The Protective Effect of Plant-Based Diets in Urbanizing India

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abstract

As the nutrition transition unfolds, low-fat, fiber-rich traditional foods are displaced by the 'meat-sweet' diet with more animal protein, refined sugars and fats, and processed foods. Together with reduced physical activity, these dietary changes lead to increases in obesity and other non-communicable diseases. Yet in India, the dynamics of the nutrition transition confront the country's long history of vegetarianism. In this context, it is unclear if plant-based diets have protective effects for health. This paper thus aims to (1) estimate the protective effect of vegetarianism against unhealthy BMI, disentangling this from household wealth and urban status; and (2) evaluate the extent to which this plant-based protective effect operates differentially by place of residence. Findings contribute to our understanding of how vegetarianism operates with respect to health outcomes in the non-Western context amidst intensifying pressures towards diet Westernization.

key words: nutrition transition, vegetarianism, India, plant-based diets, body mass index

statement of the problem

Urbanization and globalization profoundly transform food systems and eating practices, de-linking production and consumption from culturally-, environmentally-, and locally-embedded practices. With economic development and higher wages, people begin to replace low-fat, fiber-rich traditional foods with Western diets, aptly called the 'meat-sweet' diet with its high intake of animal protein, refined sugars and fats, and processed foods. Diet westernization is driven by demand for more convenient foods with shorter prep times, greater exposure to non-traditional foods in large urban markets, and supermarket chain growth (Pingali 2007; Reardon et al. 2003). At the same time, migration to urban centers and service-sector employment increase, so that more people fall into more sedentary lifestyles. These two areas of fundamental change – diet and lifestyle – together comprise the nutrition transition profile of degenerative disease (Caballero and Popkin 2002; Popkin 1993, 1999). As this stage of the nutrition transition rapidly unfolds across a greater number of places, the burden of non-communicable diseases grows. Obesity rates, for example, have doubled since the 1980s (The World Health Organization); as Popkin bluntly declares in the title of his book: "The World is Fat" (Popkin 2009).

Diet is a key culprit in perpetuating non-communicable disease, but it can also be health-promoting. This is particularly true when it comes to plant-based diets[1], which have been associated with increased longevity; reduced risk of heart disease, diabetes, and cancer; weight maintenance; and diminished need for medications (Farmer et al. 2011; Fraser 2003, 2009; Orlich et al. 2013; Singh, Sabaté, and Fraser 2003; Tuso et al. 2013). Widespread adherence to plant-based diets also fosters sustainability across the 'diet-health-environment' trilemma because it would shrink the climate-damaging livestock industry (Carlsson-Kanyama and González 2009; Marlow et al. 2009; Reijnders 2001; Tilman and Clark 2014). Yet societal-level dietary dynamics generally push towards greater animal protein consumption. Meat is often viewed as a high-status food (Twigg 1983; York, Rosa, and Dietz 2003). Economic development typically involves the expansion of the middle class, thereby increasing their purchasing power and generating more demand for meat, dairy, and processed foods, with a concomitant increase in non-communicable disease. On the other hand, growing awareness of the negative health outcomes for people and for the planet associated with meat-heavy diets can prompt others – both individuals and policymakers – to adopt more sustainable plant-centered eating practices.

Such behavioral change could thus represent part of the latest stage in the nutrition transition, in which population health improves as concrete steps are taken to actively reduce non-communicable disease burden by, for example, promoting healthy body weight via health eating. It is unclear, however, how the dynamics of the nutrition transition may play out in a context which *already* has a long tradition of plant-based eating. India, home to one-seventh of the world's population, a rapidly growing economy, and the majority of the world's vegetarians, offers an ideal setting to study these dynamics. Recent trends show meat production and consumption patterns are changing; wealthier Indians shop more in large supermarkets and meat is portrayed as a symbol of status, wealth, and participation in global culture (*Meat Atlas* 2014; BBC 2012; Sandip Roy). These recent developments come into conflict with the country's vegetarian roots dating back to the pre-modern era, as presented in the Vedas and as practiced by early Brahmins. As such, religious and cultural proscriptions shape meat-eating, which varies by caste and across places (Stuart 2008). Most practicing vegetarians were raised exclusively on plant-based diets and, while longitudinal data to produce population-level estimates of nutritional intake are scarce, there appears to be high adherence across generations (Agrawal et al. 2014). In many places, institutionalized support of vegetarianism, including state-level criminalization of cattle slaughter, remains strong just as specific policies and practices are hotly contested. The ways in which these debates are resolved not only has moral and religious implications (as evidenced by the rhetoric of those involved), but also profound

[1] A 'plant-based diet' as used here refers to one with little or no animal products; it thus encompasses vegan, vegetarian, pescatarian, macrobiotic, raw foodism, and 'default' or 'forced' vegetarians, i.e. those who do not eat meat because they cannot afford it. 'Vegetarian' is a more specific term to describe those who actively abstain from the consumption of meat; 'vegans' exclude all animal derivatives including dairy.

consequences for the already resource-strapped natural environment, population-level health, and the burden of non-communicable disease.

Disentangling the health implications of vegetarianism, wealth, and urban status is thus crucial in this rapidly changing food environment as the nutrition transition unfolds in India. This study therefore aims to (1) estimate the extent to which vegetarianism has a protective effect against (a) higher body mass index and (b) overweight/obese status, separating out the effects of household wealth and place of residence; (2) evaluate the extent to which this plant-based protective effect operates differentially by place of residence. The findings will contribute to our understanding of how vegetarianism operates with respect to health outcomes in the non-Western context amidst intensifying pressures towards diet Westernization. It will also shed light on the extent to which the protective effects of plant-based diets are affected by context in what will soon be the most populous country in the world.

