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# Meat Consumption and Health Outcomes: The Economic Risk Factors of Non-Communicable Disease

Alley Bellack
*Scripps College*

# MEAT CONSUMPTION AND HEALTH OUTCOMES: THE ECONOMIC RISK FACTORS OF NON-COMMUNICABLE DISEASE

BY

ALLEY BELLACK

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PROFESSOR ROBERTO PEDACE

PROFESSOR ANDREW SCHROEDER

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## Abstract

Noncommunicable diseases (NCDs) are the most prominent cause of adult mortality, killing 38 million people each year and on the rise[1]. Cancer, heart disease, diabetes and chronic respiratory diseases are responsible for 82% of NCD-related illness and death. These four diseases, along with mental illness, are estimated to cost the developing world $21 trillion over the next two decades.[2]

Given the substantial health and economic detriments of NCDs, policy makers, government officials, and enterprises around the globe have begun to focus efforts on better understanding and preventing the proliferation of these diseases. Lifestyle factors, including increased inactivity, poor diet, and alcohol and tobacco consumption are currently the most commonly attributed risk factors of NCDs.

With the influx of epidemiological literature linking meat consumption to western disease prevalence, and the World Health Organization (WHO) releasing a statement this year classifying processed meat as a Group 1 carcinogen alongside cigarette smoking, this thesis seeks to understand more thoroughly the role of diet, specifically meat consumption, in the incidence of cancer, heart disease and diabetes around the world.

This paper analyzes previous epidemiological studies on dietary consumption and disease incidence as well as conducts an empirical analysis of data from the WHO and the Food and Agriculture Organization of the United Nations (FAO) to understand the relationship between meat consumption and disease prominence. This paper is the first of its kind to compare country-level data on dietary and lifestyle factors with respective disease incidence and mortality rates in order to observe the impact of country consumption trends on health outcomes. The results of this analysis may provide insight into global economic, health policy and individual-level consumption recommendations in order to mitigate the occurrence of ill-health.


[1] "Non Communicable Diseases." *World Health Organization*. n.d. Web.

[2] Baldwin, Wendy, and Lindsey Amato. "World Population Data Sheet 2012." *Fact Sheet: Global Burden of Noncommunicable Diseases*. Population Reference Bureau, n.d. Web.

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## I. Introduction

Non-communicable diseases (NCDs) are an established threat not only to human health, but also to economic prosperity, development and equality. NCDs are defined as non-transmittable diseases of long duration and generally slow progression, mainly comprised of four main types: cancers, cardiovascular disease, diabetes, and respiratory disease.[3]

Cancer and Heart Disease are the leading causes of death in the United States[4], and North America has the highest regional prevalence of diabetes and amongst developed nations.[5] These three diseases collectively cause the U.S. over $720 billion dollars per year in direct healthcare costs[6], and alongside other non-communicable diseases, account for over 60% of deaths worldwide[7].

According to a report by the World Economic Forum and the Harvard School of Public Health, half of those who die from non-communicable diseases are in the prime of their lives, or peak labor force participation, resulting in substantial industry-wide impairments in competitiveness and productivity due to disability and death[8]. While high income countries currently bear the largest economic burden of NCDs, low and middle-income countries are no longer exempt from the affliction and cost of disease, where almost three-quarters of NCD deaths occur[9].

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[3] "Non Communicable Diseases." *World Health Organization*.
[4] "Leading Causes of Death." *Centers for Disease Control and Prevention*
[5] "IDF Diabetes Atlas - 7th Edition." *IDF Diabetes Atlas - FAQ*. International Diabetes Federation.
[6] "Cancer Prevalence and Cost of Care Projections." *Cancer Prevalence and Cost of Care Projections*. National Cancer Institute, "Heart Disease and Stroke Cost America Nearly $1 Billion a Day in Medical Costs, Lost Productivity." *CDC Foundation*. Centers for Disease Control and Prevention.

[7] *The Global Economic Burden of Non-communicable Diseases: A Report*. Geneva, Switzerland: World Economic Forum, 2011. Harvard School of Public Health.
[8] *The Global Economic Burden of Non-communicable Diseases: A Report*.
[9] *The Global Economic Burden of Non-communicable Diseases: A Report*.

In addition to factors like poor diet and lack of exercise, the rise in prevalence of NCDs has been attributed to a conglomeration of factors including: economic growth and development, global population ageing, rapid unplanned urbanization and the globalization of unhealthy lifestyles[10].

These diseases inhibit domestic and global movements towards poverty reduction, income equality, and sustainable economic growth not only through premature death and decreased quality of life, but also by especially effecting low-income countries and households that lack access to or the disposable income for treatment. [11] Further, studies have shown that marginalized and socially disadvantaged groups are more likely exposed to harmful foods and products such as tobacco, and die sooner than more socially advantaged peoples[12].

For these reasons, in 2011, over 190 countries agreed on "global mechanisms" to reduce the preventable NCD burden including a *Global action plan for the prevention and control of NCDs 2013-2020* which seeks to reduce the number of premature deaths from NCDs by a quarter by 2025 through targeting tobacco and alcohol use, unhealthy diet and physical inactivity.[13] These four lifestyle practices are known as the predominant NCD risk factors because they increase the probability of intermediary factors which later result in NCDs, most notably: obesity, hypertension or high blood pressure, high cholesterol, and raised blood glucose[14].

This thesis is specifically interested in ascertaining the effects of dietary and lifestyle factors, specifically meat consumption, in producing disease outcomes. Meat consumption has been positively associated with country wealth and Western disease prominence: The International

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[10] Essential Medicines and Health Products Information. *The Global Economic Burden of Non-communicable Diseases (September 2011)*. World Health Organization.
[11] *The Global Economic Burden of Non-communicable Diseases: A Report*.
[12] "Non Communicable Diseases." *World Health Organization*.
[13] "Non Communicable Diseases." *World Health Organization*.
[14] "Non Communicable Diseases." *World Health Organization*.

Agency for Research on Cancer (IARC) recently analyzed over 800 epidemiological studies and concluded that processed meat, including processed poultry, causes cancer and that red meat likely causes cancer. This paper analyzes country-level lifestyle trends and disease occurrence to observe if country averages in meat consumption result in similar disease outcomes as individual-level epidemiological literature has demonstrated.

In order to assess the relationship between meat consumption and disease, this thesis examines previous literature on the topic, and then conducts an empirical analysis of country-level data on meat consumption, inactivity rates, wealth, and other lifestyle factors against incidence and mortality rates of cancer, heart disease and diabetes. To our knowledge, this paper is the first of its kind to conduct an empirical analysis comparing country-wide meat consumption and lifestyle factors to country-level disease outcomes. In our regression analysis using GLS, we use country data from the FAO and WHO in years 2000-2012. Our findings show a significant positive association between meat consumption and cancer incidence, a significant negative association in cardiovascular mortality and diabetes prevalence, and an insignificant negative association in diabetes mortality, cancer mortality and total NCD mortality. Other than cancer incidence, these results are not in congruence with our hypothesis that increased meat consumption on country-wide levels increases country mortality and incidence of cancer, heart disease and diabetes.

## II. Literature Review

### A. Epidemiological Studies

Amongst epidemiological findings, five main prospective studies have observed a large population of vegetarians for cancer and further disease incidence: the Adventist Health Study[15], the Adventist Health Study II[16], the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC)–Oxford[17], the Oxford Vegetarian Study[18], and the UK Women's Cohort Study[19]. Each of these cohort studies used self-reporting methods to record data of participating individuals. The findings of these cohorts will be analyzed further in this section, but the overarching conclusions are as follows: both EPIC-Oxford and the Oxford Vegetarian Study reported that vegetarians and vegans had a lower risk than meat consumers for all cancers combined including cancers of the stomach, bladder, lymphatic and hematopoietic tissue, but a higher risk of cervical cancer. In the Adventist Health Study, vegetarians had a significantly lower risk for colon and prostate cancer in comparison with non-vegetarians. The Adventist Health Study II reported vegetarians and vegans had a lower risk of all cancers combined, and the UK Women's Cohort study showed that a vegetarian diet was not associated with the risk of breast cancer.

The Global Burden of Disease project by Harvard, an assessment of mortality and disability of diseases, estimated that in 2013, dietary risks accounted for 11.3 million deaths and

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[15] "Associations between Diet and Cancer, Ischemic Heart Disease, and All-cause Mortality in Non-Hispanic White California Seventh-day Adventists1,2,3." *Associations between Diet and Cancer, Ischemic Heart Disease, and All-cause Mortality in Non-Hispanic White California Seventh-day Adventists.* American Society for Clinical Nutrition, 01 Sept. 1999.

[16] Orlich, Michael J., Pramil N. Singh, Joan Sabaté, Karen Jaceldo-Siegl, Jing Fan, Synnove Knutsen, W. Lawrence Beeson, and Gary E. Fraser. "Vegetarian Dietary Patterns and Mortality in Adventist Health Study 2." *JAMA Internal Medicine*. U.S. National Library of Medicine, 08 July 2013.

[17] Crowe, Francesca L., Paul N. Appleby, and Ruth C Travis. "Francesca L Crowe." *Risk of Hospitalization or Death from Ischemic Heart Disease among British Vegetarians and Nonvegetarians: Results from the EPIC-Oxford Cohort Study*. American Society for Nutrition, n.d.

[18] Appleby, Paul N., Margaret Thorogood, and And Jim I Mann. "Paul N Appleby." The Oxford Vegetarian Study: An Overview. N.p., 01 Sept. 1999.

[19] "A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care." *A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care*. The American Journal of Clinical Nutrition, n.d.

241.4 million Disability Adjusted Life Years (DALYs) and attributed 644,000 deaths (including deaths from CVD, diabetes and colorectal cancers) to a diet high in processed meat. [20] Processed meat is defined by meat that has been altered by salting, curing, fermentation, smoking, or other processed to enhance flavor or improve preservation.[21]

In a systematic review and meta-analysis published in 2010 by the American Heart Association attempting to quantify the effects of different types of meat consumption on the development of coronary heart disease, stroke and diabetes, processed meats, but not red meats were associated with higher incidence of both heart disease and diabetes. This study observed relationships between red (unprocessed) meat consumption, processed meat consumption, and total meat consumption with the aforementioned diseases. The review finalized 20 cohort studies on which to conduct randomized least squares models for trend estimation, resulting in an observed total of over two-hundred thousand people. This meta-analysis found that each serving per day of processed meat was associated with a 42% higher risk of Coronary Heart Disease (CHD) and a 19% higher risk of diabetes, whereas total meat intake was associated with a 25% higher risk of CHD and a 12% higher risk of diabetes. Red meat intake was not associated with CHD or stroke, however only 4 and 3 studies evaluated these relationships respectively.[22]

In another US cohort study published by the American Journal of Clinical Nutrition (AJCN) investigating the effects of differing types of meat consumption on the risk of Type 2 diabetes (T2D), both processed and unprocessed meat were associated with increased risk of Type 2 diabetes. The study followed roughly forty thousand men in the Health Professionals

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[20] GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet.* 2016 Oct 7; 388:1659–1724.

[21] "IARC Monographs Evaluate Consumption of Red Meat and Processed Meat." IARC Monographs Evaluate Consumption of Red Meat and Processed Meat | UICC. World Health Organization, n.d.

