Stratification of Nutritional Experiences Among Older Adults Within and Across Countries

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Introduction

Much research has been conducted on the prevalence of under-nutrition and its consequences in less developed countries, but nutritional problems in these countries have actually become more complicated, as the improvements made in reducing under-nutrition have been accompanied by the even more rapidly increasing prevalence of over-nutrition. From population health and economic standpoints, the double burden of malnutrition, or the co-existence of under- and over-nutrition at relatively high levels, is problematic. Consequences include health care expenditures, and adverse effects on mortality, morbidity, and productivity (Haddad, Cameron, and Barnett 2015). Both ends of the nutritional spectrum are significant problems in many low- and middle-income countries (Shrimpton and Rokx 2012). As a result, these diametrically opposing problems warrant further study, especially in conjunction with each other.

Additionally, under- and over-nutrition, as measured by body mass index (BMI), usually affect different segments of the population. In India, for example, "the distribution of underweight and overweight … remains socially segregated," where the segregation is along dimensions of socioeconomic status (Subramanian et al. 2009). With the heterogeneity among low- and middle-income countries, a natural question is whether the relationship of such characteristics with these nutritional extremes are consistent across these countries. To efficiently target available resources, it would be valuable to know which population segments within a country suffer from which nutritional extreme, as it would provide some insight as to where appropriate interventions should be directed.

I use the World Health Organization (WHO) Study on global AGEing and adult health (SAGE) to examine within-country nutritional disparities among older adults in six different countries – China, Ghana, India, Mexico, Russia, and South Africa. These six countries vary drastically in terms of geography, history, and culture, and should give insight as to how similar or different the patterns of nutritional problems are across countries. I analyze the patterns of nutritional status along various dimensions of development – place of residence, educational attainment, and wealth. Here, nutritional status, as measured by BMI, is classified as underweight, normal, pre-obese, and obese. I then analyze how these associations vary depending on a country's level of development.

The first analysis looks into within-country differences and how country-specific interventions could be used to address nutritional problems within a population by pinpointing certain sociodemographic sub-groups. The second analysis investigates between-country differences and how country-level development might be associated with these patterns of nutritional stratification. Taken together, these analyses attempt to examine the stratification of nutritional experiences along the development spectrum, with an ultimate goal of hopefully being able to contribute to policy decisions and disparity reduction.

Background

As countries develop, transformations take place in many aspects of society. "As incomes rise and populations become more urban, societies enter different stages of what has been called the nutrition transition. Generally, diets high in complex carbohydrates and fiber give way to more varied diets with a higher proportion of fats, saturated fats, and sugars" (Drewnowski and Popkin 1997). At some point during the nutrition transition, the prevalence of under-nutrition remains stable or starts to decline, while the prevalence of over-nutrition increases.

Progress has been made in reducing underweight prevalence, though it still is at worrisome levels in many developing countries. But at the same time, overweight prevalence is increasing dramatically, making the issue of overweight grow in both absolute and relative importance. Of 36 developing countries studied between 1992 and 2000, overweight prevalence for women actually exceeded underweight prevalence in more than half of these countries. Within these 36 countries, a high prevalence of overweight and a low prevalence of underweight is more common among countries with higher levels of urbanization and higher per capita gross national incomes, proxies of greater economic development, as in Mexico, South Africa, and Turkey (Mendez et al. 2005).

The above study compares countries, but underweight and overweight prevalences are not distributed evenly within countries. It would be worthwhile to determine which segments of the population have higher concentrations of underweight or overweight, and whether this is consistent across countries at different stages of the nutrition transition, as this could have important implications for policy interventions. What kinds of patterns have been found with regard to development-related characteristics?

In developing countries, underweight and overweight prevalences are generally problems of rural and urban areas, respectively. In Gambia, the prevalence of adult under-nutrition is still higher than that of adult obesity. And while under-nutrition seems to affect all layers of society, over-nutrition is "mainly confined to urban women 35 years or older" (van der Sande et al. 2001). The increase in overweight prevalence in China is driven by urban dwellers, while the overall decline in underweight prevalence is not observed among male rural residents (Popkin et al. 1995). Potential reasons for these patterns include more access to unhealthy foods and more sedentary lifestyles in urban areas (Caballero 2005).

Mendez et al. find in their between-country study that, while the overweight populations are generally larger than the underweight populations, the median ratio of overweight to underweight is 5.8 in urban areas and 2.1 in rural areas. In the more developed of these countries, the urban-rural differences diminish (Mendez et al. 2005). Urban-rural differentials in BMI are not found in overweight and obesity prevalence in ten European countries (Peytremann-Bridevaux et al. 2007), though interestingly, in the United States, it has been found that adults living in rural areas are more obese than their counterparts in urban areas (Befort, Nazir, and Perri 2012). If these countries are lined up by increasing level of development, over-nutrition starts off as being a greater issue for the urban dwellers, and slowly shifts to becoming a greater issue for those in rural areas.

Such a shift has also been observed in the relationship between socioeconomic status and nutritional experiences as countries develop. The association between socioeconomic status and over-nutrition is negative in developed societies, but positive in developing societies (Sobal and Stunkard 1989; McLaren 2007). There are various dimensions of socioeconomic status, such as income, wealth, and education, that would be important to analyze.

Neuman et al. find in their study of 37 low- and middle-income countries that there was a consistently positive association between BMI and household wealth quintile between 1991 and 2003, and that this pattern still held for 36 out of 37 countries based on surveys conducted between 1998 and 2008 (Neuman et al. 2011). However, as countries develop, obesity prevalence extends to other segments of the population and is no longer a problem reserved for people of high socioeconomic status (Monteiro et al. 2004). In a study of 54 low- and middle-income countries, a monotonic pattern of decreasing overweight prevalence is generally observed among females as one goes down the wealth quartiles. But in the richer of these 54 countries, women in the wealthiest quartile are actually less likely to be overweight than those in the second- and third-richest quartiles (Subramanian et al. 2011). These patterns show that higher income and greater access to unhealthy foods might be counterbalanced with increased knowledge and better healthcare (Caballero 2005). While educational attainment and income are positively correlated, it could be that more education prevents people from being at either nutritional extreme due to knowledge on health and nutrition. Having a low level of education is positively associated with underweight prevalence in men, but not women, in Iran. In this same sample, overweight and obesity are more common among both men and women with low educational attainment (Janghorbani et al. 2007).