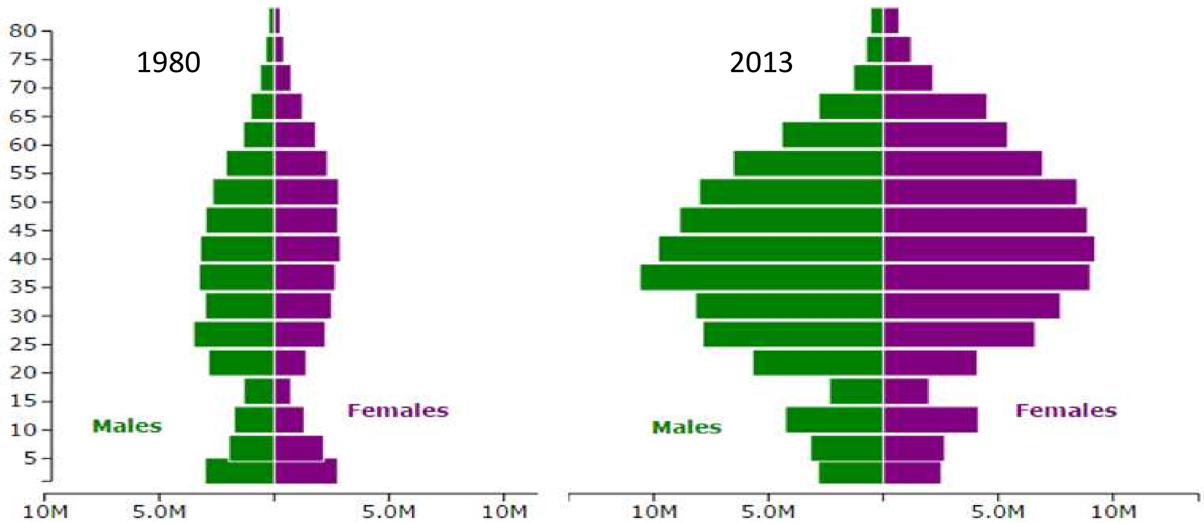
literature review

Food systems and eating practices were dramatically transformed by industrialization, urbanization, globalization. The framework of the nutrition transition serves to highlight the ways that these population-based changes in diet – accompanied by shifts to less active lifestyles – have dramatic consequences for health outcomes, especially body composition (Caballero and Popkin 2002). Akin to frameworks of the demographic and epidemiological transitions, nutrition transition theory begins with pre-modern patterns of eating and physical activity: hunter-gatherers collect food in pattern 1, early agricultural populations experience frequent famine in pattern 2, and then in pattern 3, famine recedes as agricultural surplus increases, although much of the population continues to engage in labor intensive work and subsist on primarily plant-based diets (Popkin 1993). Diet-related non-communicable diseases (DR-NCDs) are thought to have been virtually non-existent during pattern 1, only emerging with the expansion of agricultural production and the accompanying loss of dietary diversity (Milton 2000). More recently, many societies have transitioned to pattern 4, where populations consume more processed, high fat/sugar foods and animal protein and have lower levels of physical activity. Even as famine and malnutrition recede into the past, the burden of diet-related non-communicable disease (DR-NCD) grows (Popkin 2006). Following these changes, the 'fifth pattern' of nutrition transition theory should take root, characterized by behavioral change in which people actively switch to healthier diets and engage in more active lifestyles to improve health outcomes (Popkin 1993).

Many indicators reveal the changing burden of disease as places shift from pattern 3 to pattern 4 and infectious diseases decline in importance relative to DR-NCDs. One of the clearest trends has been in increasing average body mass index (BMI) with a doubling of obesity rates since the 1980s (WHO). Some countries have experienced much greater increases than others (Finucane et al. 2011), but current evidence indicates that every country now confronts health issues related to underconsumption of nutrient-rich foods and overconsumption of energy-dense foods (IFPRI 2015). In India, studies have documented notable increases in obesity, diabetes, and coronary heart disease (Misra et al. 2011). As Figure 1 (next page) reveals, the absolute increase is particularly telling: the number of overweight (BMI > 25) Indian tripled from around 25 million in 1980 to 75 million in 2013, with the numbers swelling among young and mid-age adults with both men and women affected. The proportion of adolescents and children with unhealthy body weights increased as well. These trends, understood within the context of population growth, draw attention to the "urgent need" for an integrated, multi-sector public health response (Kapil and Sachdev 2012).

Figure 1. Burden of Overweight/Obesity in India

Number of males and females (ages 20+) with BMI ≥ 25, 1980 and 2013



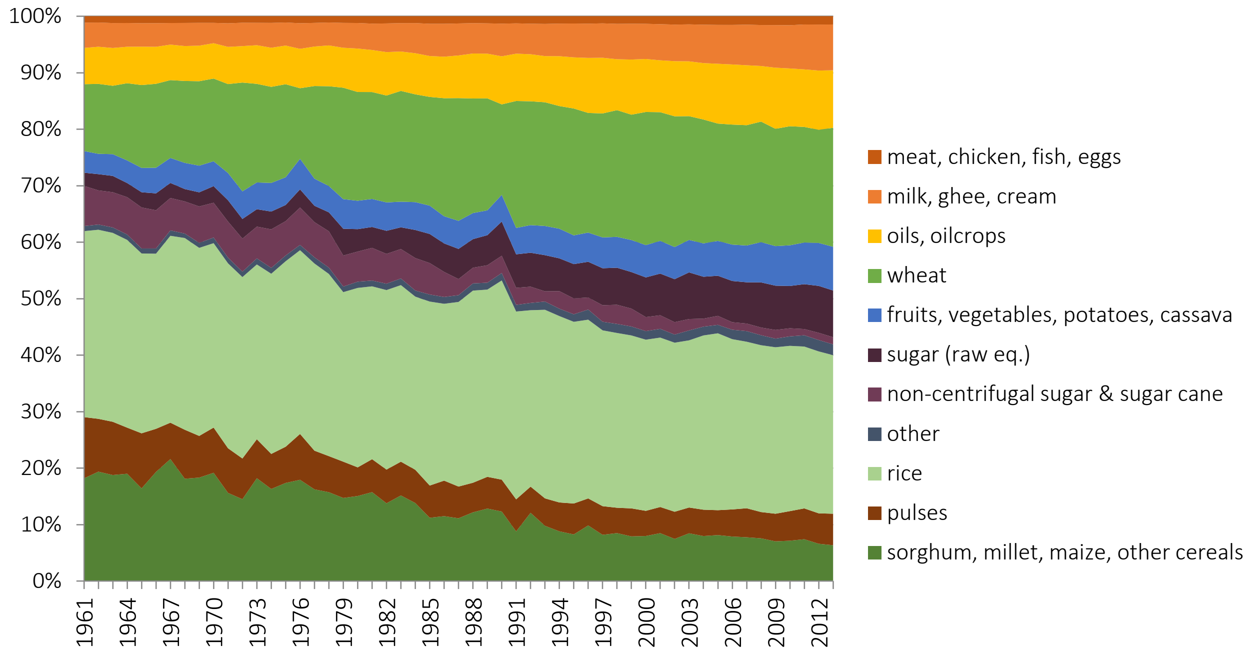
Source: Institute for Health Metrics and Evaluation (IHME). Overweight and Obesity Viz. Seattle, WA: IHME, University of Washington, 2014. Available from http://vizhub.healthdata.org/obesity. (Accessed 15 September 2015)

