Food and Agriculture Organization of the United Nations

Healthy people depend on healthy food systems

Methodology for valuing the Agriculture and the wider food system Related Costs of Health (MARCH)

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Executive Summary

Sustainability assessment is increasingly pursued through full-cost accounting of environmental and social externalities of food and agriculture systems. To this end, a "common currency" is required in order to add various impacts and carry cost-benefit analysis. While natural capital accounting and social measurement methods are currently emerging (such as the 2016 Natural Capital Protocol and the 2017 Social Capital Protocol), health impacts remain difficult to include and aggregate within valuation frameworks.

With a view to better measure, value and manage food systems, the Global Alliance for the Future of Food is supporting the multi-stakeholder project - the Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEB AgriFood) - in the development of a full-cost accounting framework for food and agricultural systems. Such a framework is a tool that can lead to better decision-making in business, government and across the food system, while harmonizing the currently fragmented landscape of measurement and valuation of agriculture externalities. Impacts on health are one of the largest externalities of food and agricultural systems, though poorly understood due to the effects of multiple exposure.

The success of the TEEB AgriFood framework is dependent on the inclusion of health externalities and there is huge potential in exploring methodologies that value health impacts. This study develops a replicable methodology to measure and place a monetary value on the impacts of food and agricultural systems on health, and concretely tests it by applying the proposed methodology to selected health conditions in the UK.

The methodology offered for assessing the food system's costs on health uses the Subjective Wellbeing Valuation (WV) approach, an OECD accepted methodology for policy evaluation. This approach is derived from economic valuation methods used to estimate the monetary value of non-market goods and services, that is, goods and services that do not have a market price. In this context, WV proposes to value changes to health in monetary terms. WV considers how much money would be needed to compensate people to return their wellbeing to the level without the health condition. The monetary value of health conditions provided by WV expresses what would otherwise be shown in Quality-Adjusted Life Years (QALYs) for morbidity.

For full-cost accounting purposes, the advantages of the WV approach over the more commonly used QALYs approach include:

- First, QALYs do not provide a natural monetary value; they are expressed on a 0 to 1 scale, with 0 being death and 1 being perfect health. The WV approach allows to derive a value for the impact of the health condition on the individual's life satisfaction, overcoming the difficulty of valuing a QALY in monetary terms.
- Second, the estimation of QALYs for a specific health condition reflects individuals' affective reactions to the "idea" of the health condition, rather than the actual experience of the condition. WV infers the impact of a health condition on the individual's true quality of life without directly asking people and thus, overcoming focussing illusion and accounting for adaptation to health conditions.
- Third, QALYs use health state descriptive systems according to a fairly narrow set of conditions (e.g. mobility, self-care, usual activity, pain, anxiety), thus excluding eventual aspects of the food system impact on health, such as confidence and energy levels. WV captures all of the impacts of a health condition on one's wellbeing, and does not rely on an existing framework to define health, which risks being too narrow.
- Fourth, the WV includes the impact of the health condition on others, for example, the impact on a close relative who takes-on caring responsibilities.

There are two key challenges of the WV approach: (i) whether it can be measured appropriately, as the impact of the health condition relies on accurately measuring the individual's wellbeing (for example, this may not be possible when severe mental health or cognitive issues affect the reliability of survey responses[1]); (ii) whether the data is available to use the appropriate statistical techniques for estimating an unbiased relationship between the health condition and subjective wellbeing.

The subjective wellbeing measure used is life satisfaction, elicited through the following question (or similar): "overall, how satisfied are you with your life nowadays?". Life satisfaction can be considered reliable in large representative samples. This links the first challenge directly to the second challenge of what data is available. Data is needed on life satisfaction, income, the health conditions and various control variables. The best source of such data is existing national surveys; however, where these are not available, it is possible to collect bespoke data or 'transfer' the values from a country similar in political, economic and cultural background. Socio-economic control variables are required to reduce the risk of confounding factors being included in the estimation of the association of the health condition with life satisfaction. Part of this second challenge is to produce a causal estimate for the impact of income on life satisfaction. This is of particular concern with regards to the effect of income on life satisfaction because of the risk of reverse causality, in other words, that individuals who are more satisfied with their lives earn more money. This risk can be overcome through an instrumental variable approach.

While this paper presents a robust economic methodology for valuing health costs, a method for determining causal inference, or even chains of inference, between heath and food and agricultural systems is yet to be established. The challenge of determining causation in health has always been shaped by data limitations, the understanding of the underlying biological/medical processes and network of connected factors in a complex world. For example, the structure underlying causal processes of the obesity epidemic requires a multi-level framing within the food system that includes: food access issues; individual dietary choices; food quality (or lack of); and presumably, even prenatal gene expression change in response to exposure to endocrine-disrupting pesticides in the environment. In addition, certain assumptions (e.g. the "obesogen theory") are still disputed and evidence (currently, or in the future) will always be subject to uncertainties.

Recognizing that a universally agreed-upon characterization of the probability of causation is still required, this study illustrates the application of the proposed valuation method to selected health conditions, including: coronary heart diseases; heart attack; stroke; emphysema; chronic bronchitis; liver dysfunction; kidney dysfunction; stomach dysfunction; colorectal cancer; obesity (BMI 30-40); severe obesity (BMI 40+); and male reproductive disorders.

UK datasets, including Understanding Society, Health Surveys of England and Northern Ireland and the British Household Panel Survey were used to estimate the wellbeing impact of each of these 12 health conditions. Estimates are reported annually and calculated at the individual level. A preliminary estimate of the probability that a health condition is caused by the agriculture and wider food systems is then applied to the total cost of the health condition, including the number of people affected in the country by those health conditions.

