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The Economics of Obesity:
Research and Policy Implications from a Canada-U.S. Comparison

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1. Introduction

Why do obesity rates differ across the United States and Canada, for which groups do they differ, and what do these differences suggest for policy and for research? In this paper, we use cross-sectional data on middle aged adults in the two countries to answer these questions. We are motivated by the public health challenge stemming from obesity, which has been well-documented. The health risks associated with obesity include premature death, type 2 diabetes, heart disease, stroke, hypertension, gallbladder disease, osteoarthritis, sleep apnea, asthma, breathing problems, cancer, high blood cholesterol, complications of pregnancy, menstrual irregularities, hirsutism, stress, incontinence, and depression (Bray *et al*. 1998; USDHHS 2001).

Data from the 2004 Canadian Community Health Survey (CCHS) indicate an obesity[1] rate for Canada of 23.1% and an overweight[2] rate of 59.1%. U.S. data from the National Health and Nutrition Examination Survey (NHANES) 1999-2002 show that 65.1% of the American adult population is overweight and 30.4% are obese (Hedley *et al*. 2004). The problem of obesity does not affect all populations equally, particularly in the U.S. The obesity rate in the U.S. is higher for women at 33.2% compared to the rate for men (27.6%). By race, these gender differences are exacerbated. For example, the obesity rate among non-Hispanic white women is 30.7% compared to a rate of 49% among non-Hispanic black American women, whereas obesity rates across race for men do not differ significantly (Hedley *et al*. 2004). In Canada, obesity rates do not vary substantially by sex (23.2% for women and 22.9% for men). However, obesity rates are higher for white women (24.8%) and white men (25.5%) compared to their non-white counterparts (Tjepkema 2005).

Obesity rates in both countries differ by income and education levels. Unconditionally on other covariates, rates are generally reported to fall as either income or education rises (Flegal *et al*. 2002; Paeratakul *et al*. 2002; Tjepkema 2005). In both countries, obesity falls for both men and women as education increases. However, for income, differences exist by gender across countries. In the U.S., among women generally obesity rates fall as income increases; however, obesity rates by income are relatively flat for white men and show a slight monotonic positive gradient among non-white men (Chang and Lauderdale, 2005). In Canada, middle-income women are found to have higher obesity rates compared to their counterparts in high-income households, while obesity among Canadian men is found to increase slightly with income (Tjepkema 2005).

Obesity rates have increased over the last two decades to epidemic proportions in both countries. Based on the current figures noted above obesity rates have doubled in the U.S. from 15% in 1976-80 and have quadrupled in Canada from the 5.6% rate in 1985 (Flegal *et al*. 2002; Katzmarzyk 2002a, b). Despite the higher rate of increase in Canada, there remains a significant gap in prevalence rates across the two countries. This study undertakes an empirical examination of the determinants of Body Mass Index (BMI) drawing on national samples of adults aged 35-45 in Canada and the U.S. to uncover cross-country differences. We assess the extent to which we can explain the cross-country BMI gap in terms of socioeconomic and demographic variables by implementing switching regressions. The results show that if the measured population

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[1] Obesity is defined as Body Mass Index (BMI) greater than or equal to 30, where BMI is calculated as weight in kilograms divided by height in meters squared.
[2] Overweight is defined as BMI greater than or equal to 25.

characteristics were the same in Canada as they are in the U.S., the gap would only fall by about one third for women and would change trivially for men. Further, the one third portion of the gap that can be explained is not attributable to differences in income, education, or household composition but rather by differences in racial composition.

As we find that differences in income, education, living arrangements, or race explain little of the "obesity gap" between Canada and the United States, we address the importance of contextual factors on obesity and pose the question as to whether such factors may help to explain the gap. Obesity is the result of a number of biological, behavioral, cultural, social, environmental and economic factors and complex interactions between these variables that promote a positive energy balance. Among the many different complex and diverse factors that could contribute to a positive energy balance, diet and physical activity are important modifiable ones. Social, environmental, and economic factors affect obesity through their influence on individuals' decisions and behaviors. External economic contextual factors such as food prices, restaurant outlet density, supermarket availability and access to physical activity-related facilities may play an important role in influencing people's lifestyles and risks for developing obesity, and may explain some of the gap across countries. Given that data limitations preclude the determination of the extent to which contextual factors may contribute to the cross-country weight gap, we present empirical evidence for our U.S. sample on the potential importance of contextual factors and discuss related policy implications.

2. Contextual Factors and Obesity

Much of the recent obesity research in the U.S. has sought to determine the importance of contextual factors as determinants of BMI and obesity. In particular, in the economics literature, recent research has begun to relate BMI and obesity outcomes to food prices and access to restaurants. Lakdawalla and Philipson (2002) argue on the basis of both theory and evidence from microdata that the obesity epidemic in the U.S. is a result of two simple changes in incentives: the relative price of consuming a calorie has fallen over time while the opportunity cost of burning a calorie has risen over time. Other econometric studies focusing on incentives as determinants of body weight include Chou *et al*. (2004), who use data from the 1984-1999 Behavioral Risk Factor Surveillance System to show that the increases in the per capita number of restaurants, lower real food prices, and higher cigarette prices significantly contributed to the upward trend in obesity with the largest effect stemming from greater restaurant availability. Sturm and Datar (2005) analyzed weight changes in children in kindergarten through the third grade and find that lower fruit and vegetable prices, but not generally prices of other food items or outlet density, predicted smaller increases in body weight. Examining the importance of food prices and restaurant outlet density on BMI, obesity, and the consumption of fruit and vegetables among adolescents using the Monitoring the Future Surveys from 1997-2003, Powell *et al*. (2005) find that changes in prices and restaurant densities change outcomes in the manner predicted by the standard economic model. Fruit and vegetable consumption is lower when fruit and vegetable prices are higher, or when the price of fast food is lower, or when full service restaurants (versus fast food restaurants) are less readily available. Further, BMI is lower when fast food is more expensive. However, this study found that changes in all observed economic and sociodemographic characteristics together only explain roughly one-quarter of the change in mean BMI and one-fifth of the change in overweight over the 1997-2003 sampling period.

In addition to the focus on food prices and restaurant outlet density, the public health and economics literature has also examined potential barriers to obtaining a variety of healthful foods due to a lack of local area supermarkets. It is hypothesized that lower levels of access are likely to adversely affect dietary patterns and contribute to the risk of obesity. Larger sized food stores such as supermarkets, particularly chain supermarkets, have been shown to be more likely to stock healthful foods (Sallis *et al*.1986; Horowitz *et al*. 2004) and to offer foods at a lower cost (Mantovani et al. 1997; Chung and Myers 1999). In turn, food costs are found to be associated with diet quality (French *et al*. 2001; Drewnowski and Specter 2004) and studies reveal significant correlations between diet quality and the availability of healthful foods in stores (Cheadle *et al*.1991; Fisher and Strogatz, 1999). Examining supermarket availability directly, adult fruit and vegetable consumption was found to increase with each additional supermarket in a census track (Morland *et al*. 2002). Another recent study found increased proximity to supermarkets to be associated with higher quality diets (Laraia *et al*. 2004).