In the context of clear upward trends, the burden of obesity falls both between and *within* countries. In more industrialized societies, the least advantaged typically bear the most weight. For example, U.S. families living in poverty have been the most affected by overweight (Miech RA et al. 2006) even as notable gains in life expectancy have been made in privileged areas (Wang et al. 2013). Children and adults of less advantaged social backgrounds are more likely to be overweight or obese, a finding that emerged in research of the 1960s that has been consistent across wealthy country settings (Laitinen, Power, and Järvelin 2001; Lamerz et al. 2005; Moore, Stunkard, and Srole 1962). Across much of the Global South, the BMI-wealth gradient differs sometimes quite dramatically across countries and neighborhoods (Corsi, Finlay, and Subramanian 2012; Corsi, Kyu, and Subramanian 2011). In India, the relationship is clearly reversed: the wealthiest are the first to experience expanding waistlines – even as malnutrition, stunting, and underweight persist in poorer segments of societies (Gouda and Prusty 2014; Griffiths and Bentley 2001; Patel 2012). This positive relationship between wealth/socioeconomic status and overweight/obesity exists at both the individual- and state-level, underscoring the key role of economic development in health outcomes and the disease burden (Subramanian and Smith 2006).

Unhealthy diets, together with changing in physical activity, play a major role in driving the growth of obesity across virtually every country. In wealthier industrialized societies with the highest obesity rates, indicators of the fourth stage of the nutrition transition abound. The reliance on animal-derived proteins, the proliferation of fast food outlets, the abundance of processed foods on supermarkets shelves, and the influence of food corporations are all signs consistent with this stage (Nestle 2013; Patel 2012; Popkin 1993). Yet the transition from the third to fourth stage is still unfolding in much of the Global South. In India, the shift towards greater consumption of animal proteins has been quite limited. Nearly one in three Indians are vegetarians (≈ 30% NFHS 2005/6) and less than 10% of the daily food supply per capita derives from animal sources (FAOSTAT, see Figure 2 next page). Even so, when examining the diet in historical context, dietary changes of the past five decades are substantial. Figure 2 shows trends in the share of different foods and food groups in the diet of the average Indian (percent of food measured in kcal of daily food supply per capita). The proportion of calories from traditional grains, pulses, and unprocessed sugar has declined sharply, just as the contribution of oils, wheat, and refined sugar to the average diet has increased dramatically. Calories from dairy and eggs have doubled in importance and the pace of increase appears to be picking up. The consumption of chicken has risen in recent years, but, together with red meat consumption, it remains a very small proportion of the average diet. Taken together, these changes indicate the onset of the fourth stage of the nutrition transition in India.

Figure 2. The Unfolding Nutrition Transition in India

Contribution of items to daily per capita food supply (% of kcal), 1961-2013



Source: Created by author using food supply estimates (kcal /capita/day) of the Food and Agriculture Organization of the United Nations. FAOSTAT.

At the same time, these country-level trends mask substantial within-country variation. Moreover, they offer little in terms of understanding how Indian vegetarians may be more or less susceptible to negative health outcomes, especially obesity, in the context of changing diets.

Extensive research has documented the protective effects of plant-based eating against non-communicable diseases in wealthy countries such as the U.S. (Fraser 2009; Orlich et al. 2013). In these settings, a plant-based diet is increasingly viewed as a cost-effective intervention to treat medical conditions, especially chronic ones, and reduce reliance on medicines (Tuso et al. 2013). At the aggregate level, it has been posited that plant-based eating brings more people closer to optimal health, whereas meat-eaters as a group are more vulnerable to the extremes of DR-NCDs, i.e. both malnutrition/ underweight status and excess calories/overweight (Sabaté 2003). Yet population-level studies are often difficult to carry out given the still relatively low adherence to vegetarianism and veganism in most places.

Therefore, although the health-protective effects of vegetarianism are well documented in the wealthy-country context, less is known across the Global South – even as India is home to most of the world's vegetarians. A hospital-based survey in a district of Karnataka, a state in south west India, documented a linear relationship between BMI and vegetarian status. BMI was lowest in vegans (23.9 kg/ m^2), slightly higher among ovolactovegetarians (25.9 kg/m^2), and highest in non-vegetarians (29.2 kg/m^2) (Zaman, Zaman, and Arifullah 2010). Another recent study leverages population-level data and finds that Indian vegetarians are more protected against type 2 diabetes, even after controlling for wealth;

the analysis also controls for BMI (Agrawal et al. 2014; Zaman et al. 2010). Yet unhealthy BMI itself is also a risk factor for many diseases and chronic conditions, and estimates of BMI by vegetarian status after controlling for wealth are needed. Vegetarianism generally appears to be protective against obesity, but estimates are confounded by socioeconomic status given the historical connections between vegetarianism and certain higher-caste groups.

Moreover, it is possible that there is place-based divergence in the protective effects of vegetarianism. Substantial research has documented the importance of food environments in more industrialized countries, focusing on such dimensions as fast food restaurants, pricing, and grocery store accessibility (Gordon-Larsen, Guilkey, and Popkin 2011; Gustafson, Hankins, and Jilcott 2011; Kwate et al. 2009; McKinnon et al. 2009). Less is known about the importance of place across the Global South (Montgomery and Hewett 2005). Estimates of BMI in India are thus confounded by both socioeconomic status and place, with some studies pointing to the higher prevalence of overweight/obesity among wealthier urban dwellers in India (Gouda and Prusty 2014). At the same time, those who are wealthier and of higher-caste backgrounds are more likely to be vegetarian.