[22] Micha, R., S. K. Wallace, and D. Mozaffarian. "Red and Processed Meat Consumption and Risk of Incident Coronary Heart Disease, Stroke, and Diabetes Mellitus: A Systematic Review and Meta-Analysis." *American Heart Association Journal* 121.21 (2010): 2271-283.

Follow-Up Study (1986-2006), eighty thousand women in the Nurses' Health Study I (1980-2008) and ninety thousand women in the Nurses' Health Study II (1991-2005). In these cohorts, diet was assessed by food-frequency questionnaires and Type 2 diabetes was confirmed later through supplementary questionnaire. In following over four million individuals and over thirteen thousand cases of type 2 diabetes, and after adjusting for age, BMI and other lifestyle and dietary risk factors such as smoking, physical activity, medication use and family history, a one serving per day increase in meat resulted in a pooled hazard ratio (HR) of 1.12-1.32 between cohorts, or a 12-32% increase in diabetes risk. This was the first study to conclude that processed meat increased T2D risk as well as estimate the effects of different dietary food substitutions on health outcomes. The study projected substitutions for one-serving of low-fat dairy, nuts and whole grains a day, instead of meat, would lower risk of T2D by 16-35%. [23]

Another study[24] conducted by the Internal Medicine Journal followed the same cohort studies as the AJCN meta-analysis above, yet examined red meat consumption in relation to CVD and cancer mortality. The study documented over twenty thousand deaths, and after adjusting for salary, lifestyle and dietary risk factors, concluded a positive relationship between red meat consumption and risk of total cardiovascular disease and cancer mortality. Both processed and unprocessed red meat were shown to have this correlation, with processed red meat producing a relatively greater risk. It speculated that the presence of nitrites and sodium in processed meats increased the risk of heart disease further than red meat through increasing blood pressure levels. Additionally, the study stated that these nitrites found in processed meats

[23] Pan, A., Q. Sun, A. M. Bernstein, M. B. Schulze, J. E. Manson, W. C. Willett, and F. B. Hu. "Red Meat Consumption and Risk of Type 2 Diabetes: 3 Cohorts of US Adults and an Updated Meta-analysis." *The American Journal of Clinical Nutrition.* U.S. National Library of Medicine, n.d. *American Journal of Clinical Nutrition* 94.4 (2011): 1088-096.

[24] Pan, An, Qi Sun, Adam M. Bernstein, Matthias B. Schulze, JoAnn E. Manson, Meir J. Stampfer, Walter C. Willett, and Frank B. Hu. "Red Meat Consumption and Mortality: Results from Two Prospective Cohort Studies." *Archives of Internal Medicine*. U.S. National Library of Medicine, 09 Apr. 2012.

have been related to endothelial dysfunction and impaired insulin response, which explains its increased relationship with type 2 diabetes observed in other studies, and that these compounds exist as potential carcinogens especially when exposed to high-temperature cooking. The pooled hazard ratio with 95% confidence was 1.3 for total mortality given a one serving per day increase of unprocessed red meat. They estimated that substitutions of a one-serving per day of other foods including fish, poultry, nuts, legumes, low-fat dairy, and nuts were associated with a 7-19% lower mortality risk. The study concluded that 9.3% of deaths in men and 7.6% in women in the respective cohorts could be prevented if all individuals consumed less than half a serving per day (~42g/d) of red meat. When adjusted for saturated fat, cholesterol, and heme iron (a dietary iron found in red meat linked to cancer incidence), the association between red meat and coronary heart disease mortality was weakened, suggesting that these particular constituents of meat contribute to disease outcomes. The study attempted to assess the relationship between lean meat and health risks, but was ultimately unable.

Cancer in British Vegetarians published by the Cancer Epidemiology Unit in the Nuffield Department of Population Health and University of Oxford uses data from the Oxford Vegetarian Study and the EPIC-Oxford cohort study, two of the most oft cited studies[25] conducted on meat consumption and disease prevalence, that tracked four different dietary group populations: meat consumers, fish consumers (but non-meat consumers), vegetarians (dairy, but not meat or fish consuming) and vegans (non-meat or dairy consuming). The study examined over sixty thousand British men and women in these joined cohorts – roughly thirty-two thousand meat eaters, nine thousand fish eaters and twenty thousand vegetarians (including two

[25] Key, Timothy J., Paul N. Appleby, Francesca L. Crowe, Kathryn E. Bradbury, and Julie A Schmidt. "Timothy J Key." *Cancer in British Vegetarians: Updated Analyses of 4998 Incident Cancers in a Cohort of 32,491 Meat Eaters, 8612 Fish Eaters, 18,298 Vegetarians, and 2246 Vegans*. The American Journal of Clinical Nutrition, n.d.

thousand vegans) in which participants self-reported their dietary and lifestyle practices. According to the findings, smoking rates, BMI, inactivity and alcohol consumption were higher in meat eaters than the other three diet groups, with these practices lowest in vegans, and fish eaters and vegetarians in between. In both men and women, vegans had the lowest caloric, protein, fat and saturated fat intake, and the highest intake of carbohydrates and dietary fiber, with fish eaters and vegetarians again intermediate between meat eaters and vegans. After a 14.9 year follow up, the study observed that incident cancers were highest in meat eaters at 10.1% of the population followed by fish eaters at 6.0% and vegetarians 5.9%. The study concluded that the risk of some cancers, but not all, are lower in vegetarians and fish-eaters than meat eaters.

The first Adventist Health study[26](1989) was conducted on Seventh Day Adventists (SDA) in California, a cult population that largely abstains from consuming meat, and prohibits the use of alcohol and tobacco for religious reasons. Due to the population sample's relatively unified lifestyle and dietary practices, as well as their geographic isolation, the study hypothesized they could better isolate the effects of dietary practices on disease incidence. The study followed 34,198 white, adult SDA for 6 years (1977-82), when approximately 55.2% of California Seventh Day Adventists were lacto-ovo-vegetarians (meaning they consumed eggs and dairy, but not meat – otherwise a typical vegetarian), and the remainder of the population consumed relatively small amounts of meat. They also found vegetarians to consume more fruits and vegetables and less processed foods than their meat eating counterparts. Results showed significant associations between beef consumption and fatal ischemic heart disease (IHD) in men, with the relative risk equaling 2.31 for subjects who consumed beef greater than three times a week. Subjects who often weekly consumed nuts and preferred whole grain to white bread

[26] "Associations between Diet and Cancer, Ischemic Heart Disease, and All-cause Mortality in Non-Hispanic White California Seventh-day Adventists1,2,3."

displayed a lowered risk of IHD, and the study found legume and dried fruit consumption to have a negative associated risk of various cancers. Results showed higher risks of colon, prostate and bladder cancer, diabetes, hypertension, and arthritis amongst meat consumers, and concluded that in the SDA population, vegetarians are healthier than non-vegetarians. However, this result could not be attributed solely to the absence of meat, due to the fact that vegetarians had a higher consumption of fruits and vegetables as well.

The second SDA study conducted in 2013, Adventist Health Study II[27](AHS2), more holistic than the first, followed a total of 96,469 Seventh-day Adventist men and women across racial, geographical and socioeconomic groups. Dietary patterns were assessed by questionnaire and grouped into five categories: non-vegetarian, semi-vegetarian (an often meat abstaining consumer), pesco-vegetarian (a non-meat, but fish-eating individual), lacto-ovo-vegetarian, and vegan. The study followed associations with dietary patterns and cardiovascular mortality, non-cardiovascular non-cancer mortality, renal mortality and endocrine mortality. It found vegetarian diets to have a significant impact in reducing mortality overall. The study also found that associations between diet and mortality were more prominent in men than in women. The adjusted all-cause mortality (with 95% confidence) in all vegetarians combined versus non meat eaters was 0.88 and 0.85 for vegans, 0.81 for pesco-vegetarians and 0.92 for semi-vegetarians. However, no significant associations were made with reduced cancer mortality, which the study attributes to the complexity of factors affecting overall cancer risk, their dietary model methods, and the early follow up of the study. The results also showed that vegan diets in the study surpassed the protection of vegetarian diets in the prevention of obesity, hypertension, type-2

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[27] Orlich, Michael J., Pramil N. Singh, Joan Sabaté, Karen Jaceldo-Siegl, Jing Fan, Synnove Knutsen, W. Lawrence Beeson, and Gary E. Fraser. "Vegetarian Dietary Patterns and Mortality in Adventist Health Study 2." *JAMA Internal Medicine*. U.S. National Library of Medicine, 08 July 2013.

Diabetes, and cardiovascular mortality, with males experiencing greater health benefits from dietary change[28].

A few studies have analyzed the EPIC-Oxford Study for differing findings: all-cause mortality, cancer mortality, and CVD mortality. One study reports that in this cohort, vegetarian diets were associated with lower ischemic heart disease risk[29], and another concludes that vegetarian diets are resulted in lower T2D risk[30]. Updated analyses[31] of the studies have shown the risk of some cancers lower in fish eaters and vegetarians than meat eaters, but initial findings suggest that there was discrepancy in specific cause of death mortality but no significant differences in all-cause mortality.[32] Given the EPIC-Oxford study only found a relationship between vegetarians and lowered risk of CVD, not all-cause mortality like the AHS2, researches in AHS2 attribute this discrepancy to dietary differences between the vegetarian populations: vegetarians in the Adventist Health Study consumed higher quantities fruits and vegetables, and more vitamin C and fiber than those in Britain.

In relating meat consumption to Type 2 Diabetes specifically, analyses of both the Women's Health Study[33], and the Melbourne Collaborative Cohort Study[34] found significant relationships between meat consumption and disease incidence. In fact, the ladder specifically

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[28] "Beyond Meatless, the Health Effects of Vegan Diets: Findings from the Adventist Cohorts." Nutrients. U.S. National Library of Medicine, n.d.
[29] Crowe, Francesca L., Paul N. Appleby, and Ruth C Travis. "Francesca L Crowe." *Risk of Hospitalization or Death from Ischemic Heart Disease among British Vegetarians and Nonvegetarians: Results from the EPIC-Oxford Cohort Study*. American Society for Nutrition, n.d.
[30] Pan, A., Q. Sun, A. M. Bernstein, M. B. Schulze, J. E. Manson, W. C. Willett, and F. B. Hu. "Red Meat Consumption and Risk of Type 2 Diabetes: 3 Cohorts of US Adults and an Updated Meta-analysis." *The American Journal of Clinical Nutrition.* U.S. National Library of Medicine, n.d. *American Journal of Clinical Nutrition* 94.4 (2011): 1088-096.
[31] Key, Timothy J., Paul N. Appleby, Francesca L. Crowe, Kathryn E. Bradbury, and Julie A Schmidt. "Timothy J Key." *Cancer in British Vegetarians: Updated Analyses of 4998 Incident Cancers in a Cohort of 32,491 Meat Eaters, 8612 Fish Eaters, 18,298 Vegetarians, and 2246 Vegans*. The American Journal of Clinical Nutrition, n.d.
[32] Appleby, Paul N., Francesca L. Crowe, Kathryn E. Bradbury, and Ruth C Travis. "Paul N Appleby." *Mortality in Vegetarians and Comparable Nonvegetarians in the United Kingdom*. The American Journal of Clinical Nutrition, 01 Jan. 2016.
[33] "A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care." *A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care*. The American Journal of Clinical Nutrition, n.d.
[34] Shang, Xianwen, David Scott, Allison M. Hodge, Dallas R. English, Graham G. Giles, and Peter R Ebeling. *Dietary Protein Intake and Risk of Type 2 Diabetes: Results from the Melbourne Collaborative Cohort Study and a Meta-analysis of Prospective Studies*. The American Journal of Clinical Nutrition, n.d.

observed animal versus plant protein intake and found that higher intakes of both total and animal protein intakes were associated with increased risk of type 2 diabetes, whereas higher plant protein intake was associated with a lower risk. Analyses of the Women's Health study concluded that higher consumption of total red meat, especially processed meats, increased the risk of developing Type 2 Diabetes in adult women, independent of known diabetes risk factors. This study intended to follow up on the results of the Seventh Day Adventists study findings that increased meat consumption led to higher incidence of Type 2 Diabetes, and speculated that the specific compounds found in red meat that result in disease incidence are: nitrates, saturated fat, heme iron, cholesterol and animal protein. The study commented on significant positive associations in dietary intakes of these aforementioned compounds in their relation to diabetes. However, they were unable to assess the relationship between nitrates and chemical preservatives used in food preparation and diabetes risk, concluding that the specific ways in which consumption of meat effect Type 2 Diabetes incidence (ie. by increasing insulin resistance), require further investigation.