These studies have documented shifts in patterns of nutritional status as countries develop. What mechanisms might there be for these shifts? As countries develop, occupations comprising the workforce tend to shift from those requiring more energy expenditure to those that are less physically demanding. That, combined with more leisure activities at home (e.g., watching television) and perhaps fewer opportunities for exercise in urban areas, leads to more sedentary lifestyles (Goryakin and Suhrcke 2014). In addition, globalization of low- and middle-income countries has led to the diffusion of nutritional habits from higher-income countries. Food consumption patterns have shown signs of convergence toward a more western diet, which is higher in calories, fats, refined carbohydrates, and processed foods (Popkin et al. 2012; Goryakin and Suhrcke 2014). Increased demand for these foods also gives rise to the spread of global supermarket chains and fast food restaurants, further perpetuating the problem (Pingali 2007).

The interrelation between under- and over-nutrition demonstrates why it is necessary to study these two nutritional extremes simultaneously, and which is what many previous studies fail to take into account. For each country, which population segments are important to target for each of the two nutritional extremes? It is certainly important to look at the stratification of nutritional experiences within each country to determine where efforts need to be directed toward ameliorating both under- and over-nutrition, but previous literature highlights why it might also be important to look at countries together. Can a one-size-fits-all policy work for different countries? If not, are there discernible patterns? The strong connection between development and the nutrition transition puts forward a reasonable hypothesis, that there is a continuum in the relationship between under-/over-nutrition and development-related characteristics. Studying countries together might help to isolate the points of development associated with trend reversals in an effort to understand when shifts in priorities might be appropriate. Both these within- and between-country differences are important for aid allocations and interventions.

Data and Methods

For my analyses, I use the first wave of SAGE, which was implemented between 2007 and 2010. SAGE is an ongoing longitudinal study (though data from later waves have yet to be released) of health and well-being in China, Ghana, India, Mexico, Russia, and South Africa that focuses mostly on people aged 50 years or over (WHO 2017b). The objective is to study the relationship of categorical and continuous BMI, calculated using measured height and weight, with various development-related (place of residence, educational attainment, and wealth) and demographic (sex and age) factors among older adults in these six countries.

The dependent variable in these analyses is BMI. There is a clear ordering of BMI categorizations. Underweight is defined as BMI < 18.5 kg/m^2, normal as 18.5 kg/m$^2 \leq$ BMI < 25 kg/m^2, pre-obese as 25 kg/m$^2 \leq$ BMI < 30 kg/m^2, and obese as BMI ≥ 30 kg/m^2 (WHO 2006). Consequently, performing a multinomial logistic regression would sacrifice parsimony and interpretability. On the other hand, while a conventional ordinal logistic model would take the ordering into account and simplify the analysis and its resulting interpretation, the proportional odds assumption has been tested and generally rejected. A partial proportional odds model for an ordinal dependent variable would provide an alternative that falls in between, by relaxing the proportional odds assumption for certain variables while being more parsimonious and interpretable than a multinomial logistic regression model (Williams 2006). As a result, a partial proportional odds model for each of the six countries is run to quantify the relationship between BMI category and various social, economic, and demographic characteristics.

All of the independent variables used in the analyses are categorical, except for age. The reference group is male for sex, urban for place of residence, less than high school for educational attainment, and the first quartile for wealth. Respondents in the SAGE surveys are asked about asset ownership. I compile whether these respondents' households have the following – electricity, bicycle, car, mobile phone, computer, television, land, and jewelry. However, ownership of one asset is likely dependent on ownership of another asset. I create an asset index that linearly combines these binary variables together using principal components analysis (PCA) (Vyas and Kumaranayake 2006). For each of the six countries, the first principal component already explains about 95% of the variance among observations, so only this first one is used. This way, an index representing wealth is constructed without unnecessarily increasing the dimension of the problem. One of the issues with using PCA is interpretability, as a unit in the wealth index does not translate into the ownership of a certain asset. Thus, instead of using the principal component as a continuous variable, I convert it into a categorical variable of wealth quartiles, with the first and fourth quartiles representing the poorest and the richest, respectively. Even if such an index were interpretable, an absolute measure is not ideal as different countries have different standards of living.

I restrict my study sample to those at least 50 years of age to focus on the experiences of older adults. Due to the age of survey participants in these analyses, pregnancy is unlikely to be an issue. Observations with missing data on any of the variables are excluded by listwise deletion, and the resulting sample sizes for China, Ghana, India, Mexico, Russia, and South Africa are 8892, 1842, 3106, 1557, 3372, and 2240 respectively.

While I am not using the longitudinal aspect of the SAGE survey (the second wave has not been released for all countries), there is still something to be said about development and the nutrition transition. The six countries in this study are at different stages of development. By suitably ordering these countries, it would be possible to overlay the process of development with the nutrition transition. To this end, I use national gross domestic product (at purchasing power parity) per capita (GDPpC) in the year 2010, measured in current international dollars, as a measure of development. According to GDPpC in 2010, the ordering of these six countries from least to most developed is Ghana (2998), India (4316), China (9333), South Africa (11,647), Mexico (14,765), and Russia (20,498) (The World Bank 2018). If development is indeed an important player in the landscape of nutritional experiences, the coefficients across countries for a specific variable should reflect the GDPpC rankings of these countries.

Differences between countries could be attributable to a myriad of factors, as these countries are so heterogeneous. I need a method to test my hypothesis that these differences are associated with level of development. Instead of studying each of the six countries separately, I combine the data from all six countries and use the same independent variables as before, along with the natural logarithm of GDPpC and interactions between log(GDPpC) and the development-related covariates. These additional variables would help determine whether BMI category is associated, not only with an individual's characteristics, but also with the level of development of the country where the individual is. There are a few advantages to doing this – I have a simplified and unifying model, quantifying the association of BMI with level of development (if one exists), and providing a way to make predictions for individuals in a country other than the six in SAGE.

All analyses so far treat BMI as a categorical variable. However, one might not be interested in the association of a specific category of nutritional status with other variables, but in the association of BMI with other variables. Thus, additional models are studied where BMI is used as a continuous dependent variable in multiple regressions. While the interpretations might be different, the stories are actually quite similar. These results can be found in the Appendix.