Future decades will likely bring more fast food establishments, supermarkets, and other elements of a globalized food system that promote the consumption of more processed foods, refined sugars, and animal proteins. Many still rely on agriculture-based livelihoods, but population growth in urban areas – primarily metropolitan suburbs – is projected to increase (Lozano-Gracia et al. 2013). Given India's size, even a small shift away from vegetarianism percentage-wise could have a substantial impact on the resources required to feed the still-growing population. Research has found that those living in urban settings are most likely to be overweight (Gouda and Prusty 2014), but it is not clear which neighborhood characteristics (e.g. wealth or uniquely urban environmental traits) matter most. Supermarkets, fast food outlets, and Westernized eating patterns are likely to expand unevenly into communities across India, growing most rapidly in wealthier, urban neighborhoods that are most distanced from agricultural production. Interestingly, in the past 25 years, overall per capita calorie consumption has declined in rural places, while average consumption in urban areas stayed constant (Deaton and Drèze 2009). The mechanisms of such place-based divergence are poorly understood, yet understanding these dynamics is an essential piece of the planetary health puzzle.

The protective effects of vegetarianism likely differ across place, although it is unclear what these patterns would look like. On the one hand, vegetarians in cities could have Westernized patterns of eating without eating meat, chicken, or fish. Instead of a 'meat-sweet' diet, they may develop a 'ghee-soda-sweet' diet characterized by more processed and refined foods than traditional diets. If that is the case, the risks of diabetes and obesity could be as high among vegetarians as they are among non-vegetarians. This would be particularly worrisome from a public health perspective, as much of the subcontinent population may be more predisposed to diabetes at lower BMI than other populations (Kaveeshwar and Cornwall 2014). On the other hand, India's long and rich tradition of plant-based eating could provide the basis for buffering larger segments of the population against some of the most detrimental consequences of pattern 4 (degenerative disease) even in the context of urbanization. Avoiding animal-derived foods may confer specific health benefits and/or those who are vegetarians could consume more pulses, nuts, and other traditional, less-processed foods to fulfill protein needs. In sum, the protective effects of vegetarianism in India are poorly understood, especially as they may operate differently across neighborhoods and degree of urbanization.

research hypotheses

My primary outcome of interest for this paper is body mass index (BMI) and then with a dichotomous indicator of overweight/obese status (BMI ≥ 23). Vegetarianism is defined as those who 'never' consume meat, chicken, or fish. I ask the following:

R1: To what extent is there a 'protective effect' of vegetarianism against (a) higher BMI, and (b) obesity, and how does this change after controlling for wealth, type of place of residence?

R2: Does the protective effect of vegetarianism operate similarly across levels of urbanization?

data & methods

In order to answer these questions, I use data from the third National Family Health Survey (NFHS-3), a nationally representative sample collected in 2005/6 that covers 99 percent of India's population. As with most Demographic and Health Surveys (DHS), the sample design is stratified and clustered. Households are drawn separately from a total of 3850 primary sampling units (PSUs) which generally correspond to villages in rural areas and wards in urban areas (from which census enumeration blocks are randomly selected) (IIPS and Macro International 2007). Because households are drawn from these PSUs, it becomes possible to estimate neighborhood-level wealth from households clustered in the same geographic area. For initial analyses, I restrict the sample to the 75,972 non-pregnant, non-breastfeeding women (ages 20 to 49).

measures

Body mass index (*BMI*), my outcome of interest, is an attractive and affordable indicator from a population health perspective. Measurement requires height and weight. When collected by the interviewer, BMI is not subject to self-report biases, the procedure is non-invasive, and administrators do not require special medical training or expertise. Moreover, BMI provides a good snapshot of overall population health. High BMI (> 25) has been connected to greater risk of diet-related non-communicable diseases such as cardiovascular disease (Milton 2000). BMI is defined as weight in kilograms divided by height in meters squared:

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$$

I first treat BMI as a continuous variable, and then dichotomize this to focus on the factors predictive of overweight/obesity in the India context. This step is taken because when using BMI, the analyses is confounded by the still-persistent problem of malnutrition and underweight. A lack of purchasing power means that in impoverished areas, many people may be 'default' or 'forced' vegetarians, and more likely to be underweight. Predicting obesity focuses the analyses on the determinants of unhealthy excess weight, which could vary from the factors that predict underweight. For this step, I use Indian-standard cut-offs that are consistent with recommendations for studies of the Indian subcontinent, due to the way that elevated risks of heart disease and other negative outcomes develop at lower levels of excess body weight (Agrawal et al. 2014; WHO Expert Consultation 2004):

underweight	≤ 18.5 kg/m^2
normal	18.5 to 22.9 kg/m^2
overweight	23 to 24.9 kg/m^2
obese	≥ 25 kg/m^2

Vegetarianism. Part of NFHS-3 includes a dietary questionnaire, which asks how often respondents consume given food items (four possible responses: weekly, daily, occasionally, or never). I focus on meat, chicken, and fish consumption here. Vegetarians are defined as those who 'never' consume these foods (no meat, chicken, or fish).

Wealth. I use the continuous version of the wealth index variable provided by DHS. This was calculated using principal components analysis to assign each of 33 household assets a weight; the items are household electrification; type of windows; drinking water source; type of toilet facility; type of flooring; material of exterior walls; type of roofing; cooking fuel; house ownership; number of household members per sleeping room; ownership of a bank or post-office account; and ownership of a mattress, a pressure cooker, a chair, a cot/bed, a table, an electric fan, a radio/transistor, a black and white television, a color television, a sewing machine, a mobile telephone, any other telephone, a computer, a refrigerator, a watch or clock, a bicycle, a motorcycle or scooter, an animal-drawn cart, a car, a water pump, a thresher, and a tractor. Scores are then standardized to a normal distribution (IIPS and Macro International 2007, vol. I, p. 43). In supplementary analyses (see appendices), I then use the wealth index score to derive neighborhood-level wealth as the PSU-mean; this step is taken before narrowing the analytic sample to non-pregnant, non-breastfeeding women ages 20+, in order to ensure that the most information available is included in the neighborhood wealth score.

Type of place of residence. There are six distinctions available to differentiate places based on degree of urbanization: rural areas; small towns (population < 50,000); large towns (50,000-100,000); small cities (100,000-1 million); large cities (1-5 million); and the largest population centers, or mega cities (population ≥ 5 million). Dummy variables were used in the regressions with 'small town' as the reference category.