This emerging literature suggests that there are significant associations between contextual local area economic factors and BMI/obesity controlling for individual level sociodemographics. However, there is no consensus on the extent to which these factors can explain the dramatic increases in obesity witnessed across the US population over the last few decades. Further, this body of research has not yet assessed the extent to which different subpopulations are differentially impacted by these various factors.

3. Empirical Examination of Obesity in Canada and the U.S.

In this section, we exploit large individual-level survey datasets to compare and contrast the determinants of BMI in the U.S. and Canada. Our goals are, first, to determine if differences in sociodemographic characteristics explain higher mean BMI in the U.S. Second, we determine if there are substantive differences in predictors of body weight in the two countries. Third, we wish to determine whether the gap in BMI across the two countries occurs primarily in certain subpopulations. Finally, we draw on our U.S. sample to examine the importance of contextual factors such as food prices and supermarket availability on BMI.

3.1. Data

Canadian Survey Data

The Canadian data used in the study are drawn from the 2000-2001 Canadian Community Health Survey (CCHS). The CCHS is a cross-sectional survey conducted by Statistics Canada with the goal of collecting information on Canadians' health and health care utilization. To make the Canadian sample comparable to the U.S. sample, we restricted attention to respondents aged 35 to 44. We also removed respondents who had immigrated in the last 10 years, as the U.S. sample contains no recent immigrants. After also removing observations with missing education or weight and height data, our CCHS sample consists of observations on 20,545 Canadian adults.

U.S. Survey Data

For our American sample, we draw on the National Longitudinal Survey of Youth (NLSY79) which began in 1979 with a cohort of 12,686 people aged 14 to 22. For comparison to the 2001/02 Canadian data we draw on the 2002 NLSY79 cross-section. This cross-section contains 7446 observations on adults aged 37 to 45 with non-missing data.

Variable Definitions:
In order to derive comparable variables definitions that match the Canadian sample several U.S. variables available with data in a continuous format (such as age and income) were categorized according to the variable specifications in the Canadian data. Also, the U.S. race categories were collapsed to match the Canadian specification. The Canadian data were sub-sampled to include two age categories (age 35 to 39 and age 40 to 44) that best match the 37-45 age range of the U.S. sample. The following paragraphs detail the variables used in our analyses. Summary statistics for the Canadian and U.S. samples are presented in Table 1.

BMI/obesity: In our analyses, self-reported height and weight variables are used to generate two alternative anthropometric measures: BMI and obesity. BMI is the primary outcome variable in our study and is defined as: BMI (=weight(kg)/height(m)^2). Individuals' body weight is classified based on BMI where for adults age 20 and over obesity is defined as BMI>=30. It should be noted that height in the Canadian data was top-coded at 6'2" (for comparable purposes we altered the U.S. height variable in the same manner).[3]

Basic Demographics: This study controls for basic demographic measures available in both surveys that include the following variables: gender (indicator for male); race (indicator for white); age (indicator for age 40-45, default -- age 35-39); country of birth (indicator for foreign born); and living arrangements (indicators for living alone, living with partner/spouse and no child, living with partner/spouse and at least one child (default), single parent, and other living arrangement).

Income and Education: Income categories are defined in current Canadian dollars as per the CCHS data set which includes indicators for less than $15,000 (default), between $15,000 and $30,000, between $30,000 and $50,000, between $50,000 and $80,000, and above $80,000. The continuous U.S. income data are converted to Canadian dollars using purchasing power parity (PPP) obtained from Statistics Canada (PPP=1.19, 2001). Education categories also are defined as per the four Canadian education categories of high school drop out (default), high school graduate, some college, and college graduate and above. The U.S. years of education data are classified into these categories based on less than twelve years of education, twelve years of education, thirteen to fifteen years of education, and sixteen or more years of education, respectively.

3.2. Summary Statistics
The differences in the distribution of BMI across countries and across men and women are illustrated by Figure 1. The figure shows kernel density estimates of BMI stratified by sex and by country. For both sexes, the distribution of body weight in the U.S. stochastically dominates that in Canada. For men, the difference is reasonably well approximated by a level shift, although BMI is somewhat more dispersed in the U.S. than it is in Canada. Conversely, for women, the distribution in the U.S. is more right-skewed in addition to being shifted out.

Table 2 presents mean BMI stratified by sex, education, income and country. Without controlling for any other covariates, we see from this table that among our national samples of

[3] We re-ran several of the key models discussed in the following section for the U.S. data without the height censoring to verify that the censoring has little effect on the estimates.

adults aged 35-45, BMI is falling as education levels rise for women in both countries but does not differ significantly across education categories for men in either country. BMI among males in both countries is higher as income levels rise above the middle income categories (though not significantly different in the top income category for US men) while BMI among women falls in the higher income categories. Minority male and female populations in the U.S. have significantly higher BMI than their white counterparts though the difference is much larger among women. BMI among Canadian women does not differ significantly by race, whereas Canadian minority men have slightly lower BMI compared to white Canadian men.

3.3. Econometric Methods

We begin with models of the form,

$$BMI_t = X_t\beta + \delta D_t + \mu_t \qquad (1)$$

where BMI_t denotes respondent t's body mass index, X_t is a vector of covariates including measures of household income, education levels, household structure, and race, D_t indicates that the respondent is from the U.S. sample, β is a vector of parameters to be estimated, and μ_t is a disturbance term. In these models the parameter δ measures the increase in mean BMI in the U.S. which cannot be attributed to differences in X_t. We present estimates of several models varying the controls in X_t. We use ordinary least squares regression and adjust the covariance matrix for both clustering at the State or Province level and heteroskedasticity of arbitrary form. In all models, we stratify by sex because we anticipate the body weight differences across men and women will not be well-captured by a simple level shift.

We continue by relaxing the implicit assumptions in equation (1) that the relationship between the covariates X_t and BMI are the same in the U.S. and Canada and that the weight gap does not itself vary with X_t, that is, that δ is constant across observations. We estimate switching regressions of the form,

$$BMI_{0t} = X_t\beta_0 + \mu_{0t} \qquad (2)$$

$$BMI_{1t} = X_t\beta_1 + \mu_{1t} \qquad (3)$$

where a subscript 0 denotes Canada and 1 denotes the U.S. The parameters β_0 are estimated by OLS using the U.S. sample and similarly for β_1. Here, the difference between a given individual's weight in the U.S. and Canada is ($BMI_{1t} - BMI_{0t}$). However, only one of the two outcomes is observed for a given individual; the other is counterfactual and predicted from the estimated model:

$$E[BMI_{1t} - BMI_{0t} \mid X_t] = X_t(\hat{\beta}_1 - \hat{\beta}_0) = \hat{\delta}_t, \qquad (4)$$