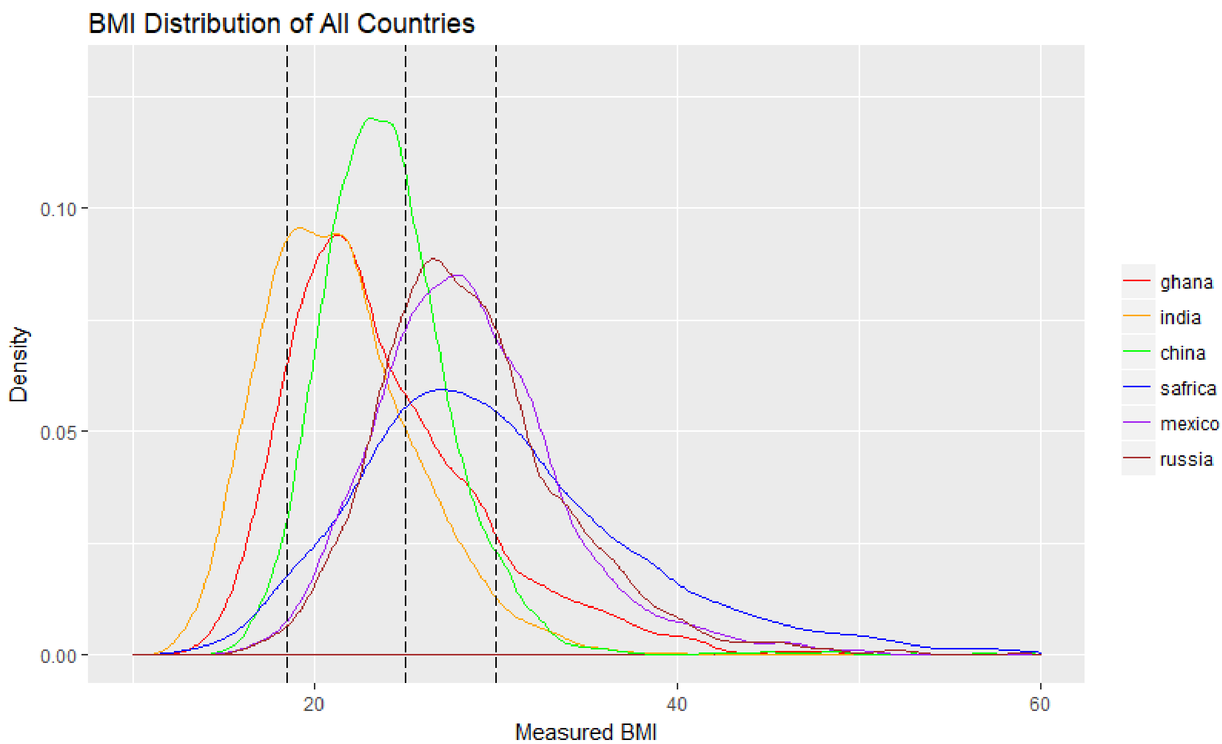
Most analyses are run in R (version 3.4.1) (R Core Team 2017). Partial proportional odds models are run in Stata using the gologit2 package (Williams 2006). When discussing the results, the term "significant" means significant at the level of five percent.

Results

Distribution of BMI and BMI categories:

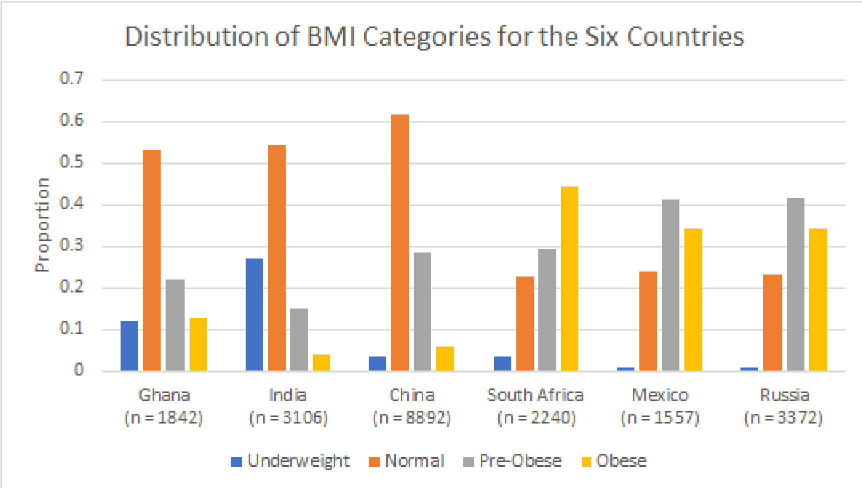
Figure 1 shows the BMI distribution for each of the six countries – China, Ghana, India, Mexico, Russia, and South Africa. Extreme BMI values above 60 kg/m^2 (only 51 values out of 21,009 observations, or about 0.24%) have been removed to prevent long tails from distorting the overall picture. The left, middle, and right dotted vertical lines represent respectively the thresholds between underweight and normal, between normal and pre-obese, and between pre-obese and obese.

Figure 1: BMI density curves for the six countries



There appear to be three distinct groups of countries in Figure 1. India and Ghana are at the lower end of the BMI distribution, Russia, Mexico, and South Africa are at the higher end, and China falls somewhere in between. The BMIs of these countries differ not only in their means, but also in their variations. The spread in South Africa is largest whereas the distribution in China is tightest. These density curves are drawn with BMI as a continuous variable. Figure 2 shows the proportion of people in each BMI category (underweight, normal, pre-obese, and obese), along with the sample sizes for the six SAGE countries, arranged in ascending order of GDPpC. It describes how adult nutritional status varies across the six countries in this analysis.