[1] This is an issue for all survey based methods which attempt to measure the impact of health conditions life quality.

The total annual wellbeing impacts to society, measured in monetary terms, depends on three factors: the wellbeing impact (or cost) of the health condition at the individual level; the amount which the health condition that can be attributed to agriculture and the wider food system; the number of people in a country suffering from the health condition.

With this information, the negative wellbeing impact caused by the presence of selected diseases can be inferred. Since this welfare impact is expressed in monetary terms, it is often expressed in annual cost. In the UK, the annual food system-related cost of selected diseases varies from, as much as USD 90 billion for obesity (a condition that is strongly dependent on the food system and affects 13.5 million individuals), to USD 7 billion for kidney disorders (that are partly caused by agricultural pollutants in food and the environment and affect 3 million individuals). The monetary value created here could be also used to assess the contribution of a given policy in reducing the probability of a diseases (e.g. obesity) and therefore disentangle the (marginal) impact of this policy in terms of the reported cost (e.g. USD 90 billion for obesity).

These monetary value estimates are plausible in that they increase with the condition severity, and related conditions have similar costs. Furthermore, the ordering of the monetary values reflects the orderings of QALYs for the same health conditions - but the wellbeing values suggest a higher impact of the health conditions on quality of life.

While the costs of the different health conditions cannot be added, in order to avoid double counting where health conditions are related, they are useful in cost-benefit evaluation of specific policy interventions. For example, this paper shows that the wellbeing cost of coronary heart disease, heart attack and stroke in the UK is USD 52 billion, while the National Health Service expenditure on treating cardiovascular diseases is significantly lower (i.e. USD 18 billion in 2006).

By using the WV approach, this paper fills the gap in cost-benefit analysis of individual health valuation, as an alternative to QALYS, within the context of full-cost accounting of different environmental and social impacts. Cost-benefit analysis requires, in addition to individual wellbeing costs calculated using WV, accounting for individual healthcare expenses, public health expenditures met by the government, loss of income to individuals, loss of productivity to businesses and loss of tax receipts by governments.

The full implementation of this Methodology for valuing the Agriculture and the wider food system Related Costs of Health (referred to as MARCH) requires establishing a methodology of attributing food system causation ratios to most relevant health conditions. Multi-disciplinary working groups need to be established to engage in this challenging task and shed light on decision-making affecting the health of human kind.

Unlike in the past, uncertainty of causation should not delay tackling food system-related health effects and action is needed before it is too late. Action today can turn the argument on its head, because good food and agriculture offer the largest opportunity for the health of soils, plants, animals and human beings.

1. Introduction

The multiple stakeholders' initiative, The Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEB AgriFood), which is housed in UNEP[2] and to which FAO contributes, is currently developing a universal true-cost accounting framework that will account for the food system impacts on the environment and social wellbeing. While environmental and livelihood costs are relatively easy to monetize and aggregate in a unique index, health valuation is lagging behind, both in terms of determining food system-health linkages and the valuation of health conditions. Decision-makers are often interested in assessing the impact of intervention measures on health but cost-benefit comparisons require a common metric. As a result, a technique for converting all food system-related outcomes into a "common currency" is required, and such techniques have long been a topic of research in health economics and, more generally, valuation literature in microeconomics.

There is today a growing interest among the public, policy-makers and the research community in understanding the complex links between food systems and health. A large body of medical research explores the health effects of various food-related risk factors, such as dietary habits, food quality and environmental and occupational conditions which can be attributed to agricultural activity. This project brings together the two areas of research – medical and economic – with the aim of developing a replicable, robust methodology to measure health costs associated with the food system, along with step-by-step guidelines for applying the method on the ground.

Chapter 2 briefly introduces the links between food system and health outcomes. This field of knowledge is subject to heated debates and the scientific literature is characterized by uncertainties. A broad-brush landscape is hereby presented from the nutritional, environmental and occupational health perspectives, with more details on selected health conditions that serve to illustrate the economic valuation method offered by this document. The following health conditions are introduced: cardio-vascular diseases, colorectal cancer, obesity, metabolic disorders, lung diseases, male reproductive disorders and Alzheimer's disease. Chapter 3 sets-out the available methods for valuing health outcomes and discusses their advantages and disadvantages. The focus here is on the non-financial costs for individual persons associated with different health conditions, which is traditionally expressed in Quality-Adjusted Life Years. Non-financial costs (such as the burden of pain, discomfort and anxiety) are often hard to measure and value and they also tend to outweigh the financial costs of health problems, such as outlays on medical treatment and medication, or the cost of foregone earnings. The valuation method chosen is the wellbeing valuation approach, which relies on measures of people's subjective well-being (SWB). This method combines estimates of the impact that (i) a given health conditions and (ii) money has on people's SWB to express the health condition's value in monetary terms. This approach is accepted by the OECD and governments worldwide (e.g. Canada, UK) as a robust method for policy evaluation. Chapter 4 provides step-by-step guidelines for implementing the wellbeing valuation approach in order to measure the food system-related costs of health. It then illustrates how this method can be applied in practice, using actual UK data. Chapter 5 provides recommendations for further research. Annex 3 offers the survey instrument for applying MARCH in any other context.

[2] United Nations Environment Programme.

2. Overview of food system-related diseases[3]

2.1. Food systems and healthiness

Health depends on many factors, including heritable traits (epigenetics), access to medical care and all sorts of environmental conditions. Environmental variables account for more than half of health risk factors. Although food and agriculture choices play a key role in health, it is difficult to isolate single causations. This is not just a methodological difficulty because the nature of the matter is systemic, