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NUTRIENT INTAKE:
A CROSS-NATIONAL ANALYSIS OF TRENDS AND ECONOMIC CORRELATES

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ABSTRACT

Nutrition is a key input in the health production function, and a better understanding of how we eat can aid in guiding effective policy change towards better population health. This study documents prevalence rates, trends in, and potential correlates of nutrient intake for panels of countries, categorized by geographical regions and levels of development. We assemble data from 209 countries, spanning 51 years (1961-2011), based on original data compilations using 960 country-years for BMI, 370 country-years for glucose, and 321 country-years for cholesterol. Our estimates inform the nature and scope of nutrient intake on a global scale, and contribute towards an understanding of the drivers of the general upward trend in food intake and obesity. The cross-national trends, across countries spanning the spectrum of economic development and geographic regions, suggest that simply analyzing aggregate caloric intake masks the heterogeneity in trends for the various food groups. Food groups analyzed include cereals, sugars and sweeteners, vegetable oils, meat, starch, milk, fruits, animal fats, alcoholic beverages, oil crops, pulses, vegetables, fish, and eggs. Fixed effects regression analyses reveal that caloric intake is strongly associated with hunger depth, body mass index, cholesterol levels, and glucose levels. Moreover, changes in real GDP per capita, labor force participation, and health care measures in a nation can partly explain the increase in caloric intake. We note that substantial heterogeneity remains. While these associations should not be interpreted as causal, they provide a first step towards understanding shifts in aggregate eating patterns across the globe and levels of economic activity.

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I. Introduction

Nutrient intake varies drastically around the world and has exhibited substantial variation across countries and over time. In 2011, the United Nations General Assembly identified unhealthy diet as one of four global causes of noncommunicable diseases, together with tobacco use, harmful use of alcohol, and insufficient physical activity (WHO, 2011a). Nutrition is a key input into health, both indirectly as it is related to food consumption which regulates body weight and obesity, as well as directly (WHO 2011a). Since what we eat can have complex direct and indirect effects on health, disease and comorbidities, a better understanding of how we eat can aid in guiding effective policy change towards better population health.

Higher obesity rates across countries and over time can be partly attributed to higher levels of food consumption and caloric intake (WHO, 2011a). However, associated with changes in *levels* are potential changes in the *composition* of caloric intake, which would in turn affect nutrient intake and have independent effects on morbidity and mortality, even after accounting for any effects on obesity. Thus, if the increase in obesity cross-nationally and over time is associated with shifts towards poorer nutrient intake, then this would compound any adverse effects on health. While the focus in the public health literature on obesity s well-placed, this therefore presents only a partial picture of health production. A significant gap exists with respect to an understanding of the shifts in nutrient and caloric intake globally and over a long time span.

Poor diets, in combination with lack of exercise, are found to affect the heart, the brain, and the peripheral arteries, leading to cardiovascular diseases, intestinal cancers, high blood pressure, and obesity, diabetes and other diseases (Eurodiet, 2000; World Cancer Research International, 2009; European Chronic Diseases Alliance, 2011). As fewer people in developed countries cook their own food, the food industry gains an increasing impact on human eating behaviors (McCarthy et al., 2013).

In Europe, the focus has been shifting from "healthy foods" to "healthy eating." For example, the European Medical Research Council has conducted research ranging from patterns of meals, to brands of foods, labeling, food perceptions, and public engagement in policy (European Science Foundation, 2009) and the International Association for Research on Cancer (2011) has determined a connection between nutrition and heart disease, as well as nutrition and various cancers. Overall, research in Europe has shown an excess rather than a lack of nutrients (Elmada, 2009). There has been a gap in the empirical literature in terms of studying differences in nutritional intake based on wide country panels. Studies that focus on broad country panels and other health outcomes, such as infant mortality, immunizations, and HIV prevalence, have found that there is a strong link between income and health cross-sectionally, but this link weakens over time (Casabonne and Kenny, 2012).

For most of the developing world, addressing food security and in some parts, coping with hunger, has been the central question. Eliminating malnutrition – one of the Millenium Development Goals – has been the focus of evidence-based direct nutrition interventions, and the "scaling up" nutrition movement (Horton, 2008). The above problems were exacerbated by the food price crisis of 2007-2008. The food price index increased from 127.2 in 2006 to 201.4 in 2008, falling again in 2009 to 160.3. (See http://www.fao.org/worldfoodsituation/foodpricesindex/en/.) The 2007-2008 food price crisis and the subsequent global economic crisis have led to an increase in the number of people suffering from hunger worldwide (FAO, 2009, 2011). Since poverty lines are defined based on pre-determined food and non-food baskets, the increase in food prices has a direct impact as income-based poverty increases (Ravallion, 1994). Country-specific studies on income and price elasticities of demand for different types of nutrients have shown that changes in food prices generally shift the composition of demand towards cheaper nutrients (Ecker and Qaim, 2010). Income is generally found to have a negative scale effect on overall caloric consumption and a neutral effect on food composition (Ecker and Qaim, 2010).

Our study, which focuses on the economic correlates of the trends in disaggregated caloric intake, makes several contributions to the literature. We assemble data from a multitude of sources, and provide the most comprehensive cross-national evidence to date on the prevalence and trends in indicators of caloric intake and related outcomes such as hunger depth, body mass index, cholesterol levels and glucose levels. This evidence spans a diverse set of 209 countries, across the full spectrum of economic development, over 51 years. Specifically, we closely follow disaggregated trends in the caloric intake of nutrients pertaining to cereals, sugars and sweeteners, vegetable oils, meat, starch, milk, fruits, animal fats, alcoholic beverages, oil crops, pulses, vegetables, fish, and eggs. Unlike many previous studies, we analyze data from both developed and developing nations and test for differences across regions and levels of development. The panel structure of the data allows us to account for all time-invariant country-specific heterogeneity, thus bypassing an important potential source of confounding bias, and also makes it feasible to statistically test for inter-regional differences in these trends. We further exploit the panel nature of the data to move beyond descriptive evidence and assess several questions of interest, relating changes in caloric intake and the composition of food intake to hunger depth and body mass index, as well as glucose and cholesterol levels. These latter outcomes are important indicators of health independent of obesity and food deprivation. We also conduct a joint estimation of equations relating caloric intake with economic factors such as GDP and labor force participation. Production functions relating food and caloric intake to BMI, for instance, and modeling how income or labor status affect the demand for calories and categories of food have generally not been estimated at the cross-national level. The significance of doing so stems from the fact that prior work has shown that obesity is a global epidemic, and while there are some differences across world regions, it has been rising across the spectrum of economic development. BMI and obesity are final observed outcomes realized from underlying behaviors relating to caloric intake and expenditure. In order to understand trends in obesity, it is therefore important to understand the behavior of these underlying inputs, and while this has been studied at the micro-level (usually for an individual country), we are not aware of any comprehensive long time-span cross-national studies on caloric intake and on the composition of the caloric intake. That being said, the results obtained in this study should not be interpreted as causal estimates. Nevertheless, these associations provide a useful first step towards understanding shifts in aggregate eating patterns across countries and levels of economic development.

The rest of the paper proceeds as follows. Section II details our empirical methodology, and section III describes the data and variables assembled for analysis. Section IV discusses the results, and the final section concludes with some implications for public health.

II. Empirical Implementation

We proceed in a stepwise manner to assess three issues: 1) trends in caloric intake across various food groups; 2) relationship between caloric intake across key food groups and health-related indicators; and 3) economic correlates of caloric intake across the various food groups.

Our empirical methodology begins with the following specification that allows us to estimate long-term trends in outcomes related to caloric intake.

(1) $\text{Ln Caloric Intake}_{it} = \beta_0 + \beta_1 \text{ Post2011}_t + \mu_i + \varepsilon_{it}$

Equation (1), estimated for a sample of countries for 1961 and 2011, relates the natural log of caloric intake for the i^{th} country in year *t*, to an indicator for 2011 (*Post2011*). The natural log facilitates the interpretation of the parameter β_1 as the growth in caloric intake over the sample period, and also adjusts for the skewness of the caloric intake distribution across countries. Models further include country fixed effects, which account for all unobservable time-invariant country-specific heterogeneity, for instance relating to geography, cross-national differences in data collection and reporting, and stable institutional factors. All standard errors are adjusted for arbitrary correlation in the error term (ε) within each country over time.

We estimate the above model for the full sample of countries, as well as for countries stratified across geographic regions and level of economic development. The World Bank classifies countries by income according to gross national income (GNI) per capita. The groups are: low income, lower middle income, upper middle income, and high income. The countries are divided according to 2012 GNI per capita, based on the World Bank Atlas methodology (see http://data.worldbank.org/about/country-classifications).

We analyze caloric intake for 15 food categories. While public health researchers and the community have with good reason focused on obesity trends, it is informative to broaden the lens and consider the composition of food consumption and related shifts in nutrient intake. Nutrient Intake is an important determinant in the health production function along with BMI. *Ceteris paribus*, both indicators have important independent effects on health in addition to cross-product effects. Analyzing individual food groups can help shed light on issues related to whether the increase in obesity is simply due to a scale effect (an increase in the aggregate consumption of calories) or whether individuals have substituted away from 'healthier' food options toward 'unhealthier' options, as is arguably the case during recessionary periods (Dave and Kelly 2012). These results are reported in Tables 3 and 4.

Our second step is to proceed to estimate the structural production function. This is a direct estimation of the effects of caloric intake on hunger depth, body mass index (BMI), glucose, and cholesterol:

$$\text{(2)} \qquad \text{Ln Outcome}_{irt} = \alpha_0 + \alpha_1 \text{ LnCaloricIntake}_{irt} + \mu_r + \psi_t + \varepsilon_{irt}$$

Specifically, model (2) relates these health outcomes (for country *i* in region *r* and year *t*) to a direct measure of caloric intake, fully exploiting the panel nature of the data (described in the next section), and includes region fixed effects (μ) and year fixed effects (ψ) to account for unobservable stable region-specific factors and common trends affecting all countries, respectively. The parameter of interest, α_1, captures the total effect of caloric intake (across the different food groups) on health-related indicators. Thus, when we consider cholesterol and glucose, α_1 reflects the marginal product of caloric intake from vegetable-based vs. animal based foods reflecting both the direct effect as well as the indirect effect. The latter indirect effect reflects that greater (lower) consumption of calories from (vegetables) animal-based foods may raise BMI and in turn affect cholesterol and glucose levels. In order to isolate the direct effect, which does not flow through body weight and obesity, we also estimate equation (2) adding BMI as a control. This model relates to and underscores our earlier point that nutrient intake may be an independent direct input in the health production function. We also recognize that these inputs may have cumulative and durable effects on outcomes, and the panel structure of the data makes it possible to assess lagged effects. These results are reported in Table 5 and 6. We again adjust all standard errors for arbitrary correlation within each country; this also helps to partly adjust degrees of freedom and inferences for the fact that the data on BMI, glucose, and cholesterol are imputed based on other original data sources (see data description below) and thus are flat for some country-year pairs, thus providing no new information over the preceding year.

Next, we model the economic correlates of caloric intake:

(3) $\text{Ln Caloric Intake}_{irt} = \delta_0 + \delta_1 \text{ Ln GDP}_{irt} + \delta_2 \text{ LFP}_{irt} + X_{irt}\, \Psi + \mu_r + \psi_t + \varepsilon_{it}$

Caloric Intake represents intake from the seven food categories, GDP refers to per-capita gross domestic product, LFP refers to labor force participation, and the vector X controls for both out-of-pocket health expenditures and the number of physicians per capita. Equation (3) may be viewed as a quasi reduced-form input demand function. Running the equations separately and conducting a multivariate test on the correlation across the error terms reveals the error terms to be expectedly and highly correlated; unobservables that affect the demand for some forms of caloric intake would be expected to affect the demand for other food groups as well. We therefore estimate the seven equations using a seemingly unrelated regression (SURE) framework to account for the inter-equation correlated error structure (Zellner 1962). These results are reported in Table 7.

III. Data

We assemble data on obesity, related outcomes, and its proximate inputs for 209 countries, spanning 51 years (1961-2011), from three main sources which are publicly available: 1) Food and Agriculture Organization (FAO); 2) World Health Organization (WHO); and 3) World Bank (WB). These data are publicly available at the following sources:

http://apps.who.int/gho/data/node.main.A867?lang=en,

http://faostat.fao.org/site/354/default.aspx, and

http://databank.worldbank.org/ddp/home.do.

The *mean aggregate caloric intake* per person, expressed in kilocalories (kcal) per day, is a measure of the average number of calories consumed, including all food groups. These data are derived by the FAO from food balance sheets for 1960-2011. A food balance sheet captures the pattern of a country's food supply during a given period, and shows for each basic food item or primary commodity its total availability for human consumption, corresponding to the sources of supply and its utilization. The total quantity of food commodities produced is adjusted for the total quantity imported or exported. A distinction is also made between food commodities fed to livestock or used for seed and net supplies available for human consumption, although actual food consumption may be lower than the net supplies as food availability depends on the magnitude of wastage and losses of food in the household. The per capita supply of each broad food commodity available for human consumption is obtained by dividing the respective quantity by the total population. Through the application of appropriate food composition factors for all primary and processed products, these data are then expressed in terms of dietary energy and calories. This is an average measure for both genders. Caloric intake is also obtained separately for animal-based and vegetable-based products, which are closely correlated with nutrient and fat intake (WHO, 2011a). Sufficient consumption of fruits and vegetables has been shown to be necessary for lowering the risk for cardiovascular diseases, stomach cancer, and colorectal cancer (WHO, 2011a). Saturated fats and trans-fatty acids are associated with heart disease (WHO, 2011a). Moreover, the following 15 food categories are identified: cereals, sugars and sweeteners, vegetable oils, meat, starch, milk, fruits, animal fats, alcoholic beverages, oil crops, pulses, vegetables, fish, eggs, and a miscellaneous ("other") category that includes tree nuts, stimulants, offals, spices, and aquatic products (each with an average daily caloric intake less than 20 kcal).

Data for the *mean body mass index (BMI)* for the "adult" population, defined as ages 20 years old and older, are obtained from the WHO for 1980 to 2008. The data were collected from population-based surveys and surveillance systems, based on objective measurements of height and weight of the respondents. Obesity, defined as having a BMI greater than or equal to 30 kg/m^2, has been identified as a significant risk factor for morbidities such as diabetes, coronary heart disease, stroke, high blood pressure, and several cancers related to the colon, breasts, and the prostate.

The *mean fasting blood glucose level* is defined for the population of adults ages 25 years and above, measured in mmol/L. The *mean total cholesterol* of a defined population, adults ages 25 years old and above, is also measured in mmol/L. These data are also obtained from the WHO for period spanning 1980-2008, and the information is derived through biochemical measurements from country-specific population-based samples and surveillance systems. We assess all trends and prevalence rates for BMI, and glucose and cholesterol levels separately across gender. Note that the WHO data employed here for BMI, glucose, and cholesterol are largely based on estimates using Bayesian hierarchical models carefully compiled from numerous studies and reported in a set of 2011 Lancet articles (WHO 2011b, Danaei et al. 2011a, Danaei et al. 2011b, Finucane et al. 2011, Farzadfar et al. 2011). In spite of the extensive data collected by the authors of these studies, many country-years had missing information since annual data are difficult to obtain for some countries (Danaei et al. 2011a). The estimates employed in this study are based on original data compilations using 960 country-years for BMI, 370 country-years for glucose, and 321 country-years for cholesterol.

Given that BMI, glucose, and cholesterol represent our outcome measures (in equation 2), the variance surrounding the imputation will be captured by the disturbance terms in equation (2) and only affect the precision of our estimates. The country fixed effects further account for the possibility that the measurement error in the imputed values may be systematically difference across countries. Hence, any remaining unsystematic measurement error associated with the imputed values will not bias our results. Our specification checks (detailed in the results section) provide some evidence on this.

Data on depth of hunger, GDP per capita, labor force participation, age structure, out-of-pocket health expenditures, and physicians per capita are obtained from the World Bank. (Following a reviewer's suggestion, we also run models with total health spending in lieu of out-of-pocket health expenditures. Our main conclusions are not materially affected by these alternate controls.) According to the World Bank, the *depth of hunger*, measured in daily kilocalories per person, is a measure of the intensity of food deprivation. It shows how much food-deprived individuals fall short of minimum food needs, measured by comparing the average amount of dietary energy that undernourished individuals obtain from the food they eat with the minimum amount needed to maintain body weight and pursue light activity.

IV. Results

Trends

Tables 1 and 2 present the summary statistics for our key variables for the most recent year of our sample period, for all countries and subsets based on geographic strata and the level of economic development. The mean daily caloric intake was 2828 calories in 2011 across all countries and 3639 for the United States in particular. The U.S. Department of Agriculture (USDA) recommends that men (women) consume 2,000-2,600 (1,600-2,000) calories if they are sedentary, 2,200-2,800 (1,800-2,200) calories if they are moderately active and 2,400-3,000 (2,000-2,400) calories per day if they are active (USDA and USDHHS 2010). Given that the information on caloric intake across countries does not separate genders, and given that between 32-39% of the population is physically inactive, the mean caloric intake appears to be higher than the recommended daily allowance, at least for the overall sample of countries. Aggregate caloric intake in the United States (US), Middle East & North Africa (MENA), Western Europe (WE), and Eastern Europe & Central Asia (EECA) is significantly higher than that in the rest of the world. In contrast, that in Sub-Saharan Africa (SSA) is significantly lower.

In terms of animal-based versus vegetal-based products, we see that the US, WE, and EECA have substantially higher than average intakes of animal-based products. SSA has a significantly lower intake of animal-based products. The MENA region has a significantly higher intake of vegetal-based products and a significantly lower intake of animal-based products, which may be reflective of the Mediterranean diet (Díaz-Méndez and Gómez-Benito 2010).

The breakdown into separate food categories shows some interesting findings. For sugars and sweeteners, the South/East Asia & Pacific (SEAP) and Sub-Saharan regions have significantly lower intakes (at 228 and 146 calories, respectively) than the global average (284). For vegetable oils, consumption in the US is very high (701 calories) compared to the global average of 283, followed by WE (431) and MENA (361). Starch consumption is significantly higher in SSA (344) compared to the world average (167). Meat consumption is highest in the US (432 calories), followed by WE (400). These values are high considering the world average for meat consumption is 233 calories per person per day. Milk consumption is highest in the US, WE, and EECA, while consumption of fruits is highest in Latin America & the Caribbean (LAC).

Results for the mean BMI, cholesterol, and glucose levels are discussed in more detail elsewhere (Doytch et al. 2016). Figure 1 reveals upward trends in aggregate caloric intake, intake of vegetal products, and intake of animal-based products from 1961 to 2011. Figures 2a and 2b break aggregate caloric intake down by food category (using 15 categories) for 1961 and 2011. Here we see contrasting trends – a drop in both cereal consumption as a percentage of total calories and starch consumption and upward trends for sugars and sweeteners, vegetable oils, and meats. Below, we discuss the main trends underlying these estimates.

Average calories consumed increased worldwide by 20%, from 2352 to 2828, between 1961 and 2011 (Table 3). This overall net increase is attributed to an increase in caloric intake from the consumption of vegetable oils (96%), meat (55%), and sugars and sweeteners (41%).

There was also a large increase in the consumption of eggs (71%), vegetables (67%), fish (59%), and oil crops (57%), yet it should be noted that while calories consumed from these groups increased at such high rates, the relative contributions of eggs, fish, oil crops, and vegetables remains quite low; in 2011, eggs accounted for only 0.9% of total caloric intake, and vegetables accounted for 2% (Table 1). The largest share of caloric intake in 2011 can be attributed to cereal (40%), followed by sugar and sweeteners (10%), vegetable oils (10%), meat (8%), milk (6%), and starch (6%). In contrast, for the United States, cereal accounted for only 22% of total calories while sugar accounted for almost 16% in 2011. High income and upper-middle income countries have significantly higher caloric intake than the rest of the world (Table 2). They also have significantly higher intakes of animal-based products, particularly sugars and sweeteners, meats, milk, and eggs. Over this time period, we find that a structural break in the trend occurred for total caloric intake, as well as caloric intake of vegetal products, in 1982. For animal-based products, a structural break occurred in 1969.

Aggregate caloric intake increased substantially in all regions and studied groups, except for the EECA region, which experienced a very low growth rate of 0.4% (Table 3). The fastest growth (26%) among all income groups was experienced in Lower Middle Income countries (Table 4), and the fastest regional growth is observed in the MENA region (42%).

The EECA region experienced a drastic drop in total caloric intake during the beginning of the 1990s, which drives the minor drop visible in Figure 1 during the 1990-92 period. The changes in caloric intake post-1990 are likely associated with an overall economic contraction of most of the EECA economies. This period was plagued with staggering growth of real GDP, high unemployment rates, downsizing and shutting-down of the majority of existing enterprises, overall uncertainty, and high inflation rates due to the transition from centrally-planned to market economies. The region has also experienced drastic declines in birth rates and increased emigration. The decline in caloric consumption may also therefore reflect a shift in the composition of an EECA country's population due to this emigration as the average caloric intake of the stayers may be very different than the average caloric intake of the migrants. However, we do not explicitly measure these factors in our study.

World cereal consumption increased by 8% over the time period analyzed, with SSA, MENA, and the U.S. leading this trend with growth rates of 24-26%. Nevertheless, as noted above, the U.S. also has some of the lowest levels of cereal consumption over this entire timespan. The EECA region, experienced a steep decline in cereal consumption of 28% over this period. World consumption of starch and pulses has been almost flat during the examined period. This, however, conceals significant variation across regions; while the MENA region experienced significant *increases* in these food groups, WE experienced decreases.

As previously noted, the growth in global sugar consumption was 41% over the 1961-2011 time period. However, this net aggregate increase again masks considerable heterogeneity. Increase in sugar intake was particularly high among the SSA (75%) and SEAP (67%) regions (Table 3). In terms of absolute caloric intake from sugar, the U.S. continues to have the highest level of consumption (569 kcals in 2011). With respect to level of development, sugar intake experienced the steepest growth among the low-income countries (73%); for all other income-based groups, growth was positive but below average (Table 4). Specifically, among high-income countries, sugar intake increased by a relatively modest 11%. Some of the increase in caloric intake through sweeteners has been linked to agricultural policies in the U.S. such as subsidies to corn farmers (Beghin and Jensen 2008; Rashad 2007). A significant portion of the increase in sugar (sweetener) consumption in the U.S. can be attributed to soda and other sugar-sweetened beverages (SSB), which has prompted some cities and municipalities to propose interventions that limit SSB consumptions such as taxes and availability restrictions. Note that sugar consumption in this context includes sweeteners such as high fructose corn syrup.

While estimates from Tables 1 and 2 and the figures present a snapshot of cross-regional differences in caloric intake and related outcomes, they do not inform the dynamic trends in these factors and the underlying drivers of these trends. We discuss these results next based on the multivariate specifications.

Health Outcomes

Table 5 shows results for our structural model, which relates total caloric intake and disaggregated caloric intake across vegetal- and animal-based foods on outcomes related to hunger depth and BMI. Panel A shows results for health outcomes as a function of aggregate caloric intake, while Panel B separates nutrient intake into vegetal and animal-based products. The first column shows results for hunger depth. Note that hunger depth is equal to calories needed minus average caloric intake for the undernourished. If we have aggregate average caloric intake for the population on the right hand-side of the equation, it suggests that, if hunger depth were measured for the whole population, the coefficient (α_1 from equation 2) should be -1. Since the population for which average calories is being measured is different on both sides of the equation, α_1 will not be exactly -1 and would reflect a distributional effect. In other words, if a 100% increase in caloric intake reduces hunger depth by less than 100%, it might suggest that the additional calories are not going to the undernourished population. A value of α_1 greater than 1 in absolute value might suggest that the additional calories are going where they are most needed. The parameter estimate in Table 5 of -1.2479, significant at all conventional levels, suggests that this may be the case. This is consistent with effective agricultural, food, and welfare policies which are targeted to the at-need population, and thus are effective in raising their caloric intake relatively more than the average.

Results for BMI in Panel A of Table 5 exhibit the expected positive signs, significant at conventional levels. In Panel B, we see that BMI is significantly affected by both vegetal and animal-based products.

Additional results for our structural model are shown in Table 6, which relates total caloric intake and disaggregated caloric intake across vegetal- and animal-based foods on outcomes related to glucose and cholesterol for females and males, respectively. The expected positive, significant effects of total caloric intake and disaggregated caloric intake on glucose and cholesterol can be seen when BMI is not controlled for on the right-hand side. Once BMI is controlled for, however, some interesting results emerge. With the exception of animal-based products for females, caloric intake independently of BMI does not appear to have an effect on glucose. However, *disaggregated* caloric intake has a significant effect on cholesterol even when BMI is controlled for as a confounding factor. This points to the strong independent effect that caloric intake plays in raising cholesterol independently of BMI. When viewing disaggregated caloric intake, we see that animal-based products are significantly associated with higher cholesterol while vegetable-based products are significantly associated with lower cholesterol. These effects of total and disaggregated caloric intake on glucose and cholesterol levels capture the total effects, which represent the marginal product of these inputs operating directly as well as indirectly through their effects on BMI. As the results in both Panels A and B of Table 5 suggests, caloric intake raises BMI, and this increase in BMI has adverse effects on glucose and cholesterol levels, as seen in Table 6. Caloric intake overall, and the composition of calories consumed, therefore have direct effects on glucose and cholesterol levels, conditional on BMI. These results highlight the dual mechanisms through which calories and the composition of calories may impact health, first through their effects on bodyweight, and second directly conditional on a given bodyweight. We also run models similar to those in Tables 5 and 6 but including one- and two-year lags for caloric intake and BMI. These models reveal significant lagged effects, especially with respect to the two-year lagged measures, which is consistent with the inputs having cumulative and durable effects on the output. Moreover, contemporaneous measures remain significant even after controlling for lags. This suggests that, in models that do not control for the lags, the contemporaneous measures are capturing both the current annual effect as well as potential lagged effects. These results are available upon request.

Correlates of Caloric Intake

Results for our analysis of the economic correlates of nutrient intake using a SURE regression framework, which accounts for the joint correlation in the error terms of the separate models for each of the 15 food groups, are presented in Table 7. Note that GDP per capita and labor force participation, our key variables of interest, may represent proxies for a host of other variables that are correlated or jointly determined. Generally, we see that some food groups are "normal" and some are "inferior" along the lines of what we would expect. In particular, the elasticities for cereals and starch are negative for GDP per capita. All other food categories are positive and significant for GDP per capita, with the exception of pulses. This has implications for the composition of food consumption and nutrient intake over the course of economic development; as a country develops, overall food consumption and calories rise, yet there is also some substitution and shifting from some food groups to other groups.

In contrast, we see that labor force participation is generally associated with lower levels of consumption for many food categories, exceptions being alcohol, starch, fish, and meat.

V. Discussion

This study documents prevalence rates and trends in caloric intake for various food categories. Prior studies have focused on BMI, obesity, and aggregate caloric intake, usually within a country or for a subset of countries. Focusing on nutrient intake for various food categories can shed light on substitution across food categories over time and highlight the independent effect of nutrition on health. Increases in BMI alone may not be a cause for concern for some parts of the world. An increase in BMI may represent different things for countries at various stages of development. For higher-income nations, the increase may be a cause for concern, on average, as it is a signal of the increasing trend towards overweight and obesity. For low-income and perhaps some middle-income nations, the increase in BMI may signal positive developments, such as a decrease in food insecurity and an increase in access to adequate food products and nutrition. Thus, looking directly at trends in nutrient intake can further help us assess differences across nations and over time in a key input into the health production function and also disentangle average health-promoting trends from average health-depreciating trends. Hence, this study bridges that gap and goes a long way towards assessing those trends and drivers of those trends.