Finally, in its similar geographical diversity to the empirical analysis section of this thesis, Interheart study[35] involved participants from 52 countries and roughly thirty-thousand people to assess how different dietary practices impact the prevalence of acute myocardial infarction (AMI), also known as heart attack (a symptom of heart disease), globally. In seeking to understand how diet as a major modifiable risk factor could differ in regions around the world, the study identified three dietary patterns: Oriental, which consisted of high intake of tofu, soy and other sauces; Western, high in fried foods, salty snacks, eggs and meat; and Prudent, which

[35] Romaina Iqbal, Sonia Anand, Stephanie Ounpuu, Shofiqul Islam, Xiaohe Zhang, Sumathy Rangarajan, Jephat Chifamba, Ali Al-Hinai, Matyas Keltai, and Salim Yusuf. "Dietary Patterns and the Risk of Acute Myocardial Infarction in 52 Countries." *Dietary Patterns and the Risk of Myocardial Infarction in 52 Countries* | Circulation. American Heart Association Journals, n.d.

was high in fruits and vegetables. Predictably, the study observed an inverse association between prudent diets and myocardial infarction, a positive relationship in fried and salty foods, a weak association between meat intake and Western diet, and no relationship between the oriental diet and AMI. The study speculated that the ill-health of fried foods is due to the fat used in cooking, and demonstrated that both saturated fats and salt intake have adverse associations with coronary heart disease due to the ladder increasing mean blood pressure levels and hypertension. They concluded that dietary recommendations of increased consumption of fruits and vegetables and decreased consumption of meats are likely to reduce the risk of heart attack in all world regions.

In synthesis, almost all existing literature based on previous epidemiological cohort studies associates meat intake with a higher risk of cancer, heart disease, diabetes, and in some cases, all-cause mortality.

One unique, prospective study remains on the significance of meat consumption and health outcomes. This study created a comparative risk assessment framework with dietary and weight-related risk factors to quantify the projected effects of dietary change in 2050. Published by the University of Oxford and the British Heart Foundation Centre[36], the study used many of the cohort studies mentioned above to model its framework and assess the effects of different diets on global health and environmental outcomes. They also made the first attempt at estimating the economic value of different dietary choices by their impact on global health and the environment. The study examined four dietary scenario projections on the outcomes of Coronary Heart Disease, Stroke, Type 2 Diabetes, and Cancer (as an aggregate of site-specific cancers). They calculated the relative risks of each disease due to meat consumption and other

[36] Springmann, Marco, H. Charles J. Godfray, Mike Rayner, and Peter Scarborough (2016),. "Analysis and Valuation of the Health and Climate Change Cobenefits of Dietary Change." *Proceedings of the National Academy of Sciences Proc Natl Acad Sci USA* 113.15 (2016): 4146-151.

various food commodities in region-specific locations by adopting results from previous epidemiological studies, aggregating publically available data and adjusting regional diets to accommodate one of four dietary practices: a reference based on the FAO population food consumption projections; a group following the proposed global dietary guidelines by the World Cancer Research Fund and the WHO while consuming a caloric intake to solely maintain body weight; a vegetarian diet which includes eggs and dairy; and a vegan diet comprised solely of plant-based foods. These diets had differing amounts of disease relative risk parameters, which the study used to calculate the likelihood of obtaining disease. The risk factors observed were: fruit and vegetable consumption, red meat consumption, population overweight, and obesity. Through this modeling framework and a corresponding economic analysis, the study found that dietary changes towards the consumption of more plant-based foods, and less animal foods resulted in fewer diet-related mortality and less greenhouse gas emissions. Meat consumption reduction was found to have the most positive health effects on East Asia, Western high- and middle-income countries, and Latin America. According to their results, shifting global diets to more plant-based diets could reduce global mortality by 6-10% and food-related greenhouse gases by 29-70% in 2050. In addition, the economic benefits of a global dietary shift would be $1-31 trillion US dollars, or .4-13% of global GDP in 2050.

### B. Understanding Consumers & Meat Consumption Trends

Given the evident tie in epidemiological literature between meat consumption and disease, understanding both historic trends in meat consumption and the awareness of consumers are pivotal in any future disease mitigation efforts.

A study[37] conducted in the Netherlands based on the Dutch National Food Consumption Survey analyzed the socio-demographics, food, and health awareness of vegetarians, non-vegetarian consumers of meat substitutes, and meat consumers. It found that vegetarians and meat substitute consumers were of similar socio-demographic profiles: both had higher education levels, higher socio-economic status and lived in more urbanized residential areas compared to meat consumers. Vegetarians were also found to have increased levels of concern surrounding product information, health, ecological products, and tended to be more female.

In a study conducted in the Applied Economic Perspectives and Policy Oxford Journal on how meat demand varies with price, income, and product category, results showed that high income consumers are more likely to choose steak and chicken breast and less likely to choose ground beef, chicken wings, and deli ham than lower income consumers.[38] This distinction between processed and unprocessed meat and income level places lower-income consumers at a further health risk according to previous cohort study findings that concluded processed meats place consumers at a higher disease risk.

[37] Hoek, A. C., Luning, P. A., Stafleu, A., & De Graaf, C. (2004). Food-related lifestyle and health attitudes of Dutch vegetarians, non-vegetarian consumers of meat substitutes, and meat consumers. *Appetite*, 42(3), 265–272. doi:10.1016/j.appet.2003.12.003

[38] And, Jayson L. Lusk*, and Glynn T. Tonsor. "Jayson L. Lusk." How Meat Demand Elasticities Vary with Price, Income, and Product Category. N.p., n.d.

Another study[39] by the American Journal of Agricultural Economics conducted on U.S. meat demand trends and the effects of advertising and health information on overall meat demand, found that there has been a steady increase of poultry consumption over the last two decades, predominantly at the expense of beef consumption. Their results suggested that structural change, particularly the increasing prevalence of health information, was found significant in the demand change of meat. More specifically, non-negated values of health information elasticities were larger than those of meat price elasticities, suggesting that small changes in health information result in larger impacts on meat consumption than small changes in meat prices. This information is critical in policy making changes. Similar results displaying the impact of increased consumer awareness and behavior have been established in two studies in the Journal of Health Economics: one on health status information impacting a healthier lifestyles in China[40], and the other on the impact of tobacco consumption bans in developing countries[41].

In another examination of FAO and USDA food availability data combined with the National Health and Nutrition Examination Surveys (NHANES) that evaluated meat intake type trends in the U.S. in 2012, the study[42] found that overall meat consumption continues to rise in the U.S., Europe and developed world. The study mirrors the prior findings that display a shift

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[39] Henry W. Kinnucan, Chung-Jen Hsia, John D. Jackson, and Hui Xiao. "Effects of Health Information and Generic Advertising on U.S. Meat Demand." *Effects of Health Information and Generic Advertising on U.S. Meat Demand*. American Journal of Agricultural Economics, n.d.

[40] "Does Information on Health Status Lead to a Healthier Lifestyle? Evidence from China on the Effect of Hypertension Diagnosis on Food Consumption ☆." Does Information on Health Status Lead to a Healthier Lifestyle? Evidence from China on the Effect of Hypertension Diagnosis on Food Consumption. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

[41] "The Impact of Tobacco Advertising Bans on Consumption in Developing Countries." The Impact of Tobacco Advertising Bans on Consumption in Developing Countries. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

[42] Daniel C. R., Cross A. J., Koebnick C., Sinha R. Trends in meat consumption in the USA. *Public Health Nutrition*. 2011;14(4):575–583. doi: 10.1017/S1368980010002077.

towards higher poultry consumption, presumably due to increased consumer awareness, despite red meat consumption representing the largest portion of meat consumed in the U.S. at 58%.

> “Meat can be further classified as red meat or white meat by the quantity of red versus white muscle fibers, and fresh or processed by preparation methods… Components of meat linked to chronic disease risk include fat content, particularly saturated fat in red meat, and dietary cholesterol. Meat can also be a source of several known mutagens, including *N*-nitroso compounds (NOCs) in processed meats, and heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) formed during high-temperature cooking and grilling.”

The study found that 22% of the meat consumed in the U.S. is processed, and that the type and quantities of meat consumed vary by education, race, age and gender, with men consuming more of each meat category than women, peak meat consumption occurring ages 20-49, poultry and fish intake increasing with education level, and whites, blacks and hispanics all reporting similar red meat intake. The study asserted that meat is consumed in the U.S. at more than three times the global average and speculated the prominence of Western disease to this occurrence. It also found wealth as the determinant of per capita meat consumption across the world - as developing countries generate more available income, dietary shifts toward higher meat consumption occur, resulting in the decrease of consumption of cereals and other plant foods.

### C. Health Economics Studies

A few main health economics studies stand out in their similarity to the one conducted in this paper either by observing similar variables or in their use of country-level data. The first published by the Journal of Health Economics quantifies the impact of doctors on health in OECD countries.[43] It considers factors in each country such as GDP, alcohol and tobacco consumption, education, gender and life expectancy in estimating OLS, MLE, and feasible GLS models. It also quantifies premature mortality by heart disease and infant mortality in each country as indicators of health status. The study concluded that the presence of doctors plays a significant role in health outcome across countries.