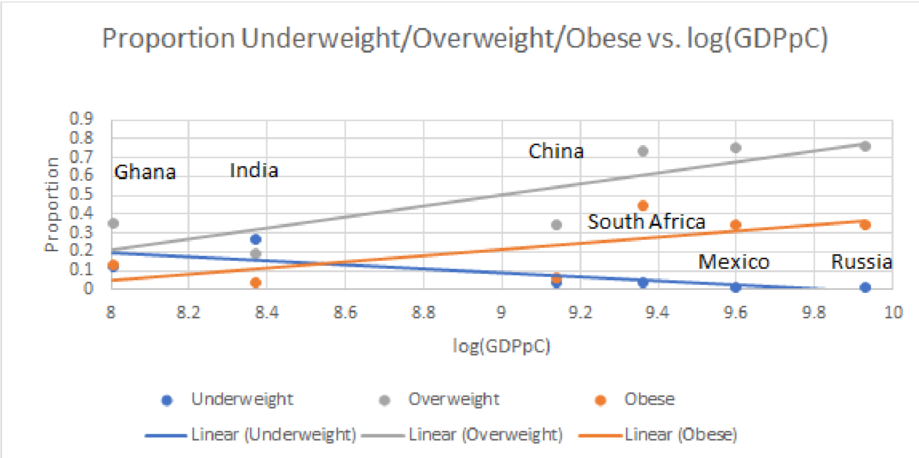
Figure 2: Distribution of BMI categories for the six countries



In Ghana, India, and China, more than half of the samples are in the normal category. In Ghana and China, pre-obese is the next largest group, followed by obese and underweight. In India, underweight is the second largest group, followed by pre-obese and obese. Of the six countries, India has the largest proportion of underweight at 27%. In South Africa, Mexico, and Russia, more than 70% of the sample populations are either pre-obese or obese, followed by normal, and then underweight. In Mexico and Russia, not even one percent is classified as underweight. While South Africa has a slightly more sizable proportion of underweight than Mexico and Russia, it is also the only country in which obese actually overtakes pre-obese. Besides India, which still shows a heavy underweight burden, the other five countries seem to have a greater over-nutrition problem that needs to be addressed.

To foreshadow the importance of development levels, I plot the proportions of underweight, overweight (pre-obese and obese), and obese in the country samples against log(GDPpC) of each of the six SAGE countries in Figure 3 below. The least-squares line for each nutritional status is also illustrated.

Figure 3: Proportions of underweight, overweight, and obese versus log(GDPpC)

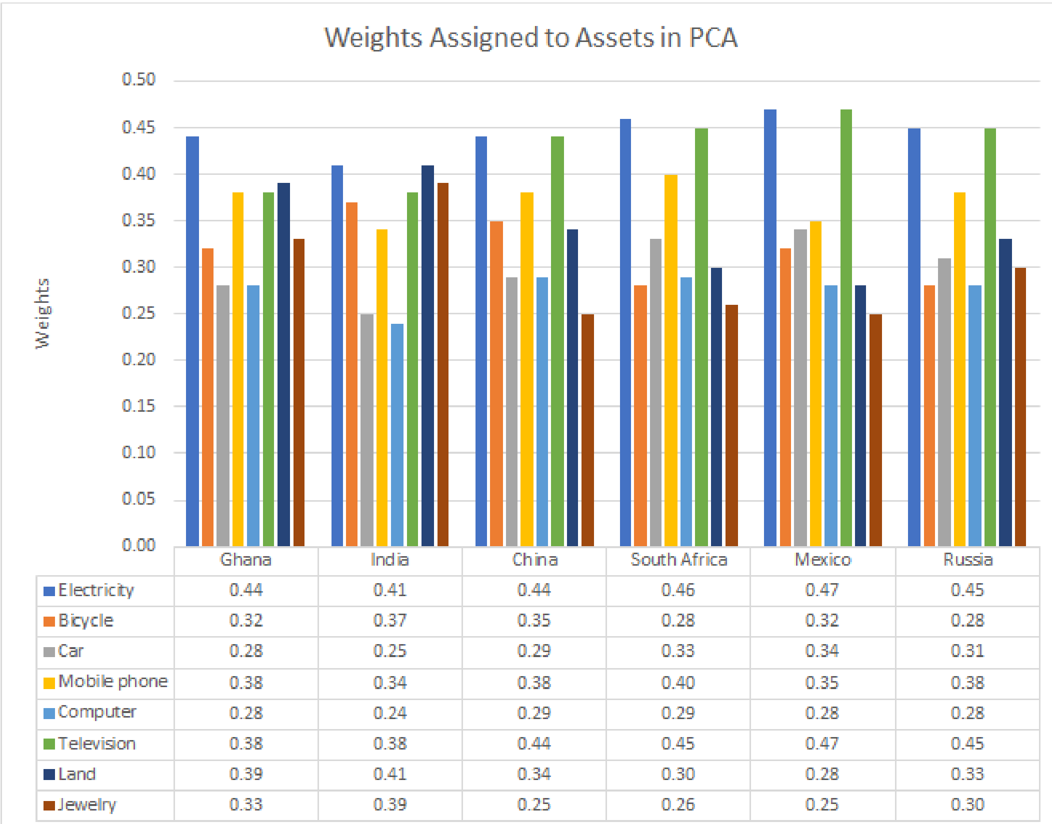


Generally, proportion of underweight is negatively associated with log(GDPpC), whereas proportions of overweight and obese are positively associated with log(GDPpC), in agreement with previous findings on nutritional status and development. The obese line is lower than the overweight line, which is expected, as obese is a subset of overweight. India is an interesting outlier here, with its underweight prevalence higher than its overweight prevalence.

Quantifying wealth:

Before running models, I perform PCA on the eight asset variables for each country. Figure 4 illustrates the weights assigned to the assets, both numerically and with a bar chart. These allow for comparison among assets and provide information on their relative importance.

Figure 4: Weights assigned to assets in PCA



	Ghana	India	China	South Africa	Mexico	Russia
Electricity	0.44	0.41	0.44	0.46	0.47	0.45
Bicycle	0.32	0.37	0.35	0.28	0.32	0.28
Car	0.28	0.25	0.29	0.33	0.34	0.31
Mobile phone	0.38	0.34	0.38	0.40	0.35	0.38
Computer	0.28	0.24	0.29	0.29	0.28	0.28
Television	0.38	0.38	0.44	0.45	0.47	0.45
Land	0.39	0.41	0.34	0.30	0.28	0.33
Jewelry	0.33	0.39	0.25	0.26	0.25	0.30

All of the weights have the same sign, meaning that they all contribute to the wealth index. That is, having any of these assets is associated with wealth. Generally, it appears that electricity, mobile phone, and television have the greatest weights in the wealth index. In Ghana and India, land also seems to have a sizeable contribution. Country-specific wealth quartiles are used in the analyses below.