Our estimates highlight the following key points. First, with the marked exceptions of cereal in the EECA region and starch in the WE region, caloric intake has been steadily increasing across world regions and across the spectrum of economic development, and has increased by 20% between 1961 and 2011, although the overall rate of increase masks considerable heterogeneity across subsets of countries and across food categories. Aggregate caloric intake clearly exceeds recommended amounts, and this increase can at least partly account for the rise in BMI and obesity (Doytch et al. 2016). Second, this increase in caloric intake represents both an increase in levels and also a shift in the composition of the foods consumed. High income and upper-middle income countries have significantly higher caloric intake than the rest of the world. They also have significantly higher intakes of animal-based products, particularly sugars and sweeteners, meats, milk, and eggs. The increase in low-income countries such as those in SSA (with a low level of caloric intake) can be viewed as responsible for improved nutrition and reduced food insecurity. Third, our multivariate analyses confirm that these shifts in the level and composition of caloric intake are associated across levels of development cross-sectionally and over time. Higher GDP per capita is associated with higher caloric intake of all food groups, with the exception of cereals and starch. Furthermore, caloric intake is associated with lower levels of hunger depth but higher levels of obesity, glucose, and cholesterol. Intake of animal-based products but not vegetal products is significantly associated with higher levels of cholesterol. Fourth, these effects are significant overall as well as conditional on BMI (with the exception of glucose), which further underscores the importance of studying the composition of calories consumed and nutrient intake. That is, the trends which have led to an increase in obesity have also led to changes in how we eat. This appears to have independent effects on clinical risk factors such as cholesterol levels. To the extent that some of the costs of lower population health are borne by the public, this increase in risk factors for noncommunicable diseases such as heart disease reflect some of the negative externalities associated with the compositional shifts in caloric intake beyond the economic costs of obesity.

While our study is novel in many respects, it has some limitations. We do not purport to estimate causal effects, and thus the results should be interpreted as associations. While the FAO, World Bank, and WHO have used methodologies to ease comparisons across countries and over time, they are necessarily imperfect and should thus be interpreted with caution. As previously noted, FAO data on caloric intake refer to data available for human consumption and not actual calories consumed. We also focus in this study on caloric and food intake, one of the two proximate drivers of bodyweight. Some of the issues that we have underscored in the study with respect to caloric intake and the composition of food consumption also apply with equal importance to physical activity. Future work should thus consider the role of physical activity in driving the observed levels and trends in BMI across nations.

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Table 1
2011 Means by World Region

Panel A	World Regions							
Variables	All	United States (US)	Latin America & Caribbean (LAC)	South/ East Asia & Pacific (SEAP)	Sub-Saharan Africa (SSA)	Middle East & North Africa (MENA)	Western Europe (WE)	Eastern Europe & Central Asia (EECA)
Total Caloric Intake	2828.2	3639.0*	2731.2	2713.2	2436.6***	3006.9*	3407.0***	3017.7***
Vegetal (kCal)	2278.9	2644.0	2163.0**	2206.3	2212.6	2600.4***	2344.7	2305.8
Animal (kCal)	549.3	995.0	568.3	507.0	223.9***	406.4**	1062.3***	711.9***
Cereals (kCal)	1122.2	798.0	975.1***	1203.6	1142.8	1445.5***	886.6***	1149.1
Sweets (kCal)	284.0	569.0**	396.5***	228.4**	146.4***	323.2	381.2***	290.2
VegOils (kCal)	283.0	701.0***	264.5	219.2***	221.3***	361.3**	431.5***	279.8
Starch (kCal)	166.9	99.0	109.5*	134.3	343.9***	60.7***	113.8	143.6
Meat (kCal)	233.1	432.0	279.9**	246.4	99.4***	171.0*	399.9***	256.4
Milk (kCal)	173.8	373.0	168.3	91.5***	74.8***	153.9	351.4***	278.6***
Fruits (kCal)	104.9	111.0	128.5**	81.5**	90.7	117.2	125.2	99.3
AnimalFat (kCal)	71.4	101.0	55.0	60.6	16.1***	31.9**	194.8***	108.8***
Alcohol (kCal)	80.3	158.0	77.7	48.3***	49.2***	10.2***	173.5***	132.5***
Pulses (kCal)	58.9	30.0	75.1*	44.3*	88.1***	74.5	24.5***	30.7***
OilCrops (kCal)	61.8	72.0	39.9*	127.2***	80.1	44.7	29.8*	25.1***
Vegetables (kCal)	62.8	69.0	43.5***	61.9	28.9***	91.4***	84.9***	94.8***
Fish (kCal)	36.5	36.0	30.6	70.6***	21.5***	17.9**	62.1***	21.5**
Eggs (kCal)	25.6	53.0	26.6	26.5	5.9***	24.7	44.3***	35.0***
Other (kCal)	64.0	38.0	58.5	68.8	29.3***	78.8	103.8***	74.4
Hunger Depth	194.7	100	199.7	208.5	254.7***	175.6	113.5***	161.7***
BMI-Males	25.04	28.50	25.87**	24.34*	22.37***	26.21**	26.87***	26.05**
BMI-Females	25.85	28.30	27.59***	25.21	23.82***	27.56***	25.67	25.95
Cholesterol-Males	4.66	5.10	4.58	4.66	4.17***	4.83*	5.36***	4.82**
Cholesterol-Female	4.78	5.20	4.78	4.79	4.33***	4.96**	5.30***	4.89*
Glucose-Males	5.54	5.90	5.56	5.61	5.31***	5.74***	5.57	5.55
Glucose-Females	5.47	5.60	5.60**	5.60**	5.32***	5.67***	5.25***	5.36*

Notes: Means are based on data from the WHO, FAO, and the World Bank; see text for details. Based on a sample of 177 countries in 2011. Data for hunger depth are from 2007. Data for BMI, cholesterol, and glucose are from 2008. Asterisks denote whether the difference in the mean for the specific region is statistically different from the rest of the world as follows: *** p-value ≤ 0.01; ** 0.01 < p-value ≤ 0.05; * 0.05 < p-value ≤ 0.10.

Table 2
2011 Means by Level of Economic Development

Panel B	**Level of Economic Development**			
Variables	**Low Income**	**Lower-Middle Income**	**Upper-Middle Income**	**High Income**
Total Caloric Intake	2453.5***	2754.4	3007.3***	3210.2***
Vegetal (kCal)	2196.1**	2324.8	2316.4	2295.8
Animal (kCal)	257.4***	429.6***	691.0***	914.4***
Cereals (kCal)	1243.8***	1214.3**	1052.9	935.2***
Sweets (kCal)	148.7***	290.8	376.7***	363.9***
VegOils (kCal)	209.1***	241.3**	305.4	393.8***
Starch (kCal)	257.3***	166.4	126.1	95.9***
Meat (kCal)	108.7***	176.6***	299.1***	386.9***
Milk (kCal)	88.3***	141.3**	225.1***	273.7***
Fruits (kCal)	81.7***	108.6	118.6	116.7
AnimalFat (kCal)	23.3***	45.9***	87.6	144.6***
Alcohol (kCal)	36.2***	58.0**	107.2**	137.4***
Pulses (kCal)	79.4***	62.7	49.5	38.9***
OilCrops (kCal)	72.2	71.5	53.6	43.8
Vegetables (kCal)	40.5***	69.6	64.8	78.9***
Fish (kCal)	22.7***	33.4	36.2	56.1***
Eggs (kCal)	7.7***	25.2	33.0***	40.7***
Other (kCal)	33.5***	53.0*	71.7	104.4***
Hunger Depth	261.1***	195.4	162.8***	131.8***
BMI-Males	22.47***	25.18	26.28***	26.81***
BMI-Females	23.41***	26.87***	27.10***	26.35
Cholesterol Level-Males (mmol/L)	4.19***	4.60	4.85***	5.18***
Cholesterol Level-Females (mmol/L)	4.36***	4.75	4.97***	5.20***
Glucose Level-Males (mmol/L)	5.33***	5.60*	5.62*	5.65***
Glucose Level-Females (mmol/L)	5.31***	5.62***	5.53	5.40

Notes: See notes to Table 1.