The second study published in the Journal of Health Economics uses both a consumer model of dietary adjustments for nutritional recommendations and an epidemiological model to evaluate the impact of changes in diet on mortality. It targeted the consumption of salt, sugar, fat, cholesterol, fruits and vegetables, and soft beverages among others and concluded that the increase of fruit and vegetable consumption, and the decrease of salt and cholesterol intake could prevent 3-4% of premature NCD deaths annually, even with modest (5%) consumption changes.[44]

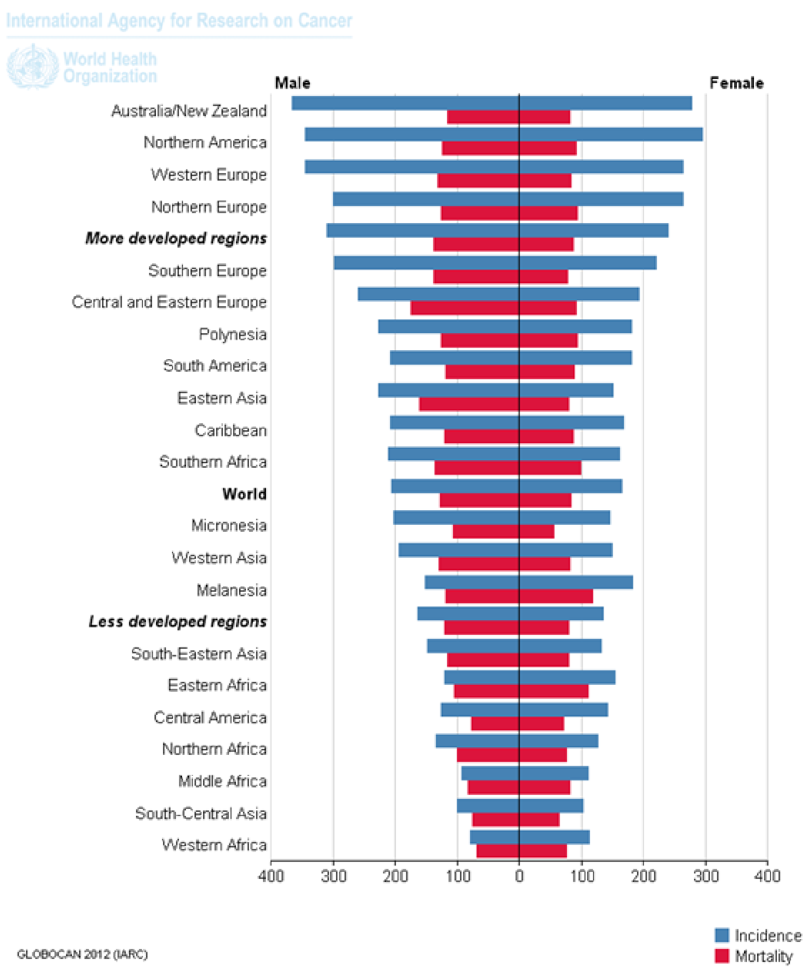
Finally, a study called Inequality and Mortality, also published in the Health Journal of Economics, observes whether changes in economic inequality affect mortality in wealthy countries.[45] It uses tax data on the share of pre-tax income going to the wealthiest 10% of population in twelve developed countries including the U.S. and U.K. It tracked GDP per capita,

[43] "International Differences in the Impact of Doctors on Health: A Multilevel Analysis of OECD Countries." International Differences in the Impact of Doctors on Health: A Multilevel Analysis of OECD Countries. Journal of Health Economics, n.d. Web. 08 Dec. 2016.
[44] "Economic Assessment of Nutritional Recommendations." Economic Assessment of Nutritional Recommendations. Journal of Health Economics, n.d. Web. 08 Dec. 2016.
[45] "Inequality and Mortality: Long-run Evidence from a Panel of Countries." Inequality and Mortality: Long-run Evidence from a Panel of Countries. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

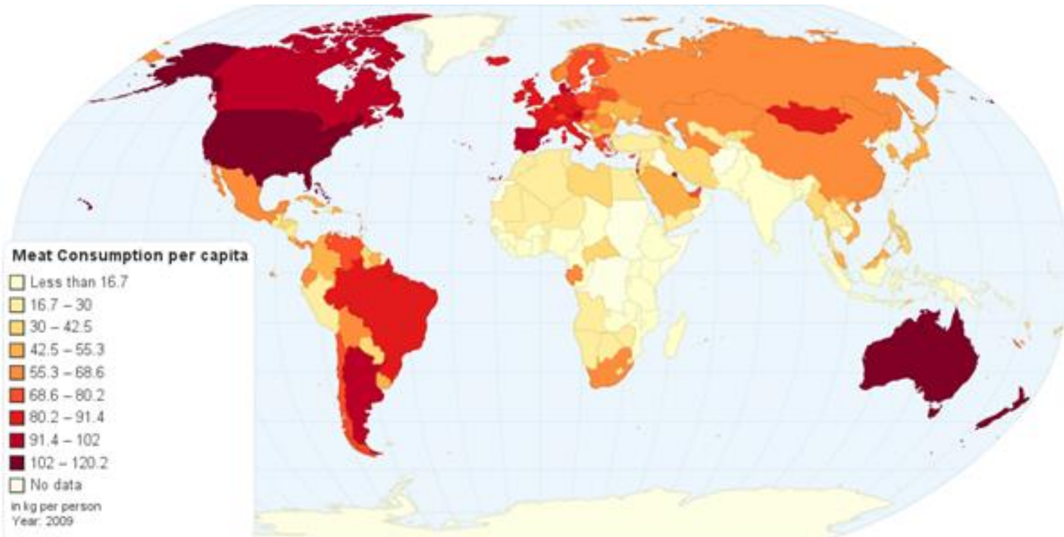
education, public and private health spending per capita, suicide, homicide, and infant mortality rates, and life expectancy in each country in order to quantify the effects of income distribution on overall health and mortality. It demonstrated that GDP is associated with lower mortality, and that income inequality is associated with higher mortality without country and year fixed effects.

### D. Meat Consumption and Development

In researching meat consumption and disease incidence per country, the following images were obtained from WHO data. The graph below is from the International Agency for Research on Cancer, part of the WHO, and illustrates the incidence and mortality rates of cancer for males and females in regions of differing development. One will notice that regions of greater development have significantly higher rates of cancer incidence, but nearly similar rates of cancer mortality, presumably due to unhealthful lifestyles and the availability of and increased spending on pharmaceutical drugs and other disease treatment measures.



The below image displays meat consumption per capita in 2009, globally. The regions with heightened meat consumption reflect the regions with higher cancer incidence in the graph above. While there may be many reasons for this relationship, it remains an interesting observation.




Research has shown that the westernization, or development of a country results in an increased meat consumption due to higher expendable income. Incidentally, the rate of noncommunicable disease also increases with development. As examined previously, this increased NCD rate is commonly attributed to poor diet, lack of exercise, and harmful use of alcohol and tobacco. Historical literature has concluded the detriment of meat consumption in relation to individual-level disease outcomes. The next section of this thesis seeks to quantify whether average meat consumption across countries, among other risk factors, contributes to disease outcomes on a country-wide scale.

## III. Data

The data used in this empirical analysis uses country level panel data on a variety of variables extracted from many sources: Cancer incidence and mortality rates were aggregated from the WHO and the International Agency for Research on Cancer. Diabetes incidence and expenditure data is from the Diabetes Atlas, and Diabetes and Cardiovascular mortality are from the WHO. GDP per capita was extracted from the World Bank, total country health expenditure from the WHO, and alcohol consumption from the FAO.

The FAO is the world's largest online agricultural database, which includes data since 1961 from over 190 FAO member countries. The data capturing meat consumption is based on data submitted by member countries through questionnaire and supplemented by national source reviews, staff estimates and corrections to close gaps. The FAO data on meat consumption used in this analysis is total meat consumption, or what the FAO considers as the sum of beef, poultry, pork, sheep, goat and other game, excluding fish.

Per capita meat consumption is measured in kg/capita/year, and is part of the FAO food supply data, valued as total commodity availability after exports and waste from farm to household. This means that the data indicates an estimate of consumption, or what is available to consume for each individual on average, and not the precise amount that is consumed by individuals themselves. For this reason, and due to the country level scale of data, the size of measurement in this analysis varies greatly from the individual-level cohort studies explained in the literature review. This data contains both weighted, or age-standardized rates as percentages and amounts per capita, which allows adequate comparison between variables and countries. Additionally, meat consumption was aggregated by taking the average consumption over a ten-year period before the observed disease incidence findings, in order to better view the compounding effects of a dietary practice over time. However, even though the average meat consumption was used in the regression analysis, meat consumption in the year 2011, when most of the other variables were tracked, was only two units larger than the average.

Disease outcomes were quantified in terms of Cancer, Diabetes and Cardiovascular disease mortality per 100,000 individuals within the population, although incidence rate data is also used for cancer and diabetes as well. Mortality data explains the total deaths attributable to a disease, whereas incidence data explains the total prevalence of disease.

Each of the following models attempt to estimate and quantify differing factors that could potentially contribute to each specific disease outcome. Out of 196 countries in the world, this analysis contains 160 country observations due to insufficient data present on many small countries and islands, or countries that were accounted for by the FAO and not the WHO, which were easier omitted. Given its variance across countries, GDP per capita was converted to logarithmic form to better observe variable relationships on a similar scale. Health outcomes, such as cancer mortality, are quantified in year 2012. However, due to data extrapolation availability, three variables: inactivity rates, alcohol consumption, and body mass index (BMI) are measured in year 2010 and act as a proxy for 2012 data. Finally, tobacco smoking in many countries was much higher for men than women, at times up to 10x higher. The data was found by gender, and the country total averages were calculated with the assumption that the population had an equal gender ratio.

## A. Variable Reference Table

| Variable Name | Description |
|---|---|
| cancer2012 | Cancer mortality in 2012 measured in deaths per 100,000 population. Age-standardized rate (ASR) |
| incCancer2012 | Age-adjusted cancer incidence rate per 100,000 persons per year |
| cvd2012 | Cardiovascular disease mortality ASR in 2012 measured in deaths per 100,000 population |
| diabetes2012 | Diabetes mortality ASR in 2012 measured in deaths per 100,000 population |
| diabprevpercent | Percent diabetes prevalence in population ASR. |
| ncdtotalper100kpop2012 | Total noncommunicable disease ASR deaths per 100,000 population in 2012 |
| meat2000, meat2001, meat2002 … | Meat supply in each respective year (2000-2011) measured in kg/person/year |
| avemeatallyears | Average meat supply available 2000-2011 in kg/person/year. Approximates individual consumption |
| numadultsdiab | Total number of adults in population with diabetes |
| gdppc2011, gdppc2012 | GDP per capita in 2011, 2012 USD |
| tothealthexppc2011, tothealthexppc2012 | Total health expenditure per capita in US dollars in 2011, 2012 |
| inactiveadultsprcnt2010 | Percent of population attaining less that 150min of moderate-intensity, or 75 vigorous-intensity physical activity per week in 2010 |
| alcoholconskcalpcperday2010 | Alcohol consumption in 2010 measured in kcal/capita/day |
| accesssanitationpercnt | Percent population access to sanitation |
| accesswaterpercnt | Percent population access to clean water |
| aveenergysupplypercnt | Average Dietary Energy Supply Adequacy (ADESA). Percentage of energy supply fulfillment in terms of Average Dietary Energy Requirement (ADER) during the reference period (3-year average period 2010-2012). Index of adequacy of the food supply in terms of calories |
| averageanimalproteingrampcperda y | Average animal protein consumption (g/capita/day) |
| averageproteinsupplygrampcperda y | Average protein supply (g/capita/day) |
| energysupplycerealsrootstuberspe | Energy supply percent obtained from cereals, roots and tubers in population. |
| logGDP2011, logGDP2011 | Log of GDP per capita in 2011, 2012 |
| tobaccoconsperc2012 | Tobacco consumption per capita in 2012 (# cigarettes smoked per person) |
| meanbmkgm22010 | Mean BMI 2010 (kg/m2) |
| eggs2012kcalcapday | Egg consumption supply in 2012 (kcal/capita/day) |
| diabExpendit | Health expenditure for diabetes in US dollars in 2010 |

| | |
|---|---|
| milk2012kcalcapday | Whole milk supply in 2012 (kcal/capita/day) |
| refsugar2012gcapday | Refined sugar supply in 2012 (g/capita/day) |
| fruitsother2012gcapday | Partial fruit supply in 2012 (g/capita/day) |
| vegetablesother2012gcapday | Partial Vegetable supply in 2012 (g/capita/day) |
| particulatespm252014 | Air quality rating in 2014. Measured in particulate matter 2.5 present |
| diabExpendit | Mean diabetes related expenditure per person with diabetes multiplied by the number of people with diabetes (2015) |