Other covariates. Occupation is used as a proxy for both social class and physical activity. Occupation reports are also used to derive an estimate for the percentage of the neighborhood working in non-agricultural activities. The percentage not working outside the household is also used to parse out differences between places where a high proportion of women have entered the labor market versus places where most women work at home. Age, education, marital status, and smoking status are also included as controls. Education is measured as years completed; by excluding those < age 20, it is more likely that respondents will have completed their education.

methods

I begin by presenting descriptive statistics for my data, showing the distribution across the dependent variables (BMI and obesity) and independent variables of interest. Multivariate ordinary least squares (OLS) and logistic regression are used to predict BMI and obesity (1=obese), respectively. This makes it possible to see how the relationships between the three independent variables of interest (vegetarianism, wealth, and place) are associated with obesity, even after accounting for additional covariates (occupation, age, education, marital status, and smoking). I then turn to the patterning of obesity, wealth, and vegetarianism by place. I separate the sample by type of place of residence, and use logistic regression to predict the likelihood of being obese in each of the six locations. Supplementary analyses separate the sample by neighborhood wealth quintile; these results are presented in the appendices.

results

Table 1 provides an overview of the sample, which includes 75,972 non-pregnant, non-breastfeeding women ages 20+. The average BMI is 22, within the range of what is considered healthy, although about one-fifth of the woman are considered obese using 25 as the BMI cutoff. One-third is vegetarian, consuming no meat, chicken, or fish. The majority of the analytic sample is rural (63%), with the remaining distributed across towns (14%), cities (19%), and megacities (4%).

Table 1. Descriptive statistics

	mean	sd	min	max
body mass index (BMI)	22.0	5.6	14	40
obese (BMI ≥ 25)	0.21	0.4	0	1
vegetarian (1 = no meat, fish, chicken)	0.33	0.5	0	1
household wealth	-0.7	9.9	-18	24
place of residence				
rural	0.63	0.5	0	1
small town (< 50,000)	0.12	0.3	0	1
large town (50,000-100,000)	0.02	0.2	0	1
small city (100,000-1 million)	0.10	0.3	0	1
large city (1-5 million)	0.09	0.3	0	1
mega city (≥ 5 million)	0.04	0.2	0	1
occupation (ref = not working outside home)				
professional/technical/managerial	0.04	0.2	0	1
clerical	0.01	0.1	0	1
sales	0.02	0.1	0	1
agricultural	0.26	0.4	0	1
services	0.04	0.2	0	1
skilled and unskilled manual	0.10	0.3	0	1
age (years)	34.1	8.2	20	49
education (years)	4.9	5.3	0	23
never married	0.10	0.3	0	1
smoker	0.13	0.3	0	1
scheduled caste	0.17	0.4	0	1
scheduled tribe	0.07	0.3	0	1
other backward class	0.39	0.5	0	1

*weighted statistics, N = 71,200 (unweighted N = 75,972)

The majority of the sample do not work outside the home; this category is used as the reference for subsequent regression analyses. The most common occupation is agricultural work (26%); given the amount of physical labor required, it is likely that these women have lower BMIs and are less likely to be obese. Another 10% are involved in skilled and unskilled manual labor, an occupational status likely to confer some protective effects against overweight due to the physical activity involved. Conversely, professions that involve more sitting and office work likely lead to higher body weights.

Table 2 (next page) shows regression results. The first columns under OLS and under logistic regression show the parameters for the bivariate relationships. The coefficient for vegetarianism is positive, and the odds ratio of 1.2 shows that, without any controls, vegetarians on average have *higher* BMI than non-vegetarians in India. Household wealth and degree of urbanization are similarly positively associated with higher BMI and obesity. The results of the full models, however, show that once accounting for wealth and degree of urbanization, the coefficient switches direction and is negatively associated with BMI. Similarly, the odds of a vegetarian being obese are 12% less than the odds of a non-vegetarian after controls are introduced, indicating that there is indeed a protective effect of plant-based eating. Interaction effects between vegetarianism and household wealth were tested but not significant, which suggests that structural and place-based characteristics likely matter more than the purchasing power of the household.

Table 2. Vegetarianism, wealth, and place predict BMI and obesity (BMI ≥ 25)

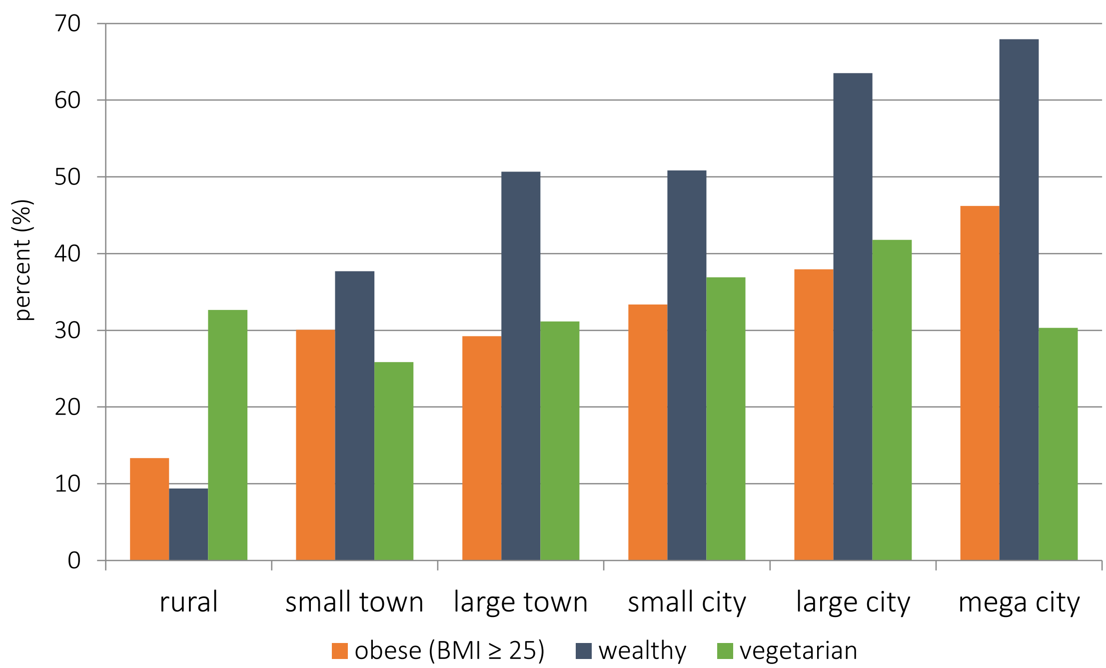
	OLS results withBMI				logistic regression (1 = obese)			
	bivariate		full model		bivariate		full model	
	b	se	b	se	odds ratio	se	odds ratio	se
vegetarian	0.46***	(0.04)	- 0.23***	(0.04)	1.20***	(0.03)	0.88***	(0.02)
household wealth	0.21***	(0.00)	0.15***	(0.00)	1.09***	(0.00)	1.07***	(0.00)
place								
rural	- 2.32***	(0.06)	- 0.75***	(0.06)	0.36***	(0.01)	0.70***	(0.03)
small town (ref)	---		---		---		---	
large town	- 0.08	(0.14)	- 0.49***	(0.13)	0.96	(0.07)	0.79**	(0.06)
small city	0.61***	(0.08)	0.11	(0.08)	1.16***	(0.05)	0.95	(0.04)
large city	1.44***	(0.09)	0.56***	(0.08)	1.42***	(0.06)	1.02	(0.05)
mega city	3.30***	(0.11)	2.23***	(0.11)	2.00***	(0.09)	1.37***	(0.07)

Observations: N = 75,972. Covariates not shown: occupation, age, education, marial status, smoker, and caste. Full table in appendix A. Standard errors in parentheses. * p <.05, ** p < .01, *** p < .001

Therefore, turning to the second research question, I now examine the patterning of obesity, wealth, and vegetarianism by degree of urbanization. Figure 3 (below) groups the weighted sample by type of place of residence, using the six categories denoting various degrees of urbanization that range from rural to megacities. The first set of bars (in orange) denote the percent of the sample that is obese. Consistent with what would be expected, this number rises with more urbanization, from a low in rural places of 13% to a high of 46% in megacities. The blue bars show the percent of households in the top third of the all-India wealth distribution based on assets. Like with obesity, average household wealth is lowest in rural places and then generally higher across towns then cities by population size.

Figure 3. Place-based differences

Obesity, wealth, & vegetarianism by type of place of residence

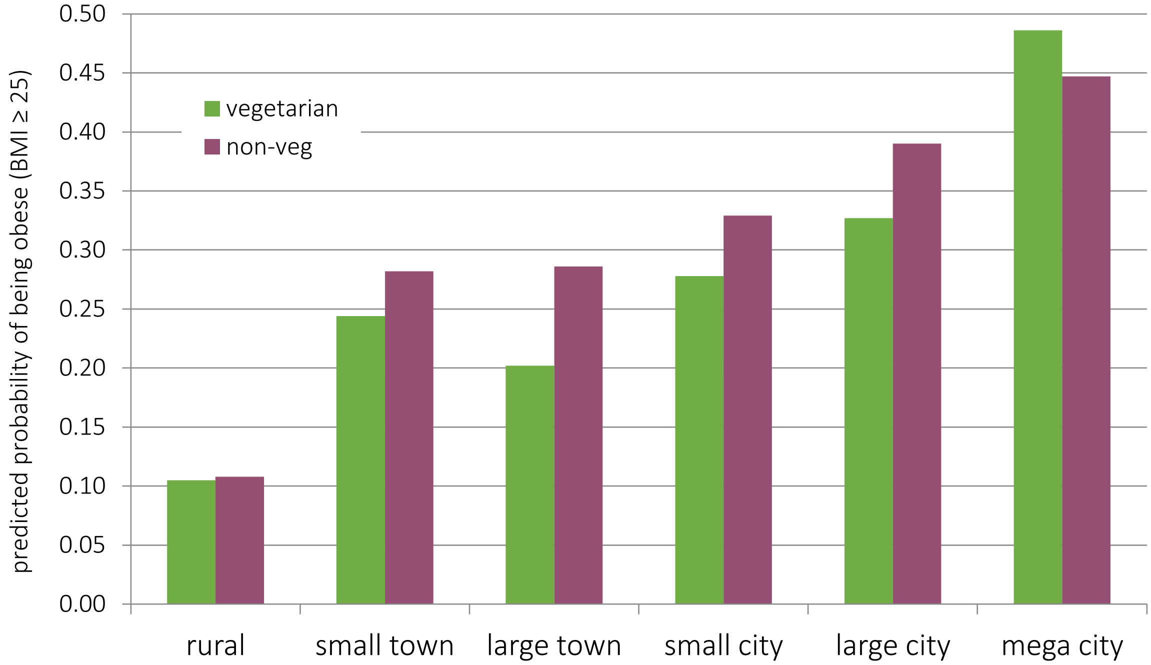


Unlike the relatively straightforward patterning of obesity and wealth, the percent vegetarian shows more nuance. Almost one-third of rural women are vegetarian, but then this number declines to 26% of women in small towns. It is then higher in large towns and cities, with large cities having the highest percent vegetarian (42%). In megacities, this is notably lower: only 30% of mega city residents are vegetarian.

In order to further investigate these findings, six logistic regressions were done to predict the likelihood of being obese across degrees of urbanization for vegetarians versus non-vegetarians (see appendix B). Figure 4 shows the predicted probabilities calculated separately by place.

Figure 4. Protective Effects of Plant-Based Diets by Place

Probability of being obese by vegetarian status by type of place of residence



In rural areas, there is no significant difference between vegetarians and non-vegetarians; about 10% are obese. However, a protective effect appears as vegetarians (green bar) are less likely to be obese than non-vegetarians in towns and cities. In large towns, there is a 8.4 point difference between the two groups. Quite surprisingly, however, the relationship reverses in mega cities: vegetarains are actually four points *more* likely to be obese than non-vegetarians after controlling for wealth and other covariates.

discussion

Vegetarians in India have higher BMIs on average than non-vegetarians, but these differences are driven by household wealth and type of place of residence. Once controlling for wealth, urbanization, and covariates including occupation to control for differences in physical activity, it is clear that vegetarianism is on average *protective*. This finding is consistent with literature showing that plant-based diets generally confer more benefits than those with a high content of animal protein. Interestingly, this effect does not seem to operate the same way in mega cities, where vegetarians appear to be more likely than non-vegetarians to be obese.

On the surface, it is unclear as to what could be driving these differences. Based on the literature and findings from other settings, however, it is likely that the food environments are very different in mega cities. Patterns of physical activity could also diverge from smaller cities and towns. Additionally, due to the structure of data collected in the DHS, it is possible that slums and the food environments in those areas could be affecting the results. Additional analyses could delve more deeply into the possible interaction between vegetarianism, neighborhood wealth, and place of residence.

Moving forward, future work may also explore more nuanced specifications of vegetarianism, such as separating out those who are vegans (no dairy, eggs, meat, chicken, or fish) and pescatarians (no meat or chicken but fish allowed), and possibly looking at frequency of consumption to check whether a predominantly plant-based diets has the same health benefits as one that always excludes these items.

In sum, it is important to further examine place-based divergence of the protective effects of plant-based eating. Characteristics of the food environment such as fast food restaurant availability and affordability and supermarkets are challenging to measure at the national level, but undoubtedly play a role in shaping dietary habits and subsequently health across India. It would also be important to further develop the idea of institutionalized vegetarianism; some states and localities have clear prohibitions against cattle slaughter; but these places could also be wealthier if the concentration of high-caste groups has been high historically. Higher levels of wealth are often associated with more Westernized eating patterns, as even McDonald's in India offers vegetarian options. Due to the institutionalized nature of vegetarianism across some of India, the nutrition transition could unfold without a concomitant increase in meat consumption. Yet to the extent that the consumption of dairy and processed/refined foods replaces traditional eating habits, diet-related non-communicable disease will likely rise nonetheless. A better understanding of how this protective effect of vegetarianism operates in towns and smaller cities could thus be key to preventing future growth in obesity rates and other DR-NCDs.

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Appendix A. Full results for Table 2. Vegetarianism, wealth, and place predict BMI and obesity (BMI ≥ 25)

	OLS results withBMI				logistic regression (1 = obese)			
	bivariate		full model		bivariate		full model	
	b	se	b	se	odds ratio	se	odds ratio	se
vegetarian	0.46***	(0.04)	- 0.23***	(0.04)	1.20***	(0.03)	0.88***	(0.02)
household wealth	0.21***	(0.00)	0.15***	(0.00)	1.09***	(0.00)	1.07***	(0.00)
place								
rural	-2.32***	(0.06)	- 0.75***	(0.06)	0.36***	(0.01)	0.70***	(0.03)
small town (ref)	---		---		---		---	
large town	-0.08	(0.14)	- 0.49***	(0.13)	0.96	(0.07)	0.79**	(0.06)
small city	0.61***	(0.08)	0.11	(0.08)	1.16***	(0.05)	0.95	(0.04)
large city	1.44***	(0.09)	0.56***	(0.08)	1.42***	(0.06)	1.02	(0.05)
mega city	3.30***	(0.11)	2.23***	(0.11)	2.00***	(0.09)	1.37***	(0.07)
occupation (ref = not working)								
professional/technical/managerial			- 0.26*	(0.10)			0.89*	(0.05)
clerical			- 0.51**	(0.18)			0.84	(0.08)
sales			0.29*	(0.13)			1.10	(0.08)
agricultural			- 0.73***	(0.05)			0.59***	(0.03)
services			0.10	(0.10)			0.95	(0.06)
skilled and unskilled manual			- 0.59***	(0.06)			0.78***	(0.03)
age (centered)			0.09***	(0.00)			1.05***	(0.00)
education (centered)			0.02***	(0.01)			1.01*	(0.00)
never married			- 0.77***	(0.07)			0.67***	(0.03)
smoker			- 0.74***	(0.06)			0.70***	(0.03)
scheduled caste			- 0.24***	(0.06)			0.93	(0.04)
scheduled tribe			- 0.30***	(0.08)			0.68***	(0.05)
other backward class			- 0.09*	(0.04)			0.99	(0.03)
constant			22.21***	(0.04)			0.35***	(0.01)

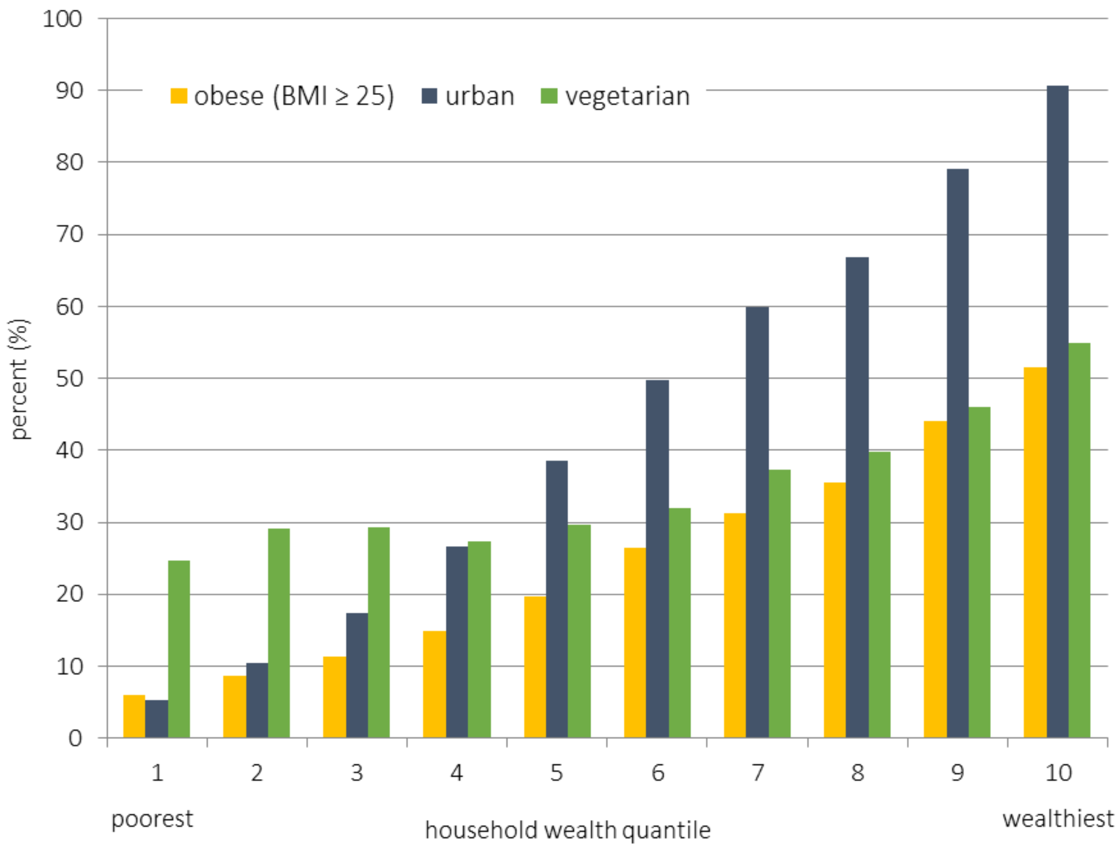
Observations: N = 75,972. Standard errors in parentheses. * p <.05, ** p < .01, *** p < .001