where we assume the error terms are independent of the covariates. Instead of a constant effect across individuals, this model generates estimates of weight gaps unattributable to other covariates which themselves vary arbitrarily with the covariates. For example, it may be the case that for a given set of covariates X_t the estimated gap $\hat{\delta}_t$ is zero, which means that for an individual with characteristics X_t we would expect BMI to be the same regardless of whether individual t lives in Canada or the U.S. Another individual may have $\hat{\delta}_t = 2$, which means that for that individual BMI would be on average two units higher in the U.S. than Canada. We estimate the population (by sex) average weight gap by integrating over the distribution of X_t,

$$\int E[BMI_{1t} - BMI_{0t} \mid X]\, dF(X) \qquad (5)$$

where $F(X)$ is the distribution function of X. The empirical analog of this expression is simply the arithmetic average of $\hat{\delta}_t$. We also provide estimates of the mean of the average weight gap within various subpopulations, which are estimated simply as the mean of $\hat{\delta}_t$ within those subpopulations. Finally, we present estimates of the partial effects of the covariates on the weight gap,

$$\frac{\partial \delta_t}{\partial X_{it}} = \beta_{1i} - \beta_{0i} \qquad (6)$$

which measures the effect on the weight gap of a marginal change in one of the covariates, other things equal. For example, if the above expression evaluates to -1.5 for the element representing the white dummy, the model predicts that the *weight gap* is 1.5 BMI units lower for white respondents than for non-white respondents. Note that these methods are equivalent to considering living in the U.S. as a “treatment” and estimating various treatment effect models, for example, equation (5) defines the unconditional average treatment effect. See Wooldridge (2001) for an exposition on these methods.

3.4. Estimation Results

Tables 3 and 4 present estimates of pooled OLS models (equation 1) for men and women, respectively, varying the set of included control variables. Consider the estimates for men first. Model 1 in Table 3 shows that the average U.S. man is heavier by 1.7 BMI units than the average Canadian man. The subsequent models add covariates to assess whether this difference can be attributed to differences in education, income, race, or living arrangements across the two countries.

Model 2 adds the white indicator and the results demonstrate that differences in race explain a very small portion of the Canada-U.S. gap for men. In model 3, we condition on income: the income-BMI gradient is itself statistically and economically significant -- moving from the lowest to highest income grouping is associated with an increase in BMI of about one unit (t=5.7) -- but differences in income explain almost none of the gap across countries. Put another way, mean height-adjusted body weight is higher at higher income levels for men, but it is not the case that much of the difference in weight between Canadian and American men is due to differences in incomes across the two countries. In model 4, we condition on education instead of income and observe that there is a very small education gradient with weight. Only college educated men are statistically significantly lower in weight than high school dropouts, and only by 0.18 BMI units (t=2.16). However, when controlling for both education and income (Model 5), we see a larger gradients for both education and income. The association between college graduation and lower weight increases in magnitude to about half a BMI unit (t=5.1) and the income gradient becomes steeper. Since, for men, education and income have partial associations with weight which are of the opposite sign and because education and income move together, the unadjusted correlations between either outcome and weight may be misleadingly small. That is, as we consider more highly educated men and therefore lighter men we also tend to be considering men with more income, who are heavier, and these two effects attenuate each other in univariate correlations. Finally, in model 6 we also control for household composition. The income gradient falls in magnitude modestly, and men living alone or single parents have lower BMI on average than men with the same income and education who are married or cohabitating. After controlling for income, education, and household structure the Canada-U.S. gap in BMI remains almost unaltered at about 1.5 units. Also note how difficult it is to predict body weight with these characteristics: the partial R^2 for income, education, and household structure is only about 1%.

Turning to the estimates for women in Table 4, Model 1 indicates that the average U.S. women is heavier than the average Canadian woman by more than three BMI units. In contrast to the men's results, including the white indicator in Model 2 decreases the gap substantially, to a little over two BMI units. Averaged across the two countries, a non-white woman is about 1.7 BMI units heavier than a white woman (t=3.2). Model 3 conditions on income and shows a fairly steep *negative* gradient: women in higher income households tend to be of lower BMI. But the relationship between income and body weight does not explain the Canada-U.S. gap, which *increases* by about a fifth of a BMI unit when income is held constant. The education-BMI gradient is negative and steeper than that for men (Model 4), and when both education and income are held constant (Model 5) both remain statistically and economically significant. Unlike the male case, since the effects of education and income have the same sign for women, controlling for one but not for the other overestimates the partial effect. In model 6, we also include living arrangements and see that the income gradient becomes steeper still and that women living with their partner or spouse and children tend to be heavier than women in any other living arrangement, except in the "other" category.

After controlling for women's education, income, and household structure, the Canada-U.S. BMI gap among women is almost the same as it was when we controlled for race alone. Taking the results for men and women together, the only sociodemographic characteristic that explains why mean BMI is higher in the U.S. than it is in Canada is the higher proportion of on-average-heavier non-white women in the U.S. Put another way, the estimates suggest that if the distributions of income, education, and household structure could be equalized in the two countries, almost nothing would happen to the gap in height-adjusted weight for either men or women across the two countries.

Switching regression estimates are presented in Table 5. For men and women, the table shows estimates of the determinants of BMI within each country (β_0 and β_1 in equations 2 and 3), and the estimated partial effect of the characteristic on the gap as defined in equation 5. The estimates for men suggest that the weight gap is substantially lower for white men than for non-white men: although men who are white or non-white weigh more on average in the U.S. than in Canada, that gap is smaller in magnitude for white men. The only other substantive predictors of the BMI gap for men are education and the "other" living arrangement. High school graduates are relatively heavier in the U.S., other things equal, whereas men in the "other" living arrangements are relatively lighter. Broadly, the estimates suggest that, for men, determinants of BMI are quite similar in the U.S. and Canada.

Determinants of BMI for women are markedly different in the U.S. and Canada. Table 5 shows that the education gradient is much steeper in the U.S. than it is in Canada, such that the BMI gap is almost a full point smaller for college graduates than for high school dropouts (t=3.03). Conversely, the income gradient is much steeper in Canada. Canadian women in households earning more than $80,000 CDN per year are 1.8 BMI units lighter than their otherwise identical counterparts in a household earning less than $15,000 per year (t=5.5). U.S. women in the high earnings households are also lighter, but by only 0.95 BMI units (t=1.96). Further, BMI falls monotonically with income for Canadian women whereas there is no statistically significant difference in BMI for U.S. women until the $80,000 threshold is crossed. The point estimates suggest that middle income women may in fact be somewhat heavier than low or high income women. The weight gap is largest in the $30,000 to $50,000 bracket, which increases the BMI gap by 1.5 units, all else equal. Women who are single parents are also lighter in Canada than we would expect given their other characteristics, but American female single parents are no heavier or lighter than women living with their partners and children. Similar to men, non-white women are heavier in the U.S. than in Canada.