## B. Descriptive Statistics

| VARIABLES | (1)<br>N | (2)<br>mean | (3)<br>sd | (4)<br>min | (5)<br>max |
|---|---|---|---|---|---|
| cancer2012 | 160 | 110.5 | 29.23 | 54 | 223 |
| incCancer2012 | 158 | 172.8 | 71.25 | 63.40 | 338.1 |
| cvd2012 | 160 | 273.2 | 126.1 | 81.60 | 712.1 |
| diabetes2012 | 160 | 32.71 | 28.48 | 1.900 | 171 |
| diabprevpercent | 158 | 7.508 | 3.964 | 0.800 | 22.30 |
| ncdtotalper100kpop2012 | 159 | 562.7 | 165.8 | 244.2 | 1,025 |
| meat2000 | 156 | 41.35 | 30.74 | 3.400 | 121.7 |
| meat2001 | 156 | 41.39 | 30.58 | 2.800 | 120.9 |
| meat2002 | 156 | 42.37 | 30.62 | 3.500 | 124.5 |
| meat2003 | 156 | 42.65 | 30.34 | 3.600 | 123.3 |
| meat2004 | 156 | 43.23 | 30.00 | 3.600 | 126 |
| meat2005 | 156 | 43.91 | 30.28 | 3.700 | 125.7 |
| meat2006 | 158 | 44.23 | 29.75 | 3.800 | 126 |
| meat2007 | 158 | 46.04 | 30.59 | 3.900 | 126.1 |
| meat2008 | 158 | 46.36 | 30.35 | 3.900 | 123.7 |
| meat2009 | 158 | 46.07 | 29.91 | 4 | 119.5 |
| meat2010 | 158 | 46.41 | 29.41 | 4 | 119.6 |
| meat2011 | 158 | 46.94 | 29.36 | 4.100 | 126.9 |
| avemeatallyears | 158 | 44.34 | 29.72 | 3.700 | 122.9 |
| numadultsdiab | 158 | 2,555 | 10,626 | 5.800 | 109,649 |
| gdppc2011 | 155 | 13,935 | 20,029 | 355.6 | 113,240 |
| gdppc2012 | 156 | 13,668 | 19,373 | 384 | 105,447 |
| tothealthexppc2011 | 158 | 924.9 | 1,645 | 12 | 9,250 |
| tothealthexppc2012 | 159 | 919.2 | 1,617 | 15 | 9,361 |
| inactiveadultsprcnt2010 | 122 | 25.20 | 11.47 | 4.100 | 63.60 |
| alcoholconskcalpcperday2010 | 154 | 24.35 | 29.60 | 0 | 161 |
| accesssanitationpercnt | 155 | 70.88 | 29.89 | 9.500 | 100 |
| accesswaterpercnt | 155 | 86.75 | 15.66 | 31.40 | 100 |
| aveenergysupplypercnt | 155 | 119.9 | 14.37 | 88 | 155 |
| averageanimalproteingrampcperday | 155 | 34.77 | 20.03 | 5 | 96 |
| averageproteinsupplygrampcperday | 155 | 79.51 | 20.21 | 37 | 132 |
| energysupplycerealsrootstuberspe | 155 | 48.61 | 14.32 | 23 | 80 |
| logGDPpc2011 | 155 | 8.573 | 1.488 | 5.874 | 11.64 |
| logGDPpc2012 | 156 | 8.581 | 1.468 | 5.951 | 11.57 |
| tobaccoconsperc2012 | 117 | 22.95 | 9.072 | 4.700 | 44.25 |
| meanbmkgm22010 | 159 | 25.12 | 2.064 | 20.30 | 29.50 |
| eggs2012kcalcapday | 39 | 18.54 | 19.14 | 1 | 76 |
| milk2012kcalcapday | 39 | 72.46 | 64.26 | 5 | 246 |
| refsugar2012gcapday | 39 | 49.36 | 32.64 | 1.940 | 118.6 |
| fruitsother2012gcapday | 38 | 60.06 | 45.01 | 2.360 | 216.2 |
| vegetablesother2012gcapday | 38 | 130.1 | 146.1 | 17.27 | 834.1 |
| particulatespm252014 | 159 | 25.84 | 17.39 | 5 | 107.7 |
| diabExpendit | 152 | 1,441 | 2,342 | 23 | 11,851 |

## IV. Models and Results

The models observed are as follows:

<u>Cancer Model</u>

Equation 1:

$$incCancer2012 = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010$$

This equation quantifies cancer incidence in 2012 in terms of average country meat consumption, inactivity rate, total health expenditure, log of GDP per capita, alcohol consumption, tobacco consumption, and BMI.

Equation 2:

$$cancer2012 = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010 + \beta_8\, incCancer2012$$

This equation estimates cancer mortality in 2012 using the same variables as equation 1, including cancer incidence.

Model Estimating Effects of Lifestyle and Dietary Practices on Cancer Mortality and Incidence

| VARIABLES | (1)<br>incCancer2012 | (2)<br>cancer2012 |
|---|---|---|
| avemeatallyears | 0.967*** | -0.0611 |
| | (0.232) | (0.177) |
| inactiveadultsprcnt2010 | -0.724* | 0.0685 |
| | (0.433) | (0.175) |
| tothealthexppc2012 | -0.000619 | 0.000269 |
| | (0.00231) | (0.00104) |
| logGDPpc2012 | 26.39*** | -14.41*** |
| | (5.419) | (4.542) |
| alcoholconskcalpcperday2010 | 0.141 | 0.104* |
| | (0.130) | (0.0605) |
| tobaccoconsperc2012 | 0.221 | 0.619*** |
| | (0.620) | (0.220) |
| meanbmkgm22010 | -1.412 | 1.342 |
| | (2.436) | (0.924) |
| incCancer2012 | | 0.478*** |
| | | (0.0709) |
| Constant | -44.85 | 100.6*** |
| | (58.82) | (34.88) |
| Observations | 98 | 98 |
| R-squared | 0.777 | 0.646 |

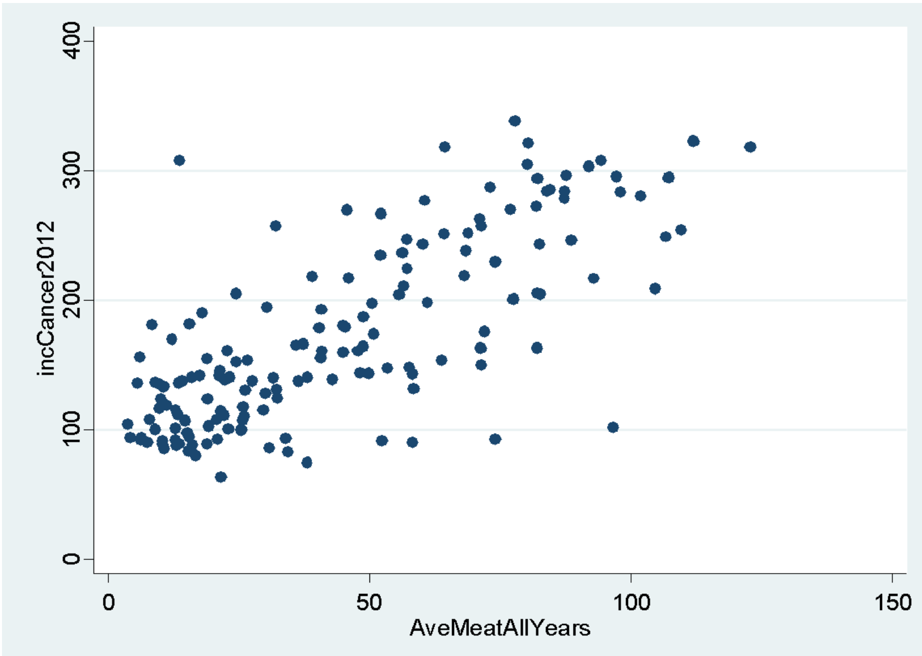
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Equation 1 shows average country meat consumption highly positively associated with cancer incidence. With a p-value of 0.00, average meat consumption increases cancer incidence by 0.967 with every unit increase in consumption. Given that disease incidence was quantified per 100,000 population, and meat consumption in kg/person/year, this means that an increase in 1 kg, or approximately 2.2 pounds of meat consumption per person per year results in an increase of 1 cancer case per 100,000 individuals on average. This effect is relatively small in comparison to the effect of GDP per capita in this model, which increases the cancer rate by 26 cases per year for every 100,000 people.  However, if we consider the effects of meat consumption on a

U.S. scale, this means that roughly 3,000 more cases of cancer would emerge if the average American consumed around 6-8 more burgers a year. This is a significant impact.

In equation 2, meat consumption in relation to cancer mortality is highly insignificant, which intuitively makes sense as many more non-preventable factors contribute to cancer mortality such as access to and quality of medication, care, treatment affordability, feasibility, etc. Inactivity decreases cancer incidence at the 10% level of significance, but does not affect cancer mortality, presumably for reasons similar to those mentioned above. Interestingly, total country health expenditure is highly insignificant in relation to both cancer incidence and mortality, whereas GDP per capita increases cancer incidence and decreases cancer mortality both at the 1% level of significance – with p-values of 0.00 and 0.02 respectively. This supports the knowledge that higher income, or "westernized" countries, host populations with poorer lifestyle and dietary habits, but also afford the ability to treat NCDs. Equation 2 demonstrates that an increased GDP per capita decreases cancer mortality by 14 cases per 100,000 people per year. Alcohol is found to increase both cancer incidence and mortality, but only significantly in mortality. Similarly, tobacco consumption increases both cancer incidence and mortality, but is highly significant in mortality with a relatively small coefficient. These two results could suggest that in addition to increasing cancer likelihood, alcohol and tobacco consumption impair the body's ability to fight cancer, or withstand cancer treatments. Average country BMI insignificantly impacts cancer incidence and mortality: decreasing the former and increasing the latter. Finally, as expected, cancer incidence increases likelihood of cancer mortality, but also by a relatively small coefficient. Equation 1 has an R-squared value of .777, meaning the observed variables account for the explanation of 77.7% of cancer incidence, which is very high. Similarly, Equation 2 accounts for explaining 64.6% of cancer mortality.

Below is a graph demonstrating the positive relationship between average country meat consumption and cancer incidence.




