicians relative to the rest of the province would cause greater mortality. Instead, the opposite is probably the case. This may indicate the presence of an endogenous relationship, which would suggest that future research may have to use larger samples to allow for some form of simultaneous or structural estimation.

The reason for the gender difference may be explained by earlier research that suggests women are more likely to utilize physicians services than men, although many of their visits may be for other family members (Verbrugge, 1985). Interestingly the results run counter to those of a recent study in the U.S. (Shi, 1994) that used state level data. Shi (1994) found primary care negatively related to health indicator variables. Although many possible reasons exist for the difference in the findings of the two analyses, this is most likely a good example of the modifiable areal unit problem where the size of the unit of analysis has influenced the outcome and this difference accentuates the importance of conducting many studies at different scales before making firm conclusions about the determinants of population health.

The First Nations variable achieved significance in the all causes female model and in the all causes and neoplasm male models. The coefficients are substantively small, but the large number of significant relationships supports the view that First Nations populations continue to experience higher mortality than the standard provincial population. Tables 1 and 2 show some possible reasons for these relationships. Counties with higher First Nations populations were significantly and negatively associated with the level of manufacturing employment and education levels. Both were found to exert a positive influence on health in the regression models. Conversely, First Nations populations were significantly and positively related to smoking and primary industry. All of these variables were found to relate positively to mortality in the regression models. Measures to improve living conditions for First Nations peoples by diversifying their economy, improving their access to education and improving anti-smoking programs may supply significant benefits to population health in northern counties.

Smoking prevalence exerted a significant effect in the female and male models. It is associated with neoplasm and respiratory illness for females. For males it is associated with neoplasms. The findings emphasize the need to control for lifestyle variables in population and community health research (Patrick and Wickizer, 1995).

By mapping the all causes SMRs for females and males, we can gain another clue about the patterns in the data. These maps are presented in Fig. 2. From the maps, it becomes apparent that many of

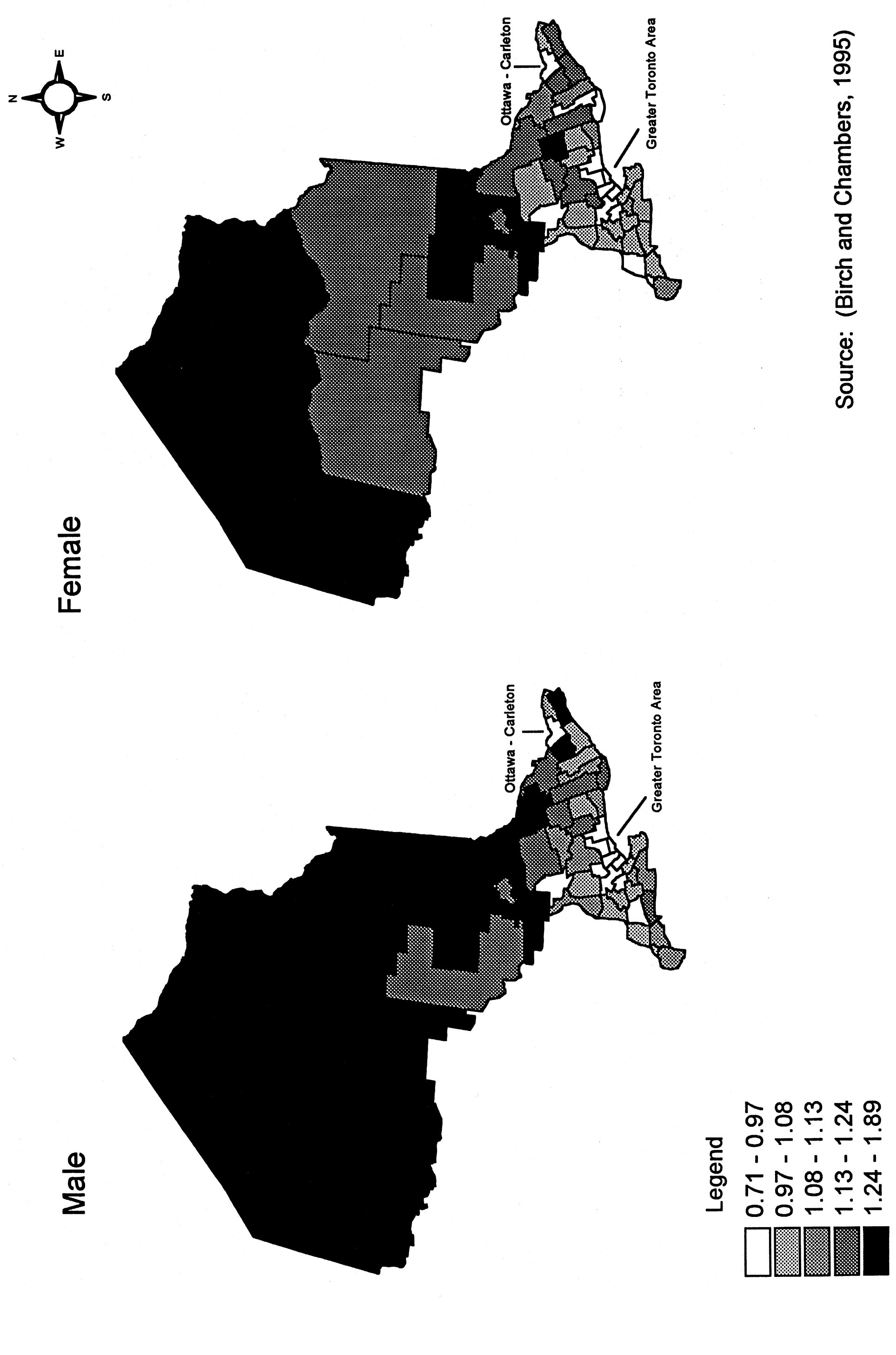

Fig. 2. Comparison of SMR all causes for males and females.