Table 6 presents the results in an alternate manner by averaging the BMI gap within specific socioeconomic groups. Other things equal, a man is 1.31 BMI units heavier if he lives in the U.S. than in Canada whereas a woman is 1.95 BMI units heavier. For both men and women there are large differences across racial groups, with much larger gaps for non-white people than for white people. For men, the gap is on average higher at lower incomes and then falls whereas for women the gap is larger for extreme incomes. For all sociodemographic groups the weight gap is positive, that is, all else equal we would expect a member of any of these groups to be heavier in the U.S. than in Canada. However, there is substantial variation. Holding education and living arrangements constant, a white man with income over $80,000 is only on average 0.76 units of BMI heavier in the U.S. than in Canada. If, conversely, we compare two non-white women with the same education and living arrangements, in the $30-50,000 income category the U.S. woman is a full five BMI units heavier than her observationally equivalent Canadian counterpart.

The differences in the income-BMI gradient across sexes and across countries are worth emphasizing. There is a large literature attempting to explain why low income and high obesity rates are associated (see, for example, Drewnowski and Specter 2004), yet this correlation is not a regularity. The estimates presented in Tables 3 through 5 show that income and BMI move in the *same* direction for men, and that this positive gradient is even steeper once education is statistically held constant. We illustrate these gradients in Figure 2. It is only for women that low income is associated with greater BMI, but that relationship is dissimilar across countries, with Canadian women experiencing much larger decreases in mean BMI as income increases. Adjusting for education reveals this gradient is not as steep in either country as univariate correlations would suggest. In other words, part of the reason low income women tend to be overweight is that women in low income household tend to have low education levels.

A simple simulation demonstrates the ineffectiveness of income redistribution policy in combating obesity. We generated counterfactual expected BMI by sex and by country by using the estimated models displayed in Table 5 and replacing the respondents' actual incomes with an income in the $50-80,000 range. These counterfactual BMIs are what the predicted BMIs would be in an alternate world where every household in the U.S. and Canada earns between 50 and 80 thousand Canadian dollars, in other words, an idealized egalitarian world. Table 7 shows that the income redistribution experiment has inconsequential effects on mean BMI.

Since the relationships between income and BMI differ across sex and across countries, we further stratified the samples by education level to investigate whether weight-income relationships are stable across education categories. That is, we estimated equations (2) and (3) separately within each education and sex group. The results are presented graphically in Figure 3.[4] In the Canadian sample, the income gradient does not differ dramatically across educational categories for either men or women. There are nonetheless some differences: men with higher educations have steeper profiles than their less educated counterparts, whereas more educated women have shallower (less negative) profiles. For the U.S. sample there are large differences across educational categories. The results are particularly striking for women: almost all of the negative correlation between BMI and income, displayed averaged across education groups in Figure 2, occurs for women with high school or lower educations. For women with post-secondary or college educations, the relationship between income and education has an inverted-U shape, and women in these education groups with high or low incomes are comparable in average weight. For women with high school education weight drops with income once income rises above the $30-$50k range, and for women who are high school dropouts weight falls rapidly with income. The results for U.S. men are entirely dissimilar to those for U.S. women: not only does weight rise on average with income, but the highest-education men have the steepest profiles. There is almost no income-BMI gradient whatsoever for U.S. men with high school or lower education.

3.5. Empirical Example of Contextual Influences: Results from the U.S. Sample

The empirical results presented above show that after controlling for cross-country differences in socioeconomic and demographic variables there still remains a significant difference in BMI across Canada and the US for all demographic groups. As noted earlier, external contextual factors are increasingly being examined as important determinants of BMI and obesity outcomes. One possible explanation for the BMI gap is differences contextual factors that tend to increase weight. For example, the price of energy dense foods may be relatively lower in the U.S. For the U.S. data, we have constructed measures of several contextual factors often argued in the literature to affect BMI: the prices of fast food meals and fruit and vegetables, and the local area density of supermarkets. We have no comparable data for Canada and unfortunately cannot

[4] Full regression estimates for these models are available from the authors on request.

provide direct evidence on how much of the weight gap these contextual factors might explain. In this section, we draw on our U.S. sample to expand the BMI model to include the contextual factors in addition to individual-level characteristics as an illustrative example of the associations between these factors and body weight.

Food and fast food price data have been obtained from the American Chamber of Commerce Researchers Association (ACCRA) Cost of Living Index reports that contain quarterly information on prices across more than 300 US cities annually. These price data are matched based on the closest city match available in the ACCRA data using the NLSY79 county geocode data. From the items provided in the ACCRA data, we create two prices indices: a fruit and vegetable price index[5] and fast food price index[6].

Data on supermarket outlets were obtained from a business list developed by Dun and Bradstreet (D&B).[7] This list is obtained through use of D&B MarketPlace software. MarketPlace contains information on more than 14 million businesses in the U.S. and allows one to draw on data by location and Standard Industry Classification (SIC) codes. Information on the overall number of chain supermarket (SIC 54110101) was pulled for the year 2002 and matched to the NLSY79 data by county-level geocode identifiers. For analytical purposes, we then computed the per capita (per 10,000 persons) number of chain supermarkets.

To examine associations between food prices and supermarket availability controlling for individual sociodemographic characteristics, we estimate a model of the form

$$BMI_t = \alpha SD_{ts} + \gamma PFF_{ts} + \delta PFV_{ts} + X_t\beta + \varepsilon_t \qquad (7)$$

where X_t represents a vector of the full set of individual-level characteristics as defined in the models estimated above, SD_{ts} measures chain supermarket outlet density available to individual t in geographic area s, PFF_{ts} defines the price of fast food faced by individual t in geographic area s, $PFVt_{is}$ defines the price of fruit and vegetables faced by individual t in geographic area s.

The results from our U.S. BMI regressions specified in equation (7) that include food prices and supermarket outlet density measures are presented in Table 8. Examining first the results for men, we see that increased availability of chain supermarkets has a statistically significant relationship with BMI: an additional chain supermarket (per 10,000 residents) in the respondent's county is associated with a 1.2 unit reduction (t=2.76) in BMI. For males, we do not find any statistically significant associations between food prices and BMI. For women, we

[5] The fruit and vegetable price index is based on the food prices available for this food category (potatoes, bananas, lettuce, sweet peas, tomatoes, peaches, and frozen corn). ACCRA reports weights for each item based on expenditure shares derived from the Bureau of Labor Statistics (BLS) Consumer Expenditure Survey. These weights are used to compute a weighted fruit and vegetable price based on the seven food items noted above and all prices are in real dollars (1982-1984=1).
[6] The fast food price is based on the following three items included in the ACCRA data: a McDonald's Quarter-Pounder with cheese, a thin crust regular cheese pizza at Pizza Hut and/or Pizza Inn, and fried chicken (thigh and drumstick) at Kentucky Friend Chicken and/or Church's Friend Chicken. The real fast food price index is computed as an average of these three food prices since they have equal weights.
[7] Information on D&B's methods is available at: 1) www.zapdata.com; 2) "The DUNSright Quality Process: The Power behind Quality Information" (2005) Dun and Bradstreet.

find that a dollar increase in the price of fast food is statistically significantly associated with a 1.5 unit reduction (t=1.97) in BMI. Increased availability of supermarkets is associated with lower BMI among women but is not statistically significant. For neither men nor women are fruit and vegetable prices statistically significantly associated with BMI, all else equal.