Heart Disease Model

Equation 3:

$$cvd2012 = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010$$

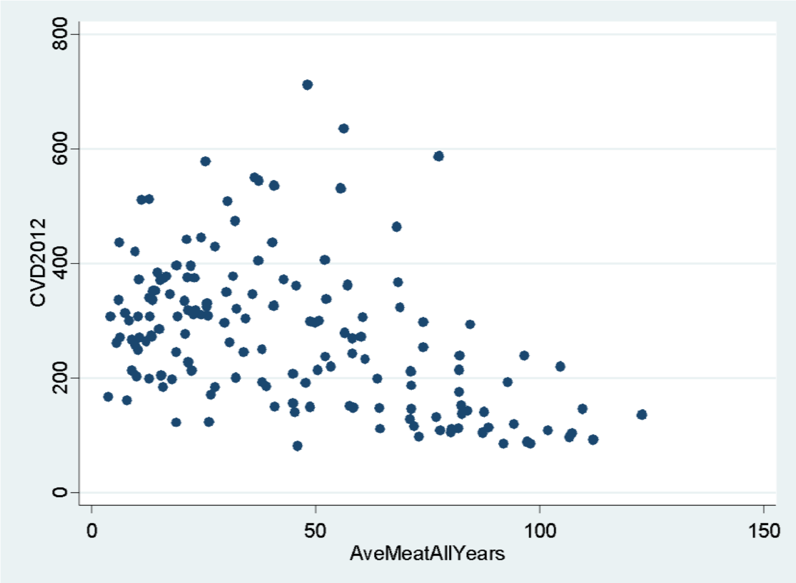
This equation estimates cardiovascular disease mortality in 2012 using average country meat consumption, inactivity rates, total health expenditure, the log of GDP per capita, alcohol consumption, tobacco consumption, and average BMI.

Model Estimating Effects of Lifestyle and Dietary practices on Cardiovascular Disease Mortality

| VARIABLES | (1)<br>cvd2012 |
|---|---|
| avemeatallyears | -1.504** |
| | (0.756) |
| inactiveadultsprcnt2010 | -1.668* |
| | (0.928) |
| tothealthexppc2012 | -0.00200 |
| | (0.00513) |
| logGDPpc2012 | -47.91*** |
| | (14.89) |
| alcoholconskcalpcperday2010 | 0.473 |
| | (0.368) |
| tobaccoconsperc2012 | 3.460*** |
| | (1.210) |
| meanbmkgm22010 | 30.51*** |
| | (6.886) |
| Constant | -65.54 |
| | (176.0) |
| Observations | 99 |
| R-squared | 0.486 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Equation 3 demonstrates a highly significant decrease of cardiovascular disease mortality with increased meat consumption amongst country averages, contrary to the literature. Perhaps if CVD incidence data were available, we would find differing results. But due to the difficulty of identifying cardiovascular disease, as it is largely symptomatic – by stroke or heart attack, the data was unavailable. Interestingly, when this regression was run with animal protein consumption, the consumption of animal protein was highly significant in increasing CVD mortality, although with a small coefficient. Although this variable was ultimately left out due to high collinearity, this could suggest that other dietary consumption of animal foods plays a role in CVD mortality, or, given the high correlation between country wealth and meat consumption, that meat consumption is merely another indicator of country wealth. Finally, the variable of animal protein consumption may possibly serve solely as a proxy for caloric consumption, and for this reason increase CVD mortality, in its relationship to BMI, instead of its significance in animal food consumption. This model also shows that an increase in inactivity decreases cardiovascular mortality, which clearly contradicts research specifically targeting cardiovascular health. Without incidence data, it is difficult to pin point why this is. Total country health expenditure is again insignificant in determining CVD mortality, although it slightly decreases it according to its coefficient. Country per capita wealth, along with BMI are the two most significant variables in this model, both with p values of 0.00 and relatively large coefficients of 47.9 and 30.5 respectively. This means a higher GDP per capita decreases CVD mortality by roughly 50 cases per 100,000 people and a one-unit increase in average country BMI (kg/m2) increases CVD mortality by 30 cases per 100,000 people. Alcohol consumption is found to slightly, but insignificantly increase CVD mortality. Finally, tobacco consumption (quantified in number of cigarettes smoked per person) increases cardiovascular mortality by 3.46 cases per 100,000 population for every additional cigarette smoked, significant at the 5% level. This model accounts for just under half of the explanation of CVD mortality globally. Below is a graph of average country meat consumption and CVD mortality in 2012, evidently displaying a negative correlation.




Diabetes Model

Equation 4:

$$diabprevpercent = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010 + \beta_8\, diabExpendit + \beta_9\, numadultsdiab$$

This equation estimates diabetes prevalence in 2012 as a factor of average country meat consumption, inactivity rate, total health expenditure, log of GDP per capita, alcohol consumption, tobacco consumption, BMI, diabetes expenditure, and the number of adults with diabetes in the country.

Equation 5:

$$diabetes2012 = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010 + \beta_8\, diabExpendit + \beta_9\, diabprevpercent$$

Equation 5 estimates Diabetes mortality in 2012 using the same variables as equation 4, excluding number of adults with diabetes and including diabetes prevalence.

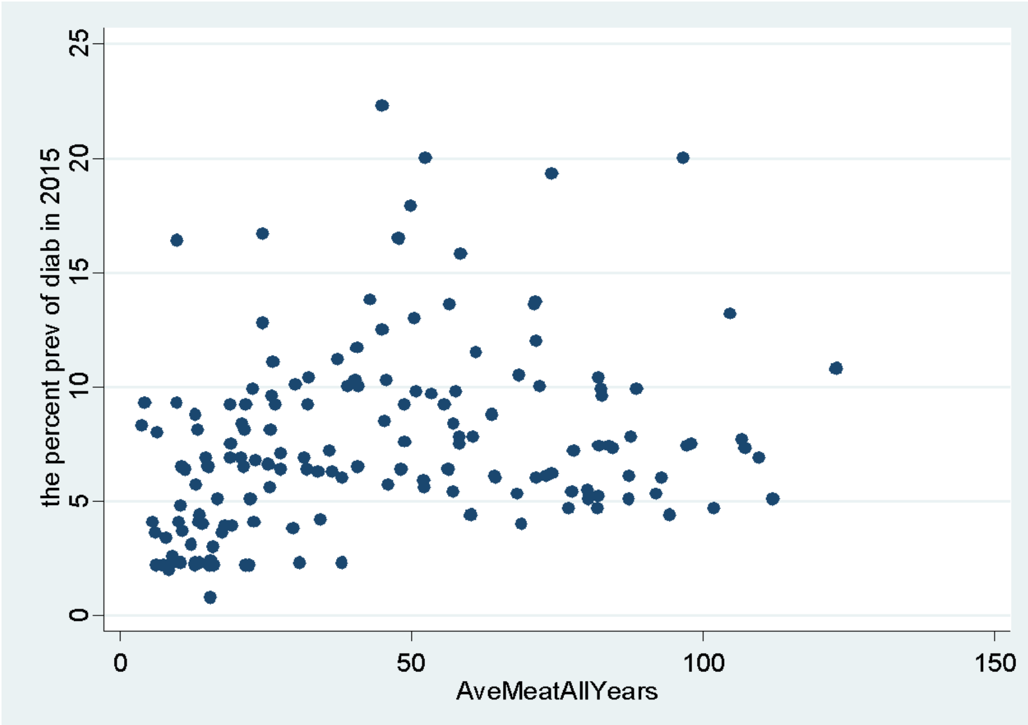
Model Estimating Effects of Wealth, Lifestyle and Dietary practices on Diabetes Mortality

| VARIABLES | (1)<br>diabprevpercent | (2)<br>diabetes2012 |
|---|---|---|
| avemeatallyears | -0.0402** | -0.132 |
| | (0.0168) | (0.153) |
| inactiveadultsprcnt2010 | 0.0637 | -0.218 |
| | (0.0407) | (0.369) |
| tothealthexppc2012 | 4.83e-05 | 0.000292 |
| | (0.000156) | (0.00104) |
| logGDPpc2012 | 1.105* | -6.294* |
| | (0.649) | (3.576) |
| alcoholconskcalpcperday2010 | -0.0142 | -0.125* |
| | (0.00938) | (0.0705) |
| tobaccoconsperc2012 | 0.0214 | -0.401 |
| | (0.0366) | (0.292) |
| meanbmkgm22010 | 0.989*** | 0.712 |
| | (0.243) | (2.894) |
| diabExpendit | -0.000481** | 0.000254 |
| | (0.000230) | (0.00114) |
| numadultsdiab | 7.03e-05*** | |
| | (2.41e-05) | |
| diabprevpercent | | 3.146 |
| | | (1.906) |
| Constant | -26.64*** | 68.36 |
| | (5.202) | (57.82) |
| Observations | 97 | 97 |
| R-squared | 0.452 | 0.355 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Equation 4 and 5 demonstrate a slight negative association between diabetes prevalence and meat consumption, with the former significant at the 5% level. Inactivity has opposite coefficients in each equation respectively, both insignificant at the 10% level. Total country health expenditure is again, highly insignificant in both equations relating to diabetes. GDP per capita significantly increases diabetes prevalence, and decreases diabetes mortality, which again demonstrates the phenomena of NCDs that higher income countries have less optimal lifestyle practices, but can afford the cost of NCD treatment. In this model, alcohol consumption is demonstrated to decrease diabetes incidence and mortality, contrary to research, and tobacco consumption insignificantly increases diabetes prevalence and decreases mortality. Mean BMI increases diabetes prevalence by 1 case per 100,000 people, with a p-value of 0.00, and a coefficient of 0.989, and insignificantly increases diabetes mortality. As diabetes expenditure per country was found to decrease diabetes prevalence, and insignificantly impact diabetes mortality. Finally, as expected, the number of adults with diabetes increases diabetes prevalence within a country, and diabetes prevalence increases diabetes mortality. Equation 4 has an R-squared value of .452, and equation 5 of .355, accounting for under half of the explanation for diabetes incidence and mortality. Below is a graph showing the relationship between diabetes prevalence and average meat consumption within countries.




Total Noncommunicable Disease Model

Equation 8:

$$ncdtotalper100kpop2012 = \beta_0 + \beta_1\, avemeatallyears + \beta_2\, inactiveadultsprcnt2010 + \beta_3\, tothealthexppc2012 + \beta_4\, logGDPpc2012 + \beta_5\, alcoholconskcalpcperday2010 + \beta_6\, tobaccoconsperc2012 + \beta_7\, meanbmkgm22010 + \beta_8\, particulatespm252014$$

This equation models total NCD mortality using average country meat consumption, inactivity rate, total health expenditure, log of GDP per capita, alcohol consumption, tobacco consumption, BMI and air quality.