Table 3: Growth in Caloric Intake (1961-2011) across World Regions

	World Regions							
Variables	**All**	**United States (US)**	**Latin America & Caribbean (LAC)**	**South/ East Asia & Pacific (SEAP)**	**Sub-Saharan Africa (SSA)**	**Middle East & North Africa (MENA)**	**Western Europe (WE)**	**Eastern Europe & Central Asia (EECA)**
Total Caloric Intake	0.20***	0.23	0.28***	0.22***	0.19***	0.42***	0.13***	0.004
Vegetal (kCal)	0.17***	0.35	0.24***	0.15***	0.19***	0.43***	0.11***	-0.02
Animal (kCal)	0.40***	-0.02	0.46***	0.77***	0.34***	0.48**	0.27**	0.11
Cereals (kCal)	0.08**	0.24	0.18***	0.09	0.26***	0.26***	-0.04	-0.28***
Sweets (kCal)	0.41***	0.10	0.23***	0.67***	0.75***	0.43**	0.08	0.15
VegOils (kCal)	0.96***	0.93	0.93***	1.14***	1.02***	1.09***	0.50***	0.95***
Starch (kCal)	0.05	0.10	-0.03	0.03	0.12	1.06***	-0.43***	-0.21
Meat (kCal)	0.55***	0.25	0.75***	0.83***	0.35**	0.56***	0.61***	0.31**
Milk (kCal)	0.37***	-0.03	0.40***	0.75***	0.28	0.53**	0.17	0.16
Fruits (kCal)	0.35***	0.33	0.13	0.57**	0.18	0.32*	0.27**	0.63***
AnimalFat (kCal)	-0.08	-0.68	-0.27	0.46**	0.07	-0.15	-0.06	-0.55**
Alcohol (kCal)	0.34***	0.37	0.52***	0.85**	0.15	0.04	0.41**	0.02
Pulses (kCal)	0.05	-0.18	0.09	0.18	0.10	0.50**	-0.26	-0.37
OilCrops (kCal)	0.57***	0.54	0.74**	0.25	0.19	0.74***	1.10***	0.74*
Vegetables (kCal)	0.67***	0.08	0.77***	0.62***	0.45***	0.95***	0.68***	0.77***
Fish (kCal)	0.59***	0.59	0.63***	0.89***	0.55**	0.85**	0.64***	0.11
Eggs (kCal)	0.71***	-0.23	0.75***	1.05***	0.56***	1.35***	0.19	0.55***
Other (kCal)	1.00***	0.00	1.05***	1.18***	0.56***	1.18***	0.79***	1.35***

Notes: Each cell represents the coefficient of the 2011 indicator from a separate regression model for the natural log of caloric intake, based on the sample of countries noted for 1961 and 2011. All models, except for those for the U.S., include country fixed effects. Standard errors are clustered for arbitrary correlation within each country over time. Asterisks denote growth rate is statistically significant as follows: *** p-value ≤ 0.01; ** 0.01 < p-value ≤ 0.05; * 0.05 < p-value ≤ 0.10.

Table 4
Growth in Caloric Intake (1961-2011) across Levels of Economic Development

Variables	Low Income	Lower-Middle Income	Upper-Middle Income	High Income
Total Caloric Intake	0.18***	0.26***	0.21***	0.15***
Vegetal (kCal)	0.18***	0.23***	0.15***	0.12***
Animal (kCal)	0.35***	0.48***	0.49***	0.30***
Cereals (kCal)	0.17***	0.20***	0.01	-0.07
Sweets (kCal)	0.73***	0.34**	0.40***	0.11
VegOils (kCal)	1.14***	0.93***	0.94***	0.77***
Starch (kCal)	0.21	0.21	-0.04	-0.21
Meat (kCal)	0.33**	0.62***	0.72***	0.60***
Milk (kCal)	0.32*	0.41***	0.45***	0.27**
Fruits (kCal)	0.23	0.45***	0.32*	0.36***
AnimalFat (kCal)	0.03	-0.15	-0.07	-0.16
Alcohol (kCal)	0.03	0.44	0.50***	0.44***
Pulses (kCal)	0.17	0.18	-0.09	-0.13
OilCrops (kCal)	0.31	0.48*	0.80***	0.78***
Vegetables (kCal)	0.51***	0.80***	0.78***	0.66***
Fish (kCal)	0.44	0.56**	0.87***	0.57***
Eggs (kCal)	0.61***	0.85***	0.94***	0.48***
Other (kCal)	0.69***	1.02***	1.25***	1.13***

Notes: See notes to Table 3.

Table 5
Hunger Depth and BMI: Caloric Intake as an Input

PANEL A	**Outcome**		
Inputs	**Hunger Depth**	**BMI-Females**	**BMI-Males**
Ln Total Daily Caloric Intake	-1.2479***	0.2509***	0.1735***
	(0.143)	(0.029)	(0.022)
Sample period	1992-2007	1980-2008	1980-2008
Year fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes
Observations	805	4,718	4,718

PANEL B	**Outcome**		
Inputs	**Hunger Depth**	**BMI-Females**	**BMI-Males**
Ln Vegetal (kCal)	-0.8503***	0.1627***	0.1037***
	(0.114)	(0.025)	(0.019)
Ln Animal (kCal)	-0.2403***	0.0611***	0.0392***
	(0.041)	(0.008)	(0.007)
Sample period	1992-2007	1980-2008	1980-2008
Year fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes
Observations	805	4,718	4,718

Notes: Each column represents a separate regression model and controls for percentage of the total population between the ages of 15 and 64, and the percentage of the total population 65 years of age and above. Standard errors are clustered for arbitrary correlation within each country over time. Asterisks denote statistical significance as follows: *** p-value ≤ 0.01; ** 0.01 < p-value ≤ 0.05; * 0.05 < p-value ≤ 0.10.