These results suggest that changes in prices and chain supermarket outlet densities change BMI in the manner predicted. BMI is lower when access to chain supermarkets (with choices of healthful foods) is more readily available and lower when the price of fast food (energy dense less nutritious food) is higher. The results also reveal that men and women respond differently to these factors. The simple model, however, does not examine how individuals' responses to such incentives may differ across income or education categories nor are we able to address issues of causation that would be better served using the full panel data. In particular, these correlations only recover demand curve slopes if price changes reflect supply shocks across regions, and we have no way to assess to what extent that is the case from our cross-sectional data.

Nonetheless, this example demonstrates the importance of expanding traditional individual-level models to incorporate aspects of the individual's local environment that may constrain or exacerbate different behaviors. This contextual example was limited to the inclusion of food prices and supermarket availability which are expected to affect food consumption patterns and, in turn, BMI. To fully understand the contribution of environmental factors to food consumption, physical activity, and weight outcomes, researchers need to obtain neighborhood measures on a host of contextual factors along with high quality individual-level survey data that include detailed outcomes measures.

4. Conclusions

The obesity epidemic is often framed in terms of specific demographic and economic determinants. A comparison of the determinants of obesity in Canada and the U.S., drawing on data on adults aged 35 to 45 from large nationally representative surveys, shows that the determinants of weight vary substantially across sexes, across countries, and across education levels. Low income and high weight are only strongly linked among Canadian women; among American women only high but not moderate incomes are associated with lower weight, and among both Canadian and American men income and weight are positively correlated. These differences are themselves unstable across educational levels within sexes and within countries: highly educated U.S. women tend to be heavier in the middle income groups, and lighter at extremes of the income distribution. The negative population correlation between income and BMI for U.S. women is driven by a steep negative relation among women with high school or less education. Conversely, U.S. men with college degrees have steep, positive income BMI-gradients, but U.S. men with high school or less education experience almost no relationship between income and BMI. These results suggest more complex underlying causes for the univariate correlations between obesity rates and income than mechanisms such as energy density and price emphasized in the public health literature.

Key sociodemographic characteristics such as income, education, race, and living arrangements cannot explain the "obesity gap" between Canada and the U.S. Even if the distributions of these variables were the same in both countries, the average American would still be somewhat heavier than an observationally identical Canadian, and by roughly the same amount as when differences in characteristics are not held constant. What is more, even if income were perfectly redistributed in both countries, obesity rates would remain almost unaltered. However, there are substantial differences across groups in the magnitude of the obesity gap.

These results cast doubt on some explanations for the obesity epidemic and the efficacy of some policy recommendations. If obesity is caused by poverty we would not expect to see the relationship between income and weight vary markedly across sexes or countries, particularly after holding other determinants of weight constant, but it does. Further, income, education, living arrangements, and race taken together can explain no more than 9% of the variation in BMI across individuals and almost none of the difference in BMI for Canadians and Americans. The important determinants of obesity remain "in the residual," not attributable to policy relevant causes such as income or education. We provide some evidence on one type of cause which remains in the residual for Canada due to a lack of relevant data, but which we are able to obtain data on for the U.S. Fast food prices, fruit and vegetable prices, and local area availability of chain supermarkets appear to have small to moderate and sometimes statistically significant relationships with mean BMI among our sample of American adults.

Research findings that suggest that contextual factors are significantly associated with the risk of obesity have implications for the importance of potential non-medical policy tools. Examples of preventive non-medical policies may include subsidies to "healthy" foods, taxes on fast food and soda, funds to improve the availability of physical activity-related facilities, urban planning funds to improve street connectivity and smart growth development of suburban areas, increased funds for school-based physical education opportunities, or restrictions on food advertising directed at children. Policies such as these have strong implications for the allocation of preventive health spending dollars. The potential importance of contextual influences on health outcomes suggests that preventive health dollars may need to be allocated outside of the traditional health care umbrella.

However, the extent to which the Canadian population similarly faces and/or responds to contextual factors as do their southern neighbors in terms of their weight outcomes is unclear -- especially in light of the cross-country differences in the relationship between weight and basic sociodemographic characteristics highlighted in this paper. The development of data bases that contain local area economic and environmental contextual variables that could be merged with Canadian individual-level data by geocode identifiers is needed to provide empirical evidence to better inform Canadian policy-makers. Survey data also need to be improved such that in addition to anthropometric data they provide detailed and accurate measures on food consumption and physical activity outcomes so that analyses also can examine how changes in incentives directly affect these intermediary behaviors. Comprehensive empirical models of food consumption and physical activity behaviors and related weight outcomes will help to uncover which type of policy levers may be most effective in reversing the obesity epidemic and reducing the associated long-run negative health outcomes and health care costs.