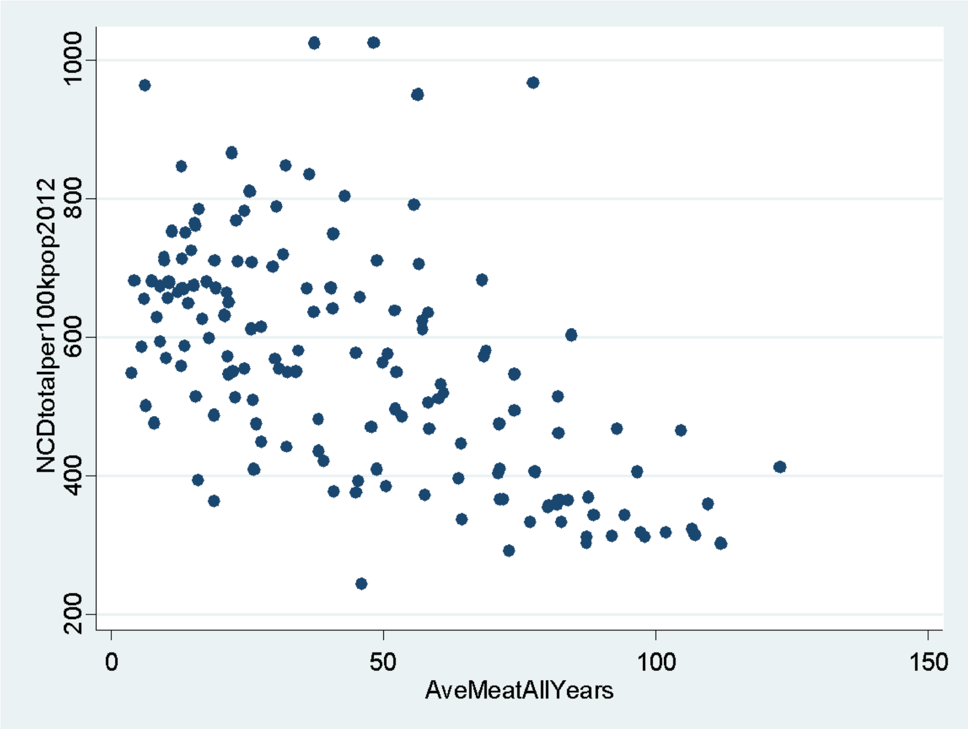
Model Estimating Wealth, Lifestyle and other Dietary Components in Total NCD Mortality

| VARIABLES | (1)<br>ncdtotalper100kpop2012 |
|---|---|
| avemeatallyears | -1.271 |
| | (0.973) |
| inactiveadultsprcnt2010 | -2.084* |
| | (1.220) |
| tothealthexppc2012 | -0.000822 |
| | (0.00537) |
| logGDPpc2012 | -79.31*** |
| | (18.60) |
| alcoholconskcalpcperday2010 | 0.124 |
| | (0.443) |
| tobaccoconsperc2012 | 3.143* |
| | (1.587) |
| meanbmkgm22010 | 31.81*** |
| | (8.125) |
| particulatespm252014 | 0.358 |
| | (0.640) |
| Constant | 469.2* |
| | (236.3) |
| Observations | 99 |
| R-squared | 0.559 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This model shows another significant negative association between average country meat consumption and total NCD deaths per 100,000 populations. The two most significant indicators of total NCD death are GDP per capita and mean BMI, both with large coefficients, -79.31 and 31.38 respectively, and p-values of 0.00. These two variables displayed some of the largest significant coefficients throughout our models. In this model, inactivity and total country health expenditure both insignificantly decrease NCD mortality, and alcohol and tobacco consumption were both found to increase NCD mortality, as expected. Finally, an increase in air particulate matter insignificantly increased total NCD mortality. This model hosts a R-squared value of

.559, accounting for over half of the explanation of global NCD mortality. Below is a graph showing the inverse association between total NCD mortality and meat consumption.



## A. Correlations

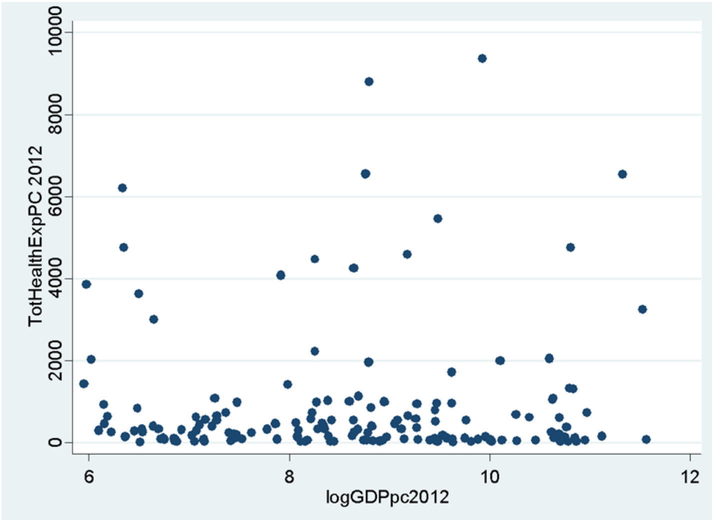
The below correlations display relationships between various dietary, lifestyle and country disease indicators. Some variables below were not used in the empirical regression analysis section of this paper due to a lack of data availability on many countries.

| | sanit | water | energy | milk | eggs | fruit | veg | avemeat |
|---|---|---|---|---|---|---|---|---|
| accesssanitationpercnt | 1.00 | | | | | | | |
| accesswaterpercnt | 0.83 | 1.00 | | | | | | |
| aveenergysupplypercnt | 0.56 | 0.59 | 1.00 | | | | | |
| milk2012kcalcapday | 0.36 | 0.38 | 0.34 | 1.00 | | | | |
| eggs2012kcalcapday | 0.66 | 0.55 | 0.42 | 0.23 | 1.00 | | | |
| fruitsother2012gcapday | 0.42 | 0.40 | 0.16 | 0.08 | 0.40 | 1.00 | | |
| vegetablesother2012 | 0.33 | 0.37 | 0.28 | -0.06 | 0.42 | 0.28 | 1.00 | |
| avemeatallyears | 0.68 | 0.62 | 0.60 | 0.47 | 0.58 | 0.36 | 0.20 | 1.00 |

This correlation table shows that average country meat consumption was highly correlated with access to sanitation, access to clean water (both indicators of development), average energy supply consumption, and relatively correlated with other animal food consumption such as milk and eggs.

| | meat11 | BMI | logGDP | avemeat | energy | animprot | aveprotein |
|---|---|---|---|---|---|---|---|
| meat2011 | 1.00 | | | | | | |
| BMI | 0.63 | 1.00 | | | | | |
| logGDP11 | 0.85 | 0.66 | 1.00 | | | | |
| avemeat | 0.98 | 0.62 | 0.85 | 1.00 | | | |
| energy | -0.84 | -0.66 | -0.82 | -0.85 | 1.00 | | |
| animprotein | 0.89 | 0.59 | 0.86 | 0.89 | -0.86 | 1.00 | |
| aveprotein | 0.77 | 0.59 | 0.78 | 0.78 | -0.71 | 0.90 | 1.00 |

This correlation table shows a high correlation between meat consumption in 2011, average protein consumption, and animal protein consumption. In congruence with the findings of literature, a high coefficient of .85 exists between meat consumption in 2011 and GDP per capita in 2011, showing a positive relationship between country wealth and meat consumption. A relatively high coefficient of .63 exists between BMI and meat consumption in 2011, and an inverse relationship exists between average energy supply and the other variables, as the energy supply variable is used to denote malnutrition. Also note that average total protein consumption is highly correlated with animal protein consumption.




This image displays total health expenditure per capita against the log of GDP per capita. One would hypothesize a positive relationship between country wealth and the amount a country spends on health expenditure, but this graph shows otherwise. Perhaps this is why the total health expenditure variable did not play a significant role in the regression analysis.

## B. Discussion

The findings of these models were not completely in congruence with the findings of the epidemiological literature on noncommunicable disease. The most predominant variables present in the regression analysis were BMI and GDP per capita. Meat consumption, and the remaining variables had relatively small coefficients in comparison. Additionally, although the variables in each model were checked for multicollinearity, some of the coefficients of variables were unexpected. For example: inactivity often had a negative coefficient, and occasionally so did alcohol and tobacco consumption.

A probable reason why the findings of these regressions were so different from epidemiological literature is due to the difference in data scale: the cohort study findings were conducted on individual-level data, whereas the empirical analysis used country-wide averages.

Our regression analyses averaged a 35-77% explanation for variation in disease outcomes, which is a relatively high R-squared value for empirical analyses. However, we would've liked to observe a few more variables in our analysis. For example, country-wide consumption data of fruits, vegetables, sugar, salt, processed foods, caloric intake, preventative care spending, and incidence of CVD and total NCDs would've helped us better understand our results.

Another interesting result from the empirical analysis showed that healthcare spending on western disease incidence and mortality rates was largely inconsequential. Demonstrated by the scatter diagram above, health expenditure wasn't correlated with country wealth, which is probably why it did not influence disease outcomes as expected.

## V. Conclusion

This paper sought out to quantify the effects of dietary and lifestyle practices, specifically meat consumption, in producing health outcomes. This study hypothesized that increased meat consumption would result in higher rates of cancer, heart disease and diabetes incidence and mortality. This prediction was confirmed by an analysis of epidemiological literature, but was not fully supported by an empirical regression analysis on country-wide data.

Initially, this thesis congregated historical research conducted on the relationship between the consumption of animal foods and resulting health outcomes. Then, we aggregated country data from the FAO and the WHO in the years 2000-2011 for 160 countries on diet and lifestyle practice averages and health outcomes in order to determine if country consumption and disease trends emulated the results of the cohort studies previously observed. From this epidemiological research, it was evident that increased meat consumption led to higher incidence and mortality of cancer, heart disease and diabetes, and at times, all-cause mortality. However, in our country-wide empirical analysis, a significant positive relationship between meat consumption was only present in cancer incidence. A significant negative relationship was shown in diabetes prevalence and CVD mortality, and an insignificant negative relationship was demonstrated in cancer mortality, diabetes mortality, and total NCD mortality.

Given these results, and other controversial findings in our model such as inactivity decreasing rates of NCD, we've concluded that this discrepancy in results is due to the wide difference in data scale between the literature and empirical analysis. Population averages can obscure important health factors and considerations that individual data, present in the cohort studies, does not.

In order to minimize NCD occurrence, popular literature suggests increasing activity levels, fruit and vegetable consumption, and decreasing sodium consumption. However, meat consumption, although demonstrated in health literature to increase the prevalence of disease, is rarely, although increasingly, addressed in risk prevention. Although the findings of this analysis were largely inconclusive in regards to the outcome of meat consumption, our findings did show a strong positive relationship between meat consumption and BMI, and country wealth, two variables that also highly contribute to disease outcomes in our model.

Another consideration in our model is the possibility of the substitution effect. As many of the cohort studies observed, when people switch from a meat eating diet to a vegetarian one, they usually increase their consumption of nutrient rich fruits and vegetables. Thus, the impact on the response variable could be caused by a substitution away from fruits and vegetables to meat, compared to the direct impact of meat. Given we lacked substantial data on fruit and vegetable consumption and other dietary factors such as sugar and salt consumption, it is possible that these dietary variables, such as sodium consumption, could be positively correlated with meat consumption, and could account for part of the coefficient of meat consumption in our models. However, given that health literature found that both the fat, cholesterol, and specific protein present in meat consumption contributes to disease, these findings may not provide as much explanation as we hope. For these reasons, we believe that the results of our model are a combination of both direct and indirect effects of meat consumption, and that the culmination of these indirect effects could have been better understood with the inclusion of variables mentioned above, which data for was largely unavailable.