Appendix B1. Logistic regression results predicting obesity (BMI ≥ 25) by type of place of residence

	(1)	(2)	(3)	(4)	(5)	(6)
	rural	small town	large town	small city	large city	mega city
vegetarian	0.97	0.82**	0.63**	0.78***	0.76***	1.17*
	(0.04)	(0.06)	(0.09)	(0.06)	(0.05)	(0.09)
household wealth	1.08***	1.06***	1.07***	1.07***	1.06***	1.03***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
occupation (ref = not working)						
professional/technical/managerial	0.85	0.94	0.78	1.00	0.78*	1.01
	(0.09)	(0.13)	(0.21)	(0.14)	(0.10)	(0.13)
clerical	1.06	0.88	0.89	0.72	0.82	0.66**
	(0.22)	(0.23)	(0.46)	(0.18)	(0.19)	(0.11)
sales	1.23	1.03	0.93	1.26	0.91	0.77
	(0.15)	(0.19)	(0.41)	(0.25)	(0.18)	(0.13)
agricultural	0.63***	0.45***	0.19*	0.50*	0.19***	0.39
	(0.03)	(0.08)	(0.13)	(0.15)	(0.09)	(0.27)
services	1.12	0.80	0.88	0.78	0.88	0.89
	(0.13)	(0.13)	(0.28)	(0.12)	(0.12)	(0.11)
skilled and unskilled manual	0.69***	0.93	0.72	0.90	0.75*	0.76*
	(0.05)	(0.11)	(0.19)	(0.10)	(0.08)	(0.09)
age (centered)	1.04***	1.05***	1.06***	1.06***	1.06***	1.05***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
education (centered)	1.00	1.02*	1.04	1.01	1.01	1.01
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
never married	0.75**	0.59***	0.48**	0.62***	0.66***	0.95
	(0.07)	(0.07)	(0.12)	(0.08)	(0.08)	(0.10)
smoker	0.68***	0.57***	1.01	0.84	0.93	0.54***
	(0.04)	(0.07)	(0.26)	(0.11)	(0.14)	(0.09)
scheduled caste	1.02	0.87	0.85	0.87	0.80*	0.92
	(0.06)	(0.09)	(0.20)	(0.09)	(0.09)	(0.09)
scheduled tribe	0.76**	0.74	0.54	0.43***	0.40***	1.15
	(0.06)	(0.14)	(0.18)	(0.11)	(0.11)	(0.38)
other backward class	0.99	1.06	0.88	1.00	0.97	0.85*
	(0.04)	(0.08)	(0.14)	(0.08)	(0.07)	(0.07)
N	38209	10712	2946	6182	12458	5465

Odds ratios shown. Standard errors in parentheses. * p <.05, ** p < .01, *** p < .001

Appendix C. Wealth gradients: Obesity, urban status, & vegetarianism by household wealth



Appendix D1. Logistic regression results predicting obesity (BMI ≥ 25) by neighborhood wealth quintile

	(1) poorest neighborhoods	(2) poor	(3) middle	(4) wealthy	(5) wealthiest neighborhoods
vegetarian	1.09	0.96	0.78***	0.79***	0.87**
	(0.09)	(0.07)	(0.05)	(0.04)	(0.04)
household wealth	1.07***	1.07***	1.06***	1.06***	1.06***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
urban (ref: rural)	2.21***	1.03	1.28***	1.18**	1.05
	(0.47)	(0.10)	(0.08)	(0.06)	(0.09)
occupation (ref = not working)					
professional/technical/managerial	1.08	0.67	0.84	0.83	1.00
	(0.31)	(0.15)	(0.13)	(0.09)	(0.08)
clerical	1.33	1.21	0.74	0.81	0.86
	(0.68)	(0.52)	(0.24)	(0.14)	(0.11)
sales	1.00	1.49	1.02	1.15	0.93
	(0.25)	(0.33)	(0.17)	(0.15)	(0.13)
agricultural	0.65***	0.67***	0.53***	0.61***	0.81
	(0.06)	(0.05)	(0.05)	(0.07)	(0.24)
services	1.14	0.92	1.02	0.70***	1.08
	(0.29)	(0.18)	(0.13)	(0.07)	(0.13)
skilled and unskilled manual	0.65**	0.68**	0.77**	0.68***	1.07
	(0.10)	(0.09)	(0.07)	(0.06)	(0.10)
age (centered)	1.03***	1.05***	1.05***	1.05***	1.06***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
education (centered)	1.02	1.01	1.00	1.00	1.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
never married	1.08	0.90	0.63***	0.62***	0.72***
	(0.22)	(0.13)	(0.07)	(0.06)	(0.06)
smoker	0.89	0.58***	0.69***	0.80*	0.74*
	(0.09)	(0.06)	(0.07)	(0.08)	(0.10)
scheduled caste	1.07	0.91	1.00	0.79***	0.96
	(0.13)	(0.09)	(0.08)	(0.06)	(0.08)
scheduled tribe	0.77	0.87	0.69*	0.54***	0.56***
	(0.11)	(0.14)	(0.10)	(0.09)	(0.10)
other backward class	0.99	1.01	1.02	0.97	0.97
	(0.10)	(0.08)	(0.07)	(0.05)	(0.05)
N	11758	13266	15379	17650	17919

Odds ratios shown. Standard errors in parentheses. * $p < .05$, ** $p < .01$, *** $p < .001$

Appendix D2. Anoter View of the Protective Effects of Plant-Based Diets
Predicted probabilities of being obese by vegetarian status across neighborhood wealth