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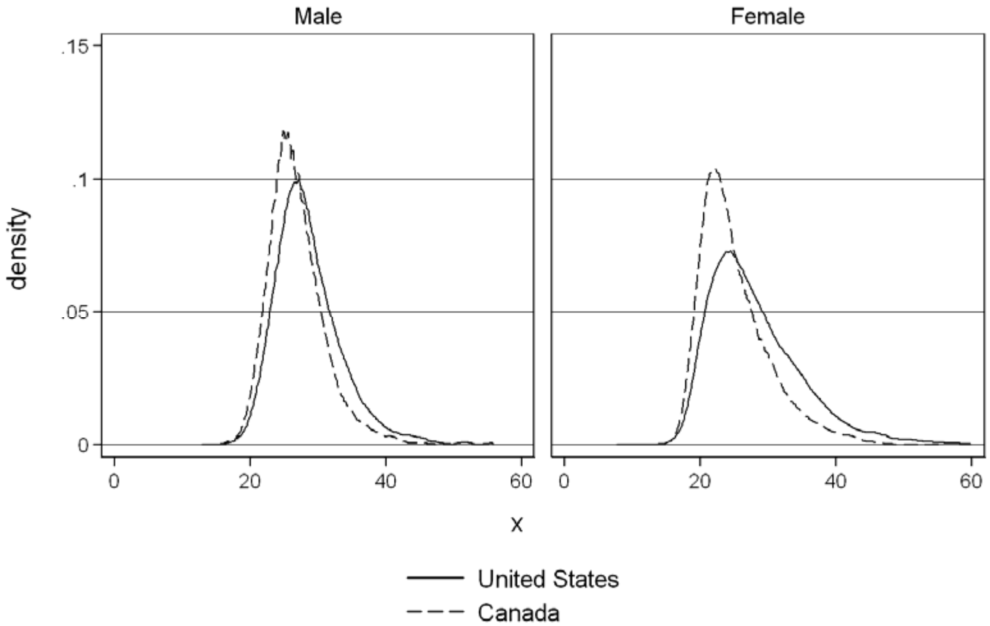
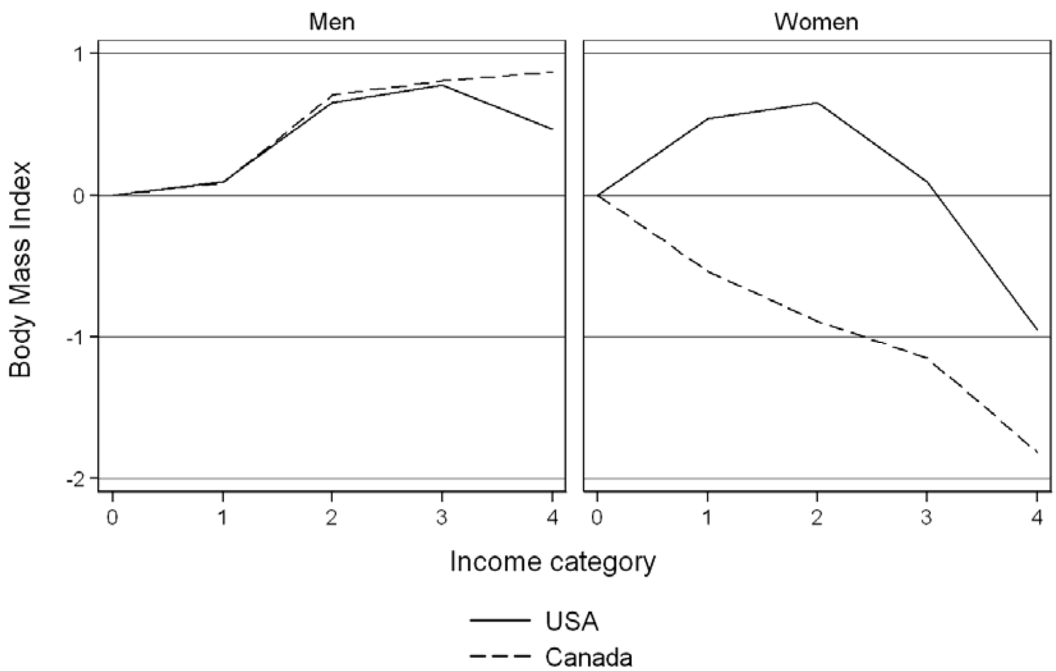
Figure 1**:** Kernel density estimates of the distribution of BMI



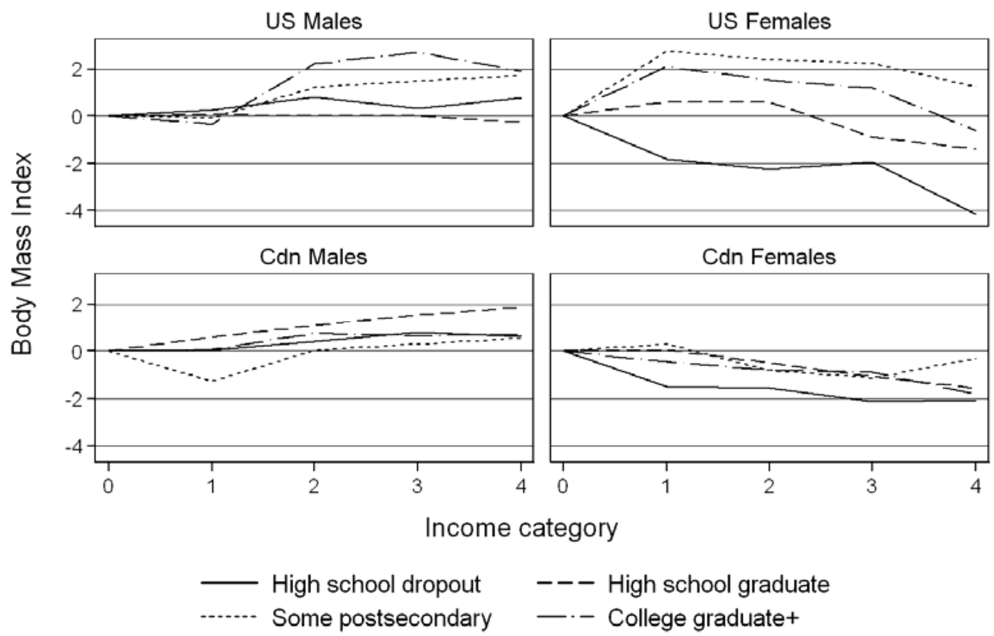
Note: Kernel density estimates of Body Mass Index. Epanechnikov kernel with optimal bandwidths evaluated at 300 points in each figure.

Figure 2: Income-BMI gradients by sex and country



Note: Figure shows regression point estimates as presented in Table 5. Education, race, age, and living arrangements have been held constant. The income categories are as follows. 0=$0-$15k, 1=15-30k, 2=30-50k, 3=50-80k, 4=80k or more. All incomes measured in 2001 Canadian dollars.

Figure 3: Income-BMI gradients by sex, country, and education level



Note: Point estimates from fully stratified regression models also including controls for race, age, and living arrangements. In each sex-country-education strata the base category is a respondent in the lowest income category. The income categories are as follows. 0=$0-$15k, 1=15-30k, 2=30-50k, 3=50-80k, 4=80k or more. All incomes measured in 2001 Canadian dollars.

Table 1: Summary Statistics

Variable	Canada			United States		
	Full Sample	Male	Female	Full Sample	Male	Female
Body Mass Index (BMI)	25.6578 (4.5969)	26.5910 (3.9867)	24.7647 (4.9573)	27.7439 (5.8167)	28.2245 (4.8066)	27.2271 (6.6980)
White	0.8905	0.8931	0.8881	0.7243	0.7338	0.7141
Aged 40-45	0.4759	0.4736	0.4781	0.6942	0.6925	0.6960
Male	0.4890	1.0000	0.0000	0.5181	1.0000	0.0000
Foreign Born	0.1475	0.1452	0.1497	0.0391	0.0391	0.0391
Education - High School Drop Out	0.1333	0.1469	0.1203	0.0862	0.0986	0.0728
Education - High School Graduate	0.2220	0.2112	0.2323	0.4235	0.4352	0.4110
Education – Some College	0.0721	0.0664	0.0776	0.2330	0.2148	0.2524
Education - College Graduate and Above	0.5726	0.5754	0.5698	0.2574	0.2514	0.2638
Income - Less Than 15,000	0.0523	0.0466	0.0577	0.0780	0.0690	0.0877
Income – Between 15,000 and 30,000	0.0968	0.0806	0.1122	0.0938	0.0830	0.1055
Income – Between 30,000 and 50,000	0.1941	0.1958	0.1925	0.1503	0.1520	0.1484
Income – Between 50,000 and 80,000	0.3027	0.3072	0.2983	0.2128	0.2262	0.1984
Income - Above 80,000	0.3035	0.3236	0.2842	0.3344	0.3475	0.3203
Income – Missing	0.0507	0.0461	0.0551	0.1308	0.1223	0.1398
Living Alone	0.1100	0.1418	0.0795	0.1705	0.2171	0.1204
Living with Partner/Spouse, No Child	0.1220	0.1213	0.1225	0.1021	0.1003	0.1040
Living with Partner/Spouse, At Least One Child	0.5714	0.5680	0.5747	0.5225	0.5231	0.5218
Single Parent	0.0722	0.0303	0.1123	0.0870	0.0382	0.1395
Other Living Arrangement	0.1245	0.1386	0.1110	0.1179	0.1213	0.1143
Price of Fast Food ($82-84)	NA	NA	NA	2.6777 (0.1516)	2.6799 (0.1526)	2.6754 (0.1506)
Price of Fruit and Vegetables ($82-84)	NA	NA	NA	0.8262 (0.0965)	0.8265 (0.0964)	0.8258 (0.0966)
Per Capita Number of Chain Supermarkets	NA	NA	NA	0.3107 (0.2321)	0.3121 (0.2318)	0.3091 (0.2325)
N	20,545	9,656	10,889	7,446	3,706	3,740