Associations between under- and over-nutrition with development-related factors:

Figure 5 has nine panels showing the bivariate relationships between the proportions of underweight, overweight (pre-obese and obese), and obese with the development-related characteristics. All of these variables will subsequently be studied in a multivariate framework.

Figure 5: Relationships between proportions of underweight, overweight, and obese with development-related characteristics

Consider first the panels on the left that show the relationships between proportion of underweight and place of residence, education, and wealth. Ghana and India show illustrative patterns. It is clear that the proportion of underweight in these two countries is higher among rural dwellers, the less educated, and the poor. Additionally, the bars for these two countries are monotonically decreasing in height. China and South Africa seem to exhibit similar patterns, although the proportion of underweight is relatively low. It appears that in the most developed country Russia, the bars level out to be around the same height.

Now consider the middle and right panels that illustrate the associations of the proportion of overweight and the proportion of obese with the development-related variables. In all countries except Russia, the proportion of overweight/obese is higher in urban areas. In Russia, the pattern is swapped – the proportion of overweight/obese is higher in rural areas. Support for the hypothesis that a shift would accompany development is evident here. There is a reversal in urban/rural gradients as level of development increases. In Ghana, the proportion of overweight/obese increases monotonically with educational attainment and wealth quartile, and the same general pattern can be seen in India. While this pattern holds for overweight by educational attainment in China and South Africa, it does not for obese. In China, the less than high school bar is the highest, though all three bars are relatively level. In South Africa, the proportion of obese is actually highest for those who have completed high school (the middle education category). These same finding is observed for overweight/obese in Mexico and Russia. Perhaps this population segment has enough resources for sustenance, but does not have the education to choose properly. The pattern is less clear for wealth quartile for the four more developed countries.

Proportional odds models with categorical BMI:

Table 1 shows the coefficients in each country-specific partial proportional odds model. To facilitate the discussion, I rank the nutritional statuses, from low to high, as follows – underweight, normal, pre-obese, and obese. Since all of the covariates are categorical, the coefficients can be interpreted as follows – being in a specific category of an independent variable (relative to the baseline category) changes the log odds of being in a higher BMI category by the value of the coefficient, holding the other variables in the model constant. The first panel shows the logarithm of the odds of being normal, pre-obese, or obese versus being underweight, the second panel shows the logarithm of the odds of being pre-obese or obese versus being underweight or normal, and the third panel shows the logarithm of the odds of being obese versus being underweight, normal, or pre-obese. If the coefficients of a variable are the same in all three panels, the variable satisfies the proportional odds assumption.

Table 1: Log odds from partial proportional odds models with BMI as an ordinal variable in Russia, Mexico, China, South Africa, India, and Ghana

log(P(normal, pre-obese, or obese) / P(underweight))						
	Ghana	India	China	South Africa	Mexico	Russia
Intercept	3.28 ***	2.19 ***	6.04 ***	2.73 ***	7.43 ***	4.72 ***
Female	0.45 **	0.36 ***	–0.05	0.85 ***	–0.42	0.35
Age	–0.03 ***	–0.02 ***	–0.04 ***	–0.00	–0.03 ***	–0.00
Rural	–0.47 **	–0.61 ***	–0.35 ***	–0.17	–0.35 **	0.26
Completed high school	–0.10	0.37 ***	–0.05	0.18	–1.46	0.14
Completed college	–0.01	1.01 ***	0.11	0.22	–0.36 *	–0.12
Second quartile	0.31 *	0.53 ***	−0.01	0.32 **	0.04	–0.57
Third quartile	0.78 ***	0.75 ***	0.13 *	1.29 **	−0.08	0.36 ***
Fourth quartile	1.35 ***	0.86 ***	0.34 *	1.05 **	0.22	0.43 ***

In this table and all tables hereinafter, * denotes significance at the 0.05 level, ** at the 0.01 level, and *** at the 0.001 level.

log(P(pre-obese or obese) / P(underweight or normal))						
	Ghana	India	China	South Africa	Mexico	Russia
Intercept	0.26	–0.72 *	–0.57 **	0.46	3.04 ***	0.80 **
Female	1.08 ***	1.01 ***	0.34 ***	0.85 ***	0.48 ***	0.49 ***
Age	–0.03 ***	–0.02 ***	–0.00	–0.00	–0.03 ***	–0.00
Rural	–0.78 ***	–0.61 ***	–0.35 ***	–0.17	–0.35 **	0.21 *
Completed high school	–0.10	0.37 ***	–0.05	0.18	0.82	0.14
Completed college	–0.01	0.55 ***	0.11	0.22	–0.36 *	–0.12
Second quartile	0.31 *	0.53 ***	−0.01	0.32 **	0.04	0.35 **
Third quartile	0.78 ***	0.64 ***	0.13 *	0.66 **	−0.08	0.36 ***
Fourth quartile	1.35 ***	0.94 ***	0.22 *	0.73 **	0.22	0.43 ***

log(P(obese) / P(underweight, normal, or pre-obese))						
	Ghana	India	China	South Africa	Mexico	Russia
Intercept	–1.34 ***	–2.13 ***	–2.42 ***	–0.70 *	1.02 *	–1.53 ***
Female	1.44 ***	1.30 ***	0.62 ***	0.85 ***	0.77 ***	1.10 ***
Age	–0.03 ***	–0.02 ***	–0.01	–0.00	–0.03 ***	–0.00
Rural	–1.15 ***	–0.61 ***	–0.35 ***	–0.17	–0.35 **	0.56 ***
Completed high school	–0.10	0.37 ***	–0.05	0.18	0.41	0.14
Completed college	–0.01	0.98 ***	0.11	0.22	–0.36 *	–0.12
Second quartile	0.31 *	–0.33	−0.01	0.32 **	0.04	0.22 *
Third quartile	0.78 ***	–0.25	0.13 *	0.22	−0.08	0.36 ***
Fourth quartile	1.35 ***	0.13	−0.10	0.27 *	0.22	0.43 ***

With the exception of China, Mexico, and Russia in the first panel, female is always significant and positive, in all three panels. The three exceptions are all insignificant. The female variable only satisfies the proportional odds assumption in South Africa. In all other countries, the female coefficient is monotonically increasing, meaning that females are more likely to be in a higher category than males and the sex differential increases as one moves up the nutritional categories. Age is significant and negative for Ghana, India, and Mexico in all three panels, and it is also significant and negative for China when comparing normal, pre-obese, or obese versus underweight. That is, holding all else constant, older individuals are less likely to be in a higher category than those who are younger. In the case of China, this is only true when comparing everything above underweight with underweight. Age does not satisfy the proportional odds assumption in China, but it does for the other five countries.