Table 6
Glucose and Cholesterol: Caloric Intake as an Input

Panel A	**Outcome**							
Inputs	**Glucose-Females**	**Glucose-Females**	**Glucose-Males**	**Glucose-Males**	**Chol-Females**	**Chol-Females**	**Chol-Males**	**Chol-Males**
Ln Total Daily Caloric Intake	0.0791***	-0.0055	0.0675***	0.0078	0.1007***	0.0278	0.1131***	0.0223
	(0.014)	(0.011)	(0.011)	(0.011)	(0.019)	(0.018)	(0.024)	(0.021)
Ln BMI		0.3373***		0.3440***		0.2907***		0.5235***
		(0.040)		(0.055)		(0.041)		(0.076)
Sample period	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,718	4,718	4,718	4,718	4,718	4,718	4,718	4,718

Panel B	**Outcome**							
Inputs	**Glucose-Females**	**Glucose-Females**	**Glucose-Males**	**Glucose-Males**	**Chol-Females**	**Chol-Females**	**Chol-Males**	**Chol-Males**
Ln Vegetal (kCal)	0.0629***	0.0053	0.0418***	0.0061	0.0043	-0.0327**	-0.0027	-0.0447**
	(0.012)	(0.010)	(0.011)	(0.010)	(0.018)	(0.016)	(0.020)	(0.018)
Ln Animal (kCal)	0.0133***	-0.0083**	0.0147***	0.0012	0.0497***	0.0358***	0.0621***	0.0463***
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)
Ln BMI		0.3544***		0.3444***		0.2276***		0.4052***
		(0.039)		(0.055)		(0.039)		(0.064)
Sample period	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008	1980-2008
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,718	4,718	4,718	4,718	4,718	4,718	4,718	4,718

Notes: See notes to Table 5.

Table 7
Economic Correlates: Caloric Intake as an Output
Seemingly Unrelated Regression Model

	Inputs			
Outcome	**Ln GDP Per Capita**	**Labor Force Participation**	**Obs**	**R^2**
Cereals (kCal)	-0.0669***	-0.0090***	832	0.282
Sweets (kCal)	0.1670***	-0.0167***	832	0.474
VegOils (kCal)	0.1921***	-0.0164***	832	0.402
Starch (kCal)	-0.1531***	0.0192***	832	0.137
Meat (kCal)	0.2635***	0.0085***	832	0.662
Milk (kCal)	0.1734***	-0.0169***	832	0.535
Fruits (kCal)	0.2203***	-0.0092***	832	0.228
AnimalFat (kCal)	0.3260***	-0.0069**	832	0.619
Alcohol (kCal)	0.2744***	0.0340***	832	0.485
Pulses (kCal)	0.0065	-0.0290***	832	0.241
OilCrops (kCal)	0.2826***	0.0019	832	0.203
Vegetables (kCal)	0.1670***	-0.0178***	832	0.456
Fish (kCal)	0.4396***	0.0172***	832	0.342
Eggs (kCal)	0.3011***	-0.0151***	832	0.632
Other (kCal)	0.2627***	-0.0060***	832	0.407

	Inputs			
Outcome	**Ln GDP Per Capita**	**Labor Force Participation**	**Obs**	**R^2**
Cereals (kCal)	-0.0687***	-0.0084***	832	0.354
Sweets (kCal)	0.2041***	-0.0171***	832	0.489
VegOils (kCal)	0.1895***	-0.0168***	832	0.413
Starch (kCal)	-0.2212***	0.0202***	832	0.172
Meat (kCal)	0.2400***	0.0090***	832	0.667
Milk (kCal)	0.1699***	-0.0173***	832	0.539
Fruits (kCal)	0.2400***	-0.0095***	832	0.232
AnimalFat (kCal)	0.2368***	-0.0060**	832	0.647
Alcohol (kCal)	0.0655**	0.0368***	832	0.600
Pulses (kCal)	0.1017***	-0.0306***	832	0.283
OilCrops (kCal)	0.3077***	0.0016	832	0.206
Vegetables (kCal)	0.0940***	-0.0158***	832	0.552
Fish (kCal)	0.4029***	0.0174***	832	0.351
Eggs (kCal)	0.2073***	-0.0124***	832	0.707
Other (kCal)	0.2294***	-0.0055**	832	0.415

Notes: Out-of-pocket health expenditures (%), physicians per capita, and controls for total population between the ages of 15 and 64 (%), and total population 65 years of age and above (%) are included in regressions to capture health care differences across countries. Results are from a seemingly unrelated regression (SURE) model due to the correlation across the error terms in the seven equations. The λ^2 value for the Breusch-Pagan test of independence of error terms was 2809.81, rejecting the null hypothesis of independence with a probability of 0.0000.