Notes: Income measured in 2001 Canadian dollars. Statistics weighted to reflect sampling populations.

Table 2: BMI in Canada and U.S. by Sex and Racial, Education and Income Groups

Variable	Canada			United States		
	Full Sample	Male	Female	Full Sample	Male	Female
By Race						
White[a]	25.7674	26.7458	24.8255	27.2473	28.0409	26.3707
Minority	24.7668**	25.2967**	24.2827	29.0484**	28.7308**	29.3663**
By Education						
Education - High School Drop Out[a]	26.5716	26.9243	26.1592	28.4363	28.0457	29.0052
Education - High School Graduate	25.7506**	26.6420	24.9750**	28.2603	28.6406	27.8274**
Education - Some College	25.6978**	26.7535	24.8328**	27.8063*	28.3756	27.2855**
Education - College Graduate and Above	25.4041**	26.4684	24.3753**	26.6056**	27.4453	25.7453**
By Income						
Income - Less Than 15,000[a]	25.7788	26.1247	25.5116	27.9557	27.5480	28.3006
Income - Between 15,000 and 30,000	25.5572	25.8951	25.3249*	28.2171	27.7617	28.6025
Income - Between 30,000 and 50,000	25.8756	26.6364**	25.1347**	28.2826	28.3998*	28.1535
Income - Between 50,000 and 80,000	25.8200	26.6937**	24.9586**	28.0579	28.6416**	27.3425*
Income - Above 80,000	25.4680	26.7699**	24.0490**	27.2141**	28.1704	26.0985**

Note: *, ** indicate that the means are significantly different from the default group at 5% and 1% levels respectively. a indicates the reference category.

Table 3: Pooled Canada-U.S. BMI OLS Regression Estimates: Male Sample

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
U.S. Indicator	1.702 (8.20)	1.596 (6.79)	1.600 (6.82)	1.509 (6.32)	1.491 (6.22)	1.506 (6.31)
White	-	-0.198 (-0.63)	-0.338 (-1.02)	-0.174 (-0.57)	-0.309 (-0.97)	-0.322 (-0.98)
Aged 40-45	-	0.106 (1.59)	0.104 (1.58)	0.098 (1.46)	0.088 (1.32)	0.092 (-1.39)
Income - Between 15,000 and 30,000	-	-	0.181 (0.88)	-	0.196 (0.95)	0.103 (0.50)
Income - Between 30,000 and 50,000	-	-	0.806 (4.81)	-	0.858 (5.01)	0.683 (3.97)
Income - Between 50,000 and 80,000	-	-	0.998 (5.74)	-	1.091 (6.11)	0.799 (4.58)
Income - Above 80,000	-	-	0.974 (5.71)	-	1.136 (6.24)	0.744 (4.02)
Income - Missing	-	-	0.484 (2.29)	-	0.545 (2.54)	0.294 (1.35)
Education - High School Graduate	-	-	-	0.083 (0.70)	-0.094 (-0.78)	-0.081 (-0.69)
Education - Some College	-	-	-	0.108 (0.72)	-0.090 (-0.61)	-0.06 (-0.41)
Education - College Graduate and Above	-	-	-	-0.177 (-2.10)	-0.460 (-4.97)	-0.421 (-4.77)
Living Alone	-	-	-	-	-	-0.633 (-9.5)
Living with Partner/Spouse, No Child	-	-	-	-	-	0.046 (0.35)
Single Parent	-	-	-	-	-	-0.474 (-2.89)
Other Living Arrangement	-	-	-	-	-	-0.283 (-1.80)
Constant	26.785 (153.12)	26.914 (85.56)	26.265 (81.98)	26.969 (85.40)	26.44 (82.80)	26.869 (77.56)
N	13,363	13,363	13,363	13,363	13,363	13,363
R-squared	0.030	0.031	0.036	0.031	0.038	0.041

Note: T-statistics are in parentheses. Standard errors have been corrected for clustering at the State or Province level and are heteroskedasticity-robust. The omitted categories are: income 0 – 15000, high school dropout, and living with spouse or partner with at least one child.

Table 4: Pooled Canada-U.S. BMI OLS Regression Estimates: Female Sample

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
U.S. Indicator	3.013 (10.54)	2.140 (5.88)	2.315 (6.77)	2.066 (5.78)	2.255 (6.68)	2.242 (6.69)
White	-	-1.738 (-3.13)	-1.557 (-2.83)	-1.621 (-2.97)	-1.511 (-2.76)	-1.504 (-2.70)
Aged 40-45	-	0.327 (3.24)	0.362 (3.60)	0.300 (2.95)	0.338 (3.34)	0.349 (3.50)
Income - Between 15,000 and 30,000	-	-	-0.285 (-1.35)	-	-0.195 (-0.90)	-0.238 (-1.05)
Income - Between 30,000 and 50,000	-	-	-0.493 (-2.59)	-	-0.318 (-1.57)	-0.476 (-2.30)
Income - Between 50,000 and 80,000	-	-	-0.739 (-3.37)	-	-0.503 (-2.19)	-0.755 (-3.22)
Income - Above 80,000	-	-	-1.631 (-6.57)	-	-1.297 (-4.94)	-1.581 (-6.22)
Income - Missing	-	-	-1.496 (-6.07)	-	-1.33 (-5.39)	-1.560 (-6.14)
Education - High School Graduate	-	-	-	-0.753 (-4.97)	-0.593 (-4.11)	-0.557 (-3.82)
Education - Some College	-	-	-	-1.097 (-6.67)	-0.898 (-5.50)	-0.843 (-5.25)
Education - College Graduate and Above	-	-	-	-1.411 (-10.45)	-1.094 (-9.12)	-1.022 (-8.31)
Living Alone	-	-	-	-	-	-0.347 (-1.90)
Living with Partner/Spouse, No Child	-	-	-	-	-	-0.349 (-2.12)
Single Parent	-	-	-	-	-	-0.609 (-3.87)
Other Living Arrangement	-	-	-	-	-	0.552 (2.75)
Constant	25.095 (112.85)	26.537 (50.47)	27.163 (53.65)	27.492 (52.04)	27.75 (55.33)	28.005 (55.82)
N	14,629	14,629	14,629	14,629	14,629	14,629
R-squared	0.051	0.062	0.072	0.069	0.075	0.078

Note: T-statistics are in parentheses. Standard errors have been corrected for clustering at the State or Province level and are heteroskedasticity-robust. The omitted categories are: income 0 – 15000, high school dropout, and living with spouse or partner with at least one child.