The rural variable is significant for all countries and panels except South Africa in all three panels and Russia in the first. The coefficients are consistently negative for Ghana, India, China, and Mexico, meaning that rural dwellers are less likely to be in a higher category than urban dwellers. The coefficients are less negative for China and Mexico than for India and Ghana. In Ghana, the proportional odds assumption is not satisfied and the coefficients get more negative with each successive panel, meaning that the residential differential becomes greater for higher BMI categories. In Russia, the rural coefficients are positive. That is, rural dwellers tend to be in a higher category than urban dwellers. As with Ghana, the proportional odds assumption is not satisfied in Russia, though the coefficient becomes more positive from the second to the third panels. The differential gets larger here too, but in the opposite direction. Since Russia is the most developed among these six countries, this might not be surprising. The proportional odds assumption is satisfied in India, China, South Africa, and Mexico.

For educational attainment in all three panels, completed high school and completed college are significant and positive for India, and completed college is significant and negative for Mexico. In India, more education is associated with being in a higher category. Furthermore, the coefficient for completed college is more positive than the coefficient for completed high school, meaning that there is a greater propensity of being in a higher category with more education. The proportional odds assumption is not satisfied for completed college in India, but there is not a clear pattern in the coefficients. In Mexico, where the proportional odds assumption is not satisfied for completed high school, the opposite is true. Completed college, relative to less than high school, is negative, so the most educated in Mexico have a lower propensity of being a higher BMI category. The proportional odds assumption is satisfied in all other instances.

All of the significant results for the wealth variables are positive. While there tends to be an increase when climbing up the quartiles (that is, a greater likelihood of being in a higher category when in a higher wealth quartile), the patterns are not always consistent. None of the wealth quartiles is significant for Mexico in these partial proportional odds models, and they are also not significant for India in the third panel, when comparing obese versus underweight, normal, or pre-obese. In such cases, wealth quartile (relative to the first) does not have a significant relationship with a person's likelihood of being in a higher BMI category. The proportional odds assumption does not seem to show any patterns among these countries and panels.

There are statistically different coefficients between countries in Table 1, as tested by added variables for country and country interactions. (Such results are not shown in this paper for brevity.) While innate country characteristics might play a role, level of development could also provide a reason for the differences. As a result, I use the continuous variable log(GDPpC) to explicitly test the association of development. Interactions are included between log(GDPpC) and place of residence, educational attainment, and wealth quartiles, as previous research has provided evidence that there are shifts that accompany development. As a country moves from less developed to more developed, high BMI shifts from a problem of urban areas and high socioeconomic status to one of rural areas and low socioeconomic status. Table 2 shows these results. As opposed to three panels here, the results from each model are displayed side by side.

Table 2: Log odds of variables from partial proportional odds models with BMI as a categorical dependent variable and log(GDPpC) as an additional independent variable

	log(P(normal, pre-obese, or obese) / P(underweight))	log(P(pre-obese or obese) / P(underweight or normal))	log(P(obese) / P(underweight, normal, or pre-obese))
Intercept	–12.41 ***	–12.93 ***	–13.93 ***
Female	0.33 ***	0.57 ***	0.90 ***
Age	−0.03 ***	–0.00 *	–0.01 ***
Rural	−2.94 **	−4.88 ***	−10.30 ***
Completed high school	4.23 ***	1.08	3.07 ***
Completed college	0.10	1.78 *	4.96 ***
Second quartile	0.85	0.85	0.85
Third quartile	0.78	4.03 ***	2.23 *
Fourth quartile	0.60	5.10 ***	4.80 ***
log(GDPpC)	1.86 ***	1.39 ***	1.33 ***
Rural * log(GDPpC)	0.27 *	0.48 ***	1.06 ***
Completed high school * log(GDPpC)	−0.44 ***	–0.11	–0.33 ***
Completed college * log(GDPpC)	0.08	–0.17	–0.53 ***
Second quartile * log(GDPpC)	−0.08	−0.08	−0.08
Third quartile * log(GDPpC)	−0.04	−0.41 ***	−0.22 *
Fourth quartile * log(GDPpC)	−0.00	−0.51 ***	−0.48 ***

Although the coefficients are different, female is significant and positive in all three columns. Females are more likely to be in a higher BMI category than males, though the log odds are higher for pre-obese or obese versus underweight or normal, and even higher for obese versus underweight, normal, or pre-obese. Age is significant and negative for in all three columns. That is, being older decreases the log odds of being in a higher BMI category. Both of these findings are consistent with what have been presented in Table 1. log(GDPpC) is significant and positive in all three columns, so a higher log(GDPpC) is associated with a higher BMI category, though the coefficient becomes less positive from left to right. That is, higher GDPpC pulls people up from underweight more strongly than it pulls people up from normal or pre-obese.

Now, consider the development-related covariates, which have additional interaction terms in the models. Rural and its interactions are significant in all three columns. The negative coefficients of rural suggest that rural dwellers, on average, have a lower propensity of being in a higher BMI category than urban dwellers. However, the coefficients become increasingly negative across the three columns. Without the interactions, this would suggest that the average rural dweller is less likely to be in a higher BMI category than the average urban dweller, and this differential gets even more pronounced up the nutritional status spectrum. On the other hand, the coefficients of the interaction between rural and log(GDPpC) are significant and positive in all three columns, and they become increasingly positive across the three columns. With a high enough level of GDPpC, the pattern switches such that rural dwellers, on average, have a higher propensity of being in a higher BMI category than urban dwellers. Due to the largest magnitudes when comparing obese versus underweight, normal, and pre-obese, the residence differential of these log odds starts off the largest, but the rate at which this gap closes is the quickest as GDPpC goes up.