the lowest SMRs are in the highly urbanized regions with diversified economies. These areas also tend to have higher educational levels, lower levels of primary industry and higher levels of manufacturing (Jerrett *et al.*, 1997). The broad process of urbanization, therefore, appears associated with population level reductions in economic insecurity. It also appears that many of the fundamental social resources mentioned above are in relatively greater abundance in urban areas.

In Ontario, the debate over health care funding and possible cutbacks now focuses on maintaining funding to the health budget and on where to allocate funds within that budget. The broader question of whether cuts to other programs such as social security and environmental protection will result in larger health consequences than cuts to the health budget remains outside the current health care reform debate. Yet our findings discussed above suggest these broader socioeconomic and environmental variables affect population health. Neglect of such evidence makes the debate over health care reform incomplete. Considerable empirical research is needed before policy action targets specific variables for intervention. Marmot *et al.* (1995) warn against the temptation of concluding that one variable is more important than another because the perceived importance may simply reflect the accuracy of measurement of one variable over another.

CONCLUSION

In this paper, we have used ecologic data from the 49 counties of Ontario to explore the relative importance of socioeconomic and environmental determinants of population health. Our statistical models used standardized mortality ratios for ages 0–64 as the response variable and a wide array of predictor variables representing the socioeconomic, environmental, lifestyle and medical care determinants of health. One model achieved high predictive power (i.e. Adj $R^2 > 75\%$, $p < 0.0001$). Education levels were a strong predictor of health, showing a consistent and large inverse relationship with many standardized mortality ratios for both sexes. A low income variable was the strongest predictor of mortality for males. This variable displayed a positive association with many male mortality variables. Municipal expenditures on environmental protection exerted a negative effect on male mortality. These and other findings suggest that substantial differences exist between the male and female determinants of health. Taken together, our findings raise questions about the current directions of health policy in Ontario where the provincial government has cut funding to social and environmental programs, while promising to maintain health care funding. They also point to the salience of studies from other jurisdictions that emphasize the importance of place in the social hierarchy and economic security as key in understanding health inequalities. The combined effect of socioeconomic, environmental, lifestyle and medical care variables suggests a need for caution in policy change, recognizing that a policy directed at one determinant will likely affect others and hence relate to population health in unanticipated ways. It thus becomes vital to consider the full range of determinants in relation to one another.

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APPENDIX A

Rationale For The Defensive Expenditures Account

The defensive expenditures account is derived as follows:

$$DE \equiv GG + PP + TS + ES + HS + RD + PD \qquad (A1)$$

where, DE = defensive expenditures in 1991 Canadian dollars; GG = general government (total expenditures*0.175); PP = protection of persons and property (conservation authority expenditures + other flood control measures + fire protection expenditure + protective inspection expenditures); TS = transportation services (costs of all capital expenditures*0.02 environmental assessment and approval cost); ES = environmental services (total expenditures); HS = health and social services (total health expenditures*0.333); RD = recreation and cultural services (total parks and recreation expenditures*0.74) and PD = planning and development (total planning expenditures).

Estimates for the government services accounting category were based on the proportion of total expenditures accounted for by the environmental services account (17.5%). The environmental services category represents a minimum proxy for defensive expenditures. It was then assumed that the percentage of government services taken up by the environmental services category would be proportional to the percentage of total expenditures absorbed by environmental services. Thus, assuming environmental services supplies a minimum proxy for defensive expenditures, then the percent of government services accounted for by defensive expenditures is estimated to be approximately 17.5%. To derive the environmental assessment cost used to estimate the defensive expenditures in the transportation services category (i.e. 2%), interviews were conducted with officials from the Environmental Assessment Branch, Ontario Ministry of Energy and Environment and previous cost surveys were consulted. The 2% figure is an average cost estimate that may not hold for all projects. For the health and social services category, interviews of environmental health experts were conducted to determine the best estimate of the proportion of health costs attributable to environmental damage. A literature review was also completed. It became evident from the interviews and literature that there was broad agreement that three macro determinants of health existed: socioeconomic environment, biophysical environment and genetic endowment (see Evans and Stoddart, 1990). In spite of this broad agreement, little agreement existed on the relative importance of each macro determinant (cf. Bennett, 1991). To overcome this problem, it was assumed that each of the three categories was equally important, thus environmental degradation would account for 33.3% of the total health expenditures. (It is worth noting that this rather speculative estimate exerts little practical effect on the value of this variable since health expenditures account for less than 1% of total defensive expenditures in most places.) Expenditures from the parks and recreation category were included because parks compensate for the loss of natural areas associated with urbanization and industrialization. Parks expenditures were estimated based on a detailed audit of the expenditures of the City of York, Ontario. The results of this audit showed parks and related services accounted for about 74% of the expenditures in the Parks and Recreation accounting category. This estimate was then assumed to represent, roughly, the proportion of this category that would be absorbed by parks for all municipalities, although this will probably result in some measurement errors in municipalities that do not share similar land use and demographic characteristics.