Table 5: Switching Regression Estimates: Decomposing the Canada-U.S. BMI Gap

	Male			Female		
	Canada	U.S.	Partial Difference	Canada	U.S.	Partial Difference
White	0.7226 (1.85)	-1.0127 (-4.68)	-1.735 (-7.61)	0.1647 (0.28)	-2.7329 (-10.02)	-2.898 (-10.33)
Education - High School Graduate	-0.3599 (-3.17)	0.3079 (1.09)	0.668 (2.48)	-0.6009 (-5.89)	-0.8494 (-1.56)	-0.249 (-0.65)
Education - Some College	-0.2627 (-1.32)	0.2177 (0.68)	0.48 (1.47)	-0.8482 (-5.68)	-1.2402 (-2.46)	-0.392 (-0.92)
Education - College Graduate and Above	-0.4454 (-4.97)	-0.5942 (-1.85)	-0.149 (-0.49)	-0.892 (-10.18)	-1.7534 (-3.03)	-0.861 (-2.06)
Income - Between 15,000 and 30,000	0.0842 (0.38)	0.0948 (0.23)	0.011 (0.03)	-0.5387 (-1.59)	0.5411 (1.29)	1.080 (2.46)
Income - Between 30,000 and 50,000	0.7071 (3.70)	0.6547 (1.91)	-0.052 (-0.14)	-0.8941 (-3.88)	0.6487 (1.60)	1.543 (3.62)
Income - Between 50,000 and 80,000	0.8061 (4.53)	0.7782 (2.16)	-0.028 (-0.08)	-1.1504 (-3.47)	0.0909 (0.18)	1.241 (2.83)
Income - Above 80,000	0.8737 (4.67)	0.4679 (1.16)	-0.406 (-1.08)	-1.8154 (-5.50)	-0.9519 (-1.96)	0.863 (1.89)
Income - Missing	0.4701 (1.71)	0.0039 (0.01)	-0.466 (-1.13)	-1.9519 (-6.65)	-0.9070 (-1.94)	1.045 (2.17)
Living Alone	-0.5692 (-9.75)	-0.9659 (-6.31)	-0.397 (-1.72)	-0.3647 (-1.60)	-0.4628 (-1.22)	-0.098 (-0.26)
Living with Partner/Spouse, No Child	-0.0708 (-0.44)	0.3321 (1.33)	0.403 (1.36)	-0.3651 (-2.24)	-0.3438 (-0.71)	0.021 (0.06)
Single Parent	-0.6399 (-3.76)	-0.3045 (-0.77)	0.335 (0.83)	-1.0158 (-5.48)	0.0431 (0.16)	1.059 (3.19)
Other Living Arrangement	-0.0669 (-0.46)	-0.8487 (-2.95)	-0.782 (-2.85)	0.591 (2.51)	0.497 (1.17)	-0.094 (-0.26)
Aged 40-45	0.0072 (0.12)	0.3041 (1.94)	0.297 (1.72)	0.3202 (3.33)	0.5035 (1.76)	0.183 (0.82)
Constant	25.9602 (82.10)	28.6197 (52.74)	2.66 (6.30)	26.7948 (48.55)	30.2929 (51.15)	3.498 (6.65)
N	9,656	3,707	13,363	10,889	3,740	14,629
R-squared	0.0139	0.0269		0.0194	0.0692	

Note: T-statistics are in parentheses. Standard errors have been corrected for clustering at the State or Province level and are heteroskedasticity-robust. The omitted categories are: income 0 – 15000, high school dropout, and living with spouse or partner with at least one child.

Table 6: Regression-adjusted BMI gap across countries, by gender, race and income

	Male			Female		
	Minority	White	Total	Minority	White	Total
Full Sample	2.80 (0.56)	0.95 (0.53)	1.31 (0.91)	4.44 (0.70)	1.35 (0.62)	1.95 (1.38)
By Income Group						
Less than 15,000	2.83 (0.49)	0.94 (0.47)	1.63 (1.03)	3.79 (0.61)	0.66 (0.65)	1.69 (1.60)
Between 15,000 and 30,000	2.95 (0.52)	1.02 (0.50)	1.49 (0.97)	4.78 (0.63)	1.68 (0.63)	2.42 (1.46)
Between 30,000 and 50,000	2.91 (0.52)	1.03 (0.51)	1.38 (0.90)	5.00 (0.58)	1.88 (0.54)	2.45 (1.32)
Between 50,000 and 80,000	3.02 (0.53)	1.11 (0.52)	1.38 (0.85)	4.52 (0.50)	1.4 (0.41)	1.82 (1.14)
Above 80,000	2.64 (0.51)	0.76 (0.47)	1.03 (0.82)	3.96 (0.39)	0.92 (0.34)	1.37 (1.13)
Missing	2.43 (0.54)	0.62 (0.54)	1.34 (1.04)	4.57 (0.55)	1.34 (0.50)	2.44 (1.61)
Total	2.80 (0.56)	0.95 (0.53)	1.31 (0.91)	4.44 (0.70)	1.35 (0.62)	1.95 (1.38)

Notes: Standard deviations are parentheses.

Table 7: Simulated Effects of Income Redistribution

		Canada	U.S.	Total
Women	Actual	25.10	28.11	25.87
	Counterfactual	25.06	28.40	25.91
Men	Actual	26.78	28.49	27.26
	Counterfactual	26.93	28.85	27.46
Total	Actual	25.89	28.30	26.53
	Counterfactual	25.94	28.63	26.65

Note: This table shows simulated effects of income redistribution. Rows labeled “actual” denote realized mean BMI values whereas rows “counterfactual” denote simulated outcomes if all respondents’ incomes were in the $50-80,000 range based on switching regression estimates from Table 5.

Table 8: Contextual Influences on BMI: Results from the U.S. Sample

	Male	Female
Price of Fruit and Vegetables	-0.7910 (-0.85)	0.2405 (0.17)
Price of Fast Food	-0.4062 (-0.60)	-1.5382 (-1.97)
Per Capita Number of Chain Supermarkets	-1.2022 (-2.76)	-0.1829 (-0.41)
N	3707	3740
R-squared	0.0307	0.0704

Note: T-statistics are in parentheses. Standard errors have been corrected for clustering at the State or Province level and are heteroskedasticity-robust. The regressions control for the full set of individual-level characteristics as shown in Table 5.