Completed high school has significant and positive coefficients in the first and third columns, and completed college has significant and positive coefficients in the second and third columns. Those who have higher levels of educational attainment, on average, are more likely to be in a higher BMI category. All of the corresponding interaction coefficients, except for completed college in the second column, are significant and negative. While more education is associated with a higher probability of being in a higher BMI category, the relationship changes in countries that are more developed, where eventually, more education is associated with a lower probability of being in a higher BMI category. The interesting comparisons for the wealth variables are the third and fourth quartiles in the second and third columns. Similar interpretations can be made here as with the education variables. While more wealth is associated with a higher probability of being in a higher BMI category, the relationship changes in countries that are more developed, where eventually, more wealth is associated with a lower probability of being in a higher BMI category. It is also interesting to note that the second quartile and its interaction are insignificant in each of the three columns, suggesting that the first and second wealth quartiles are not statistically different in their relationship with BMI category.

Discussion

Despite all six of these SAGE countries being low- and middle-income countries, there is a great deal of heterogeneity, with regard to nutritional experiences. The distribution of BMI, as well as the prevalence of underweight, normal, pre-obese, and obese, vary by country. Generally, development-related characteristics are related to BMI category. Typically, urban-living, educated, and wealthier older individuals in these countries are more likely to be in a higher BMI category.

While these results are certainly not directly causal in nature, they do reveal something about the relationship between nutritional experiences and development. In low- and middle-income countries, higher levels of education and wealth are still associated with higher BMI category (Jones-Smith et al. 2012). In countries where underweight prevalence is still high, having a higher BMI or being in a higher BMI category than average is not necessarily bad, as being in either nutritional extreme is not ideal. In such cases, development might have positive implications with respect to nutrition status, as it (and processes intertwined with it) might be associated with pulling people out of the underweight category. In countries where over-nutrition is more dominant, backward development is certainly not suggested to pull people down to the normal category. However, the associations found in these analyses and the potential effect of development on nutritional status reported in the literature, e.g., by Drewnowski and Popkin (1997), suggest that programs could be initiated to counter the population health consequences.

Some of these countries might be at a level of development that is at the cusp of a trend reversal, as can be seen, for example, in the case of Russia with the place of residence variable. In the country-specific models for Russia, those who are in urban areas, on average, are less likely to be in a higher BMI category than their counterparts in rural areas. This is counter to the results from the five other countries in this study, but corroborates findings in more-developed countries (Befort, Nazir, and Perri 2012). Of these six countries, Russia is the one with the highest level of economic development.

In countries where under-nutrition is more problematic than over-nutrition and the rural coefficient is negative (such as India), an emphasis on helping rural dwellers gain more access to nourishment might be needed. In countries where over-nutrition is more problematic than under-nutrition and the rural coefficient is negative (such as Ghana, South Africa, China, and Mexico), an emphasis on helping urban dwellers have healthier diets might be appropriate. In countries where over-nutrition is more problematic than under-nutrition and the rural coefficient is positive (such as Russia and other high-income countries), an emphasis on helping rural dwellers have healthier diets might be worth considering.

While this reversal in gradient is not as clear for the other development-related variables, the partial proportional odds model which merges all the country-specific datasets and includes log(GDPpC) interactions makes the case for intertwining processes of development and the nutrition transition, though perhaps at a higher level than these countries are at. The United States is more economically developed than these six countries and is a prime example of a nation that is facing the implications of over-nutrition. At all ages, minority groups and those with low socioeconomic status are disproportionately affected by this obesity epidemic (Wang and Beydoun 2007), as are those living in rural areas (Befort, Nazir, and Perri 2012). As these six SAGE countries become more developed, perspectives on which population segments to target for which nutritional problem might have to switch.

There are a few caveats to note. The development-related characteristics (place of residence, educational attainment, and wealth quartile) are not necessarily comparable across countries. For example, a survey participant in Russia with a college degree is different from a survey participant in Ghana with a college degree with respect to other socioeconomic and development-related factors, despite reaching the same level of education.

There is an additional issue with the wealth index. PCA is used to create this wealth index with assets. I avoid using incomes or expenditures, which suffer from recall bias and could be subject to cyclical fluctuations as a result of the economy, the seasons, etc. Additionally, survey participants in this sample are 50 years of age or older, and their incomes or expenditures might be different at the time of survey from those when they were working adults. Assets, on the other hand, take into account long-term household wealth. However, there is a disadvantage of using assets. Quality of assets is not considered and so there could be differences in the assets themselves (Vyas and Kumaranayake 2006).

I use GDPpC as a proxy for economic development, though development can also take place in non-economic spheres. Consideration has been given to using the Human Development Index (HDI). HDI is "a composite index measuring average achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living," takes into account life expectancy and education as well (UNDP 2016). However, using HDI could result in reverse causality, as the dependent variable BMI category can be a factor affecting mortality, a component of HDI, an independent variable. However, as a sensitivity analysis, these models are run with HDI in lieu of log(GDPpC), and similar results are produced.

Other sensitivity analyses are also performed. To test whether age associations might be non-linear, I use age as a categorical instead of a continuous variable in these models. Models perform similarly regardless of how age is quantified. Furthermore, while BMI category is the dependent variable in the above analyses, the continuous variable BMI is also tested as a dependent variable. The results are similar and can be found in the Appendix.

Finally, since there are only six countries in this analysis, there are also only six levels of GDPpC. As a result, interpretations from these models should be taken with caution. While there is variation in GDPpC among these six countries, more levels are needed to make credible interpretations. Added variation could come in the form of more countries or future waves of SAGE with these same countries. SAGE is a longitudinal study, though data from only one wave are available for all of these countries thus far. Future research could look at differences in nutritional status between multiple waves.

Conclusion

This line of research could be extremely relevant from a policy perspective. Traditionally, assistance from developed countries and international organizations has mainly been devoted to alleviating the under-nutrition problem. While the prevalence of under-nutrition has been reduced by such laudable efforts, the prevalence of over-nutrition is rising rapidly at the same time. Policy-makers need to adapt to this new nutritional landscape and create policies to counter both nutritional extremes (Shrimpton and Rokx 2012).