Figure 1
Average Caloric Intake, 1961-2011

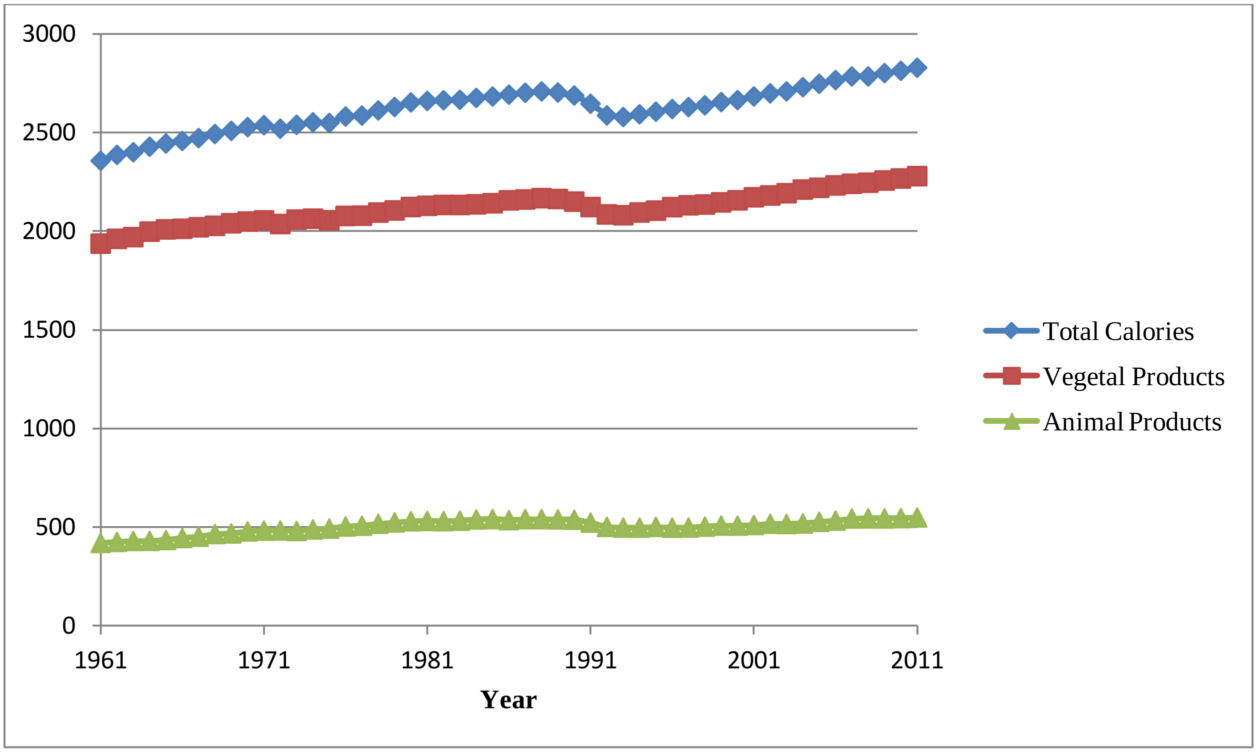
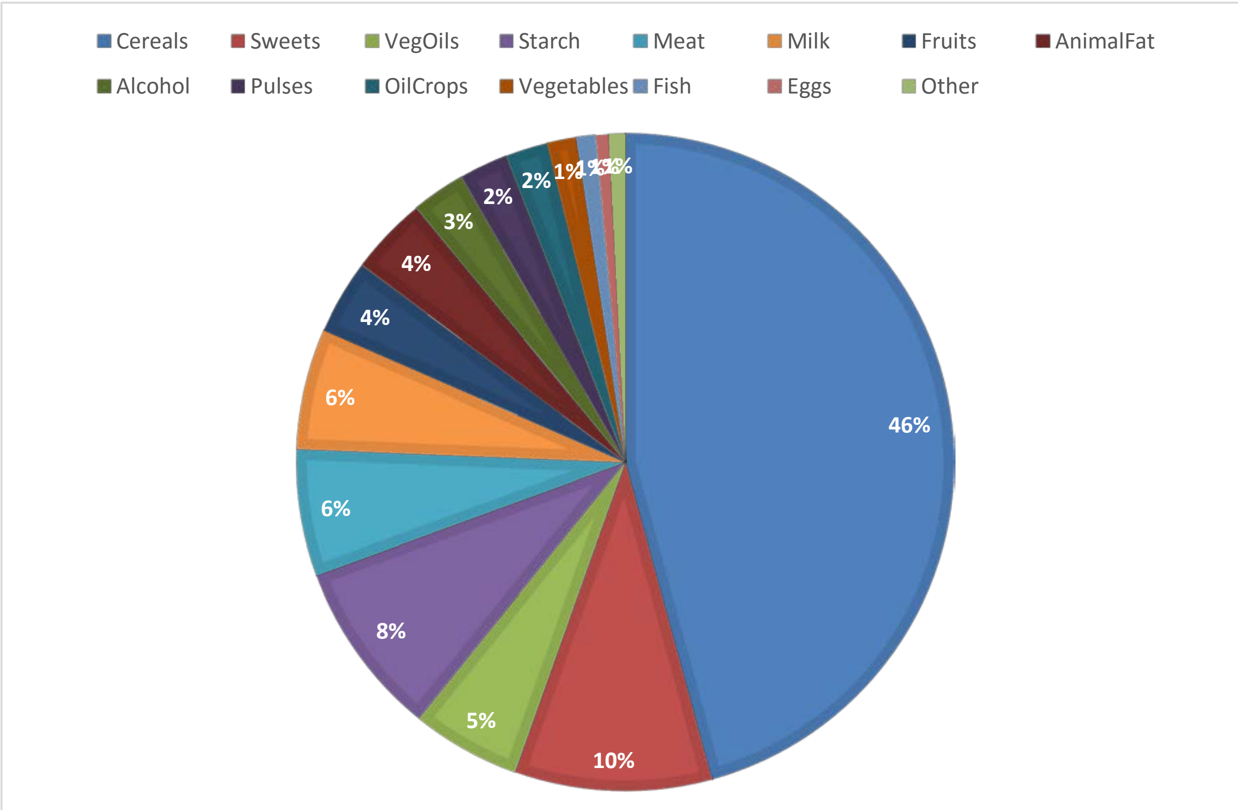
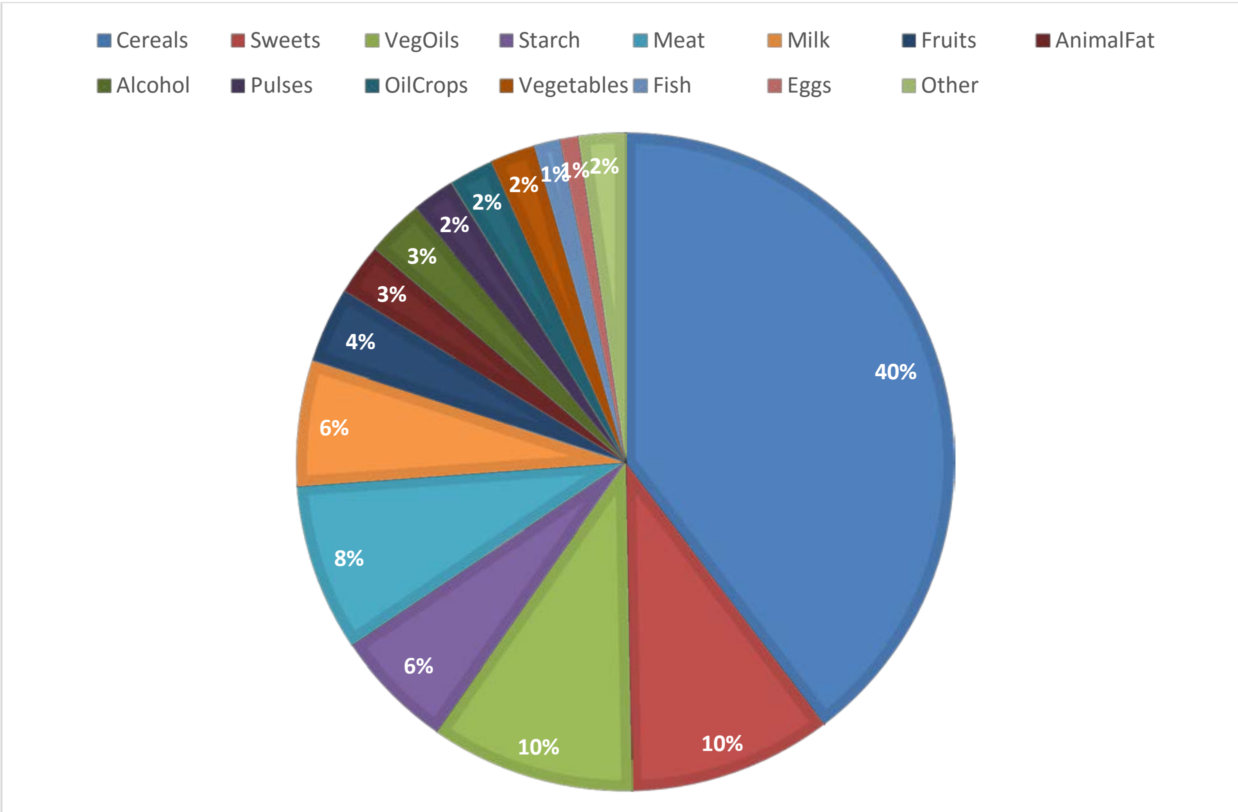


Figure 2a
Average Caloric Intake, 1961



Notes: Data are based on 177 countries from the Food and Agriculture Organization. Calories sum up to 2,352.

Figure 2b
Average Caloric Intake, 2011



Notes: Data are based on 177 countries from the Food and Agriculture Organization. Calories sum up to 2,829.