In preventing noncommunicable disease, may programs exist that target adolescents to encourage healthy lifestyle and dietary choices. A recent WHO study shows that interventions for reducing the impact of NCDs by encouraging the reduction of tobacco and alcohol use as well as unhealthy diet and physical inactivity would cost $2 billion per year, the equivalent of less than 40 cents per person in middle and low income countries.[46] Given that the economic consequences of NCDs in low and middle income countries are estimated to surpass $7 trillion over 2011-2025[47], the small cost of instilling preventative measures has the potential to yield high gains as an investment in the longevity, health and economic well-being of a population. In terms of meat consumption impacting disease outcomes, the unwritten costs, namely in healthcare, have been largely observed in other literature. David Robinson addresses them in his book, Meatonomics, and proposes three ways to combat the observed discrepancy between meat price and total meat costs considering its negative externalities such as disease incidence, environmental pollution and degradation, and water usage.[48] Finally, in recent years, the prevalence of biotech companies creating sustainable meat alternatives that do not result in disease has risen significantly, assumedly due to the increase in health warnings surrounding the consumption of meat and the public's increased awareness of the burdens of meat production and consumption.

Overall, we look forward to subsequent research observing country-wide dietary trends and disease, and recommend the decrease in consumption of meat due to its significant tie to disease evident on an individual level.

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[46] "From Burden to "Best Buys": Reducing the Economic Impact of NCDs in Low- and Middle-income Countries." World Health Organization. World Health Organization, n.d.

[47] "From Burden to "Best Buys": Reducing the Economic Impact of NCDs in Low- and Middle-income Countries."

[48] Simon, David Robinson. Meatonomics. Berkeley, CA: CONARI,U.S., 2013. Print.

## VI. Bibliography

"A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care." *A Prospective Study of Red Meat Consumption and Type 2 Diabetes in Middle-Aged and Elderly Women | Diabetes Care*. The American Journal of Clinical Nutrition, n.d. Web. 29 Nov. 2016.

*Acute Myocardial Infarction in 52 Countries | Circulation*. American Heart Association Journals, n.d. Web. 29 Nov. 2016.

Appleby, Paul N., Francesca L. Crowe, Kathryn E. Bradbury, and Ruth C Travis. "Paul N Appleby." *Mortality in Vegetarians and Comparable Nonvegetarians in the United Kingdom*. The American Journal of Clinical Nutrition, 01 Jan. 2016. Web. 29 Nov. 2016.

Appleby, Paul N., Margaret Thorogood, and And Jim I Mann. "Paul N Appleby." The Oxford Vegetarian Study: An Overview. N.p., 01 Sept. 1999. Web. 08 Dec. 2016.

"Associations between Diet and Cancer, Ischemic Heart Disease, and All-cause Mortality in Non-Hispanic White California Seventh-day Adventists1,2,3." *Associations between Diet and Cancer, Ischemic Heart Disease, and All-cause Mortality in Non-Hispanic White California Seventh-day Adventists*. American Society for Clinical Nutrition, 01 Sept. 1999. Web. 29 Nov. 2016.

Baldwin, Wendy, and Lindsey Amato. "World Population Data Sheet 2012." *Fact Sheet: Global Burden of Noncommunicable Diseases*. Population Reference Bureau, n.d. Web. 29 Nov. 2016.

"Beyond Meatless, the Health Effects of Vegan Diets: Findings from the Adventist Cohorts." Nutrients. U.S. National Library of Medicine, n.d. Web. 30 Nov. 2016.

Bloom, D.E., Cafiero, E.T., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L.R., Fathima, S., Feigl, A.B., Gaziano, T., Mowafi, M., Pandya, A., Prettner, K., Rosenberg, L., Seligman, B., Stein, A.Z., & Weinstein, C. (2011). The Global Economic Burden of Noncommunicable Diseases. Geneva: World Economic Forum.

"Cancer Prevalence and Cost of Care Projections." *Cancer Prevalence and Cost of Care Projections*. National Cancer Institute, n.d. Web. 29 Nov. 2016.

Chronic disease among Seventh-day Adventists, a low-risk group. Rationale, methodology, and description of the population.W. L. Beeson, P. K. Mills, R. L. Phillips, M. Andress, G. E. Fraser, Cancer. 1989 Aug 1; 64(3): 570–581.

Crowe, Francesca L., Paul N. Appleby, and Ruth C Travis. "Francesca L Crowe." *Risk of Hospitalization or Death from Ischemic Heart Disease among British Vegetarians and Nonvegetarians: Results from the EPIC-Oxford Cohort Study*. American Society for Nutrition, n.d. Web. 29 Nov. 2016.

Daniel C. R., Cross A. J., Koebnick C., Sinha R. Trends in meat consumption in the USA. *Public Health Nutrition*. 2011;14(4):575–583. doi: 10.1017/S1368980010002077.

"Does Information on Health Status Lead to a Healthier Lifestyle? Evidence from China on the Effect of Hypertension Diagnosis on Food Consumption ☆." Does Information on Health Status Lead to a Healthier Lifestyle? Evidence from China on the Effect of Hypertension Diagnosis on Food Consumption. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

"Economic Assessment of Nutritional Recommendations." Economic Assessment of Nutritional Recommendations. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

Essential Medicines and Health Products Information. *The Global Economic Burden of Non-communicable Diseases (September 2011)*. World Health Organization, n.d. Web. 29 Nov. 2016.

"From Burden to "best Buys": Reducing the Economic Impact of NCDs in Low- and Middle-income Countries." World Health Organization. World Health Organization, n.d. Web. 30 Nov. 2016.

GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *The Lancet.* 2016 Oct 7; 388:1659–1724.

"Heart Disease and Stroke Cost America Nearly $1 Billion a Day in Medical Costs, Lost Productivity." *CDC Foundation*. Centers for Disease Control and Prevention, n.d. Web.29 Nov. 2016.

Henry W. Kinnucan, Chung-Jen Hsia, John D. Jackson, and Hui Xiao. "Effects of Health Information and Generic Advertising on U.S. Meat Demand." *Effects of Health Information and Generic Advertising on U.S. Meat Demand*. American Journal of Agricultural Economics, n.d. Web. 29 Nov. 2016.

Hoek, A. C., Luning, P. A., Stafleu, A., & De Graaf, C. (2004). Food-related lifestyle and health attitudes of Dutch vegetarians, non-vegetarian consumers of meat substitutes, and meat consumers. *Appetite*, 42(3), 265–272. doi:10.1016/j.appet.2003.12.003

"IARC Monographs Evaluate Consumption of Red Meat and Processed Meat." IARC Monographs Evaluate Consumption of Red Meat and Processed Meat | UICC. World Health Organization, n.d. Web. 08 Dec. 2016.

"IDF Diabetes Atlas - 7th Edition." *IDF Diabetes Atlas - FAQ*. International Diabetes Federation, n.d. Web. 29 Nov. 2016.

"Inequality and Mortality: Long-run Evidence from a Panel of Countries." Inequality and Mortality: Long-run Evidence from a Panel of Countries. Journal of Health Economics, n.d. Web. 08 Dec. 2016.

"International Differences in the Impact of Doctors on Health: A Multilevel Analysis of OECD Countries." International Differences in the Impact of Doctors on Health: A Multilevel Analysis of OECD Countries. Journal of Health Economics, n.d. Web. 08 Dec.

Jayson L. Lusk*, and Glynn T. Tonsor. "Jayson L. Lusk." How Meat Demand Elasticities Vary with Price, Income, and Product Category. N.p., n.d. Web. 08 Dec. 2016.

Key, Timothy J., Paul N. Appleby, Francesca L. Crowe, Kathryn E. Bradbury, and Julie A Schmidt. "Timothy J Key." *Cancer in British Vegetarians: Updated Analyses of 4998 Incident Cancers in a Cohort of 32,491 Meat Eaters, 8612 Fish Eaters, 18,298 Vegetarians, and 2246 Vegans*. The American Journal of Clinical Nutrition, n.d. Web. 29 Nov. 2016.

"Leading Causes of Death." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 07 Oct. 2016. Web. 29 Nov. 2016.

Micha, R., S. K. Wallace, and D. Mozaffarian. "Red and Processed Meat Consumption and Risk of Incident Coronary Heart Disease, Stroke, and Diabetes Mellitus: A Systematic Review and Meta-Analysis." *American Heart Association Journal* 121.21 (2010): 2271-283.

"Non Communicable Diseases." *World Health Organization*. World Health Organization, n.d. Web. 29 Nov. 2016.

Orlich, Michael J., Pramil N. Singh, Joan Sabaté, Karen Jaceldo-Siegl, Jing Fan, Synnove Knutsen, W. Lawrence Beeson, and Gary E. Fraser. "Vegetarian Dietary Patterns and Mortality in Adventist Health Study 2." *JAMA Internal Medicine*. U.S. National Library of Medicine, 08 July 2013. Web. 29 Nov. 2016.

Phares, Author Emily H. "WHO Report Says Eating Processed Meat Is Carcinogenic: Understanding the Findings." *The Nutrition Source*. N.p., 05 Nov. 2015. Web. 29 Nov. 2016.

Pan, A., Q. Sun, A. M. Bernstein, M. B. Schulze, J. E. Manson, W. C. Willett, and F. B. Hu. "Red Meat Consumption and Risk of Type 2 Diabetes: 3 Cohorts of US Adults and an Updated Meta-analysis." *The American Journal of Clinical Nutrition.* U.S. National Library of Medicine, n.d. *American Journal of Clinical Nutrition* 94.4 (2011): 1088-096.

Pan, An, Qi Sun, Adam M. Bernstein, Matthias B. Schulze, JoAnn E. Manson, Meir J. Stampfer, Walter C. Willett, and Frank B. Hu. "Red Meat Consumption and Mortality: Results from Two Prospective Cohort Studies." *Archives of Internal Medicine*. U.S. National Library of Medicine, 09 Apr. 2012. Web. 29 Nov. 2016.

Romaina Iqbal, Sonia Anand, Stephanie Ounpuu, Shofiqul Islam, Xiaohe Zhang, Sumathy Rangarajan, Jephat Chifamba, Ali Al-Hinai, Matyas Keltai, and Salim Yusuf. "Dietary Patterns and the Risk of Acute Myocardial Infarction in 52 Countries." *Dietary Patterns and the Risk of Myocardial Infarction in 52 Countries* | Circulation. American Heart Association Journals, n.d. Web.

Shang, Xianwen, David Scott, Allison M. Hodge, Dallas R. English, Graham G. Giles, and Peter R Ebeling. *Dietary Protein Intake and Risk of Type 2 Diabetes: Results from the Melbourne Collaborative Cohort Study and a Meta-analysis of Prospective Studies*. The American Journal of Clinical Nutrition, n.d. Web. 29 Nov. 2016.

*Simon, David Robinson. Meatonomics. Berkeley, CA: CONARI,U.S., 2013. Print.*

Springmann, Marco, H. Charles J. Godfray, Mike Rayner, and Peter Scarborough (2016),. "Analysis and Valuation of the Health and Climate Change Cobenefits of Dietary Change." *Proceedings of the National Academy of Sciences Proc Natl Acad Sci USA* 113.15 (2016): 4146-151.

*"The Impact of Tobacco Advertising Bans on Consumption in Developing Countries."* The Impact of Tobacco Advertising Bans on Consumption in Developing Countries. *Journal of Health Economics, n.d. Web. 08 Dec. 2016.*

*The Global Economic Burden of Non-communicable Diseases: A Report*. Geneva, Switzerland: World Economic Forum, 2011. Harvard School of Public Health. Web.