An important consideration that policy-makers need to keep in mind is that assistance needs to target appropriate population segments. This paper parses out the appropriate segments of the population that are likely to be more afflicted by one nutritional extreme or the other. For the most part, the six country-specific models produce similar findings, despite differences in magnitude. However, the exceptions in these country-specific models demonstrate that there is a potential shift in nutritional patterns working in tandem with the processes of development. The collective model with the addition of economic development and its interactions reveals that these shifts could in fact occur, and might be at levels of economic development beyond the scope of these six countries. Further research in this direction could prove fruitful.

Appendix

Multiple regression models with continuous BMI:

To quantify the relationship between BMI and various social, economic, and demographic characteristics, I run multiple regressions for each of the six countries. Table 3 shows the coefficients of the variables in multiple regressions, with BMI as a continuous dependent variable.

Table 3: Coefficients from multiple regressions with BMI as a continuous dependent variable in Russia, Mexico, China, South Africa, India, and Ghana

	Ghana	India	China	South Africa	Mexico	Russia
Intercept	26.03 ***	23.36 ***	26.31 ***	28.58 ***	33.13 ***	27.06 ***
Female	2.94 ***	1.78 ***	0.53 ***	3.86 ***	1.91 ***	2.53 ***
Age	−0.05 ***	−0.05 ***	−0.03 ***	−0.01	−0.08 ***	−0.01
Rural	−2.28 ***	−1.44 ***	−1.06 ***	−0.87 *	−1.02 **	1.30 ***
Completed high school	−0.17	0.82 ***	−0.28 *	1.13	0.89	0.23
Completed college	0.14	1.93 ***	−0.13	0.71	−0.93 *	−0.57
Second quartile	0.52	0.78 ***	−0.20	1.22 *	−0.01	0.81 **
Third quartile	1.93 ***	1.24 ***	−0.10	1.02	−0.36	0.84 **
Fourth quartile	3.34 ***	1.78 ***	−0.08	0.88	0.64	1.07 ***
Adjusted R^2	0.175	0.125	0.021	0.049	0.058	0.058

Females, on average, have significantly higher BMI than males in each of the six countries, though the differentials vary by country. For example, females, on average, have a BMI higher than that of males by 0.53 kg/m^2 in China, while females, on average, have a BMI higher than that of males by 3.86 kg/m^2 in South Africa. The sex differential is noticeably lower in China than that of the other countries. Age is significant and negative for all countries, except for South Africa and Russia, where the age variable is insignificant. That is, older ages are significantly associated with lower BMIs in four of the six SAGE countries. Those living in rural areas, on average, have significantly lower BMI than their counterparts living in urban areas in all SAGE countries but Russia. In Russia, the opposite is true – urban dwellers, on average, have significantly higher BMI than rural dwellers. This switch in coefficients from the other countries to Russia can also be seen in Table 1.

Educational attainment is not statistically significant in Ghana, South Africa, and Russia. In India, BMI for those who completed high school is significantly higher than that of those with less than a high school education, whereas in China, those who completed high school have significantly lower BMI. Similarly, the coefficient for completed college is significantly positive in India and negative in Mexico. In India, where both education categories are significant, the differential is greater between completed college and less than high school than between high school education and less than high school education, suggesting that more education is associated with higher BMI. It does seem counter-intuitive that in China, the coefficient for having completed college is not significant, while the coefficient for having completed high school is significantly negative, since having completed high school is academically between the other two categories of completed college and the reference group of less than a high school education.

The wealth quartile variables are all relative to the baseline category of the first quartile, or poorest quartile. In India and Russia, all the wealth quartile variables are significant with positive coefficients, with the coefficients increasing in magnitude as wealth increases. In Ghana, only the third and fourth quartiles are significant, and there is not a significant difference in BMI between the poorest quartile and the second poorest quartile. While both significant coefficients are positive, the coefficient for the fourth quarter is more so. South Africa presents a somewhat different situation. The second poorest quartile has a significant positive difference in BMI over the poorest quartile.

As before when studying BMI as a categorical variable, I consider interactions between log(GDPpC) and place of residence, educational attainment, and wealth. Table 4 shows these results.

Table 4: Coefficients of variables from multiple regression with BMI as a continuous dependent variable and log(GDPpC) as an additional independent variable

Intercept	−6.64 ***
Female	1.89 ***
Age	−0.03 ***
Rural	−11.14 ***
Completed high school Completed college	8.24 *** 12.76 ***
Second quartile Third quartile Fourth quartile	−0.86 6.15 *** 9.23 ***
log(GDPpC)	3.64 ***
Rural * log(GDPpC)	1.07 ***
Completed high school * log(GDPpC) Completed college * log(GDPpC)	−0.88 *** −1.36 ***
Second quartile * log(GDPpC) Third quartile * log(GDPpC) Fourth quartile * log(GDPpC)	0.11 −0.64 *** −0.94 ***
Adjusted R^2	0.173

Being female is associated with a higher BMI and being older is associated with a lower BMI. log(GDPpC) is positively associated with BMI, demonstrating that BMI is associated, not only with an individual's characteristics, but also with the level of economic development of the country where the individual is.

Now consider the development-related variables. Rural, completed high school, completed college, third quartile, and fourth quartile are all significant, as are their interactions.

As evidenced by the negative coefficient of rural, rural dwellers, on average, have lower values of BMI than urban dwellers. The coefficient of the interaction between rural and log(GDPpC) is positive, so as GDPpC increases, the differential between urban and rural areas decreases. With a high enough level of GDPpC, the pattern switches such that rural dwellers, on average, have higher values of BMI than rural dwellers.

Completed high school and completed college have positive coefficients, relative to less than high school. That is, those who are more educated, on average, have higher BMI. The fact that the coefficient for completed college is more positive means that the BMI ordering is, in ascending order, less than high school, completed high school, and completed college. However, the negative coefficients of their interactions suggest that at a high enough level of GDPpC, less education is associated with higher BMI. Additionally, the coefficient for the interaction between completed college and log(GDPpC) is more negative than that of completed high school and log(GDPpC), so the differential of college education relative to less than high school decreases more quickly.

The third and fourth wealth quartiles, relative to the first quartile, can be interpreted similarly. Increasing wealth is associated with higher BMI at low GDPpC, and the differential decreases and may even change sign as GDPpC increases. For place of residence, educational attainment, and wealth quartiles, the patterns exhibited in Table 4 are similar to the ones in Table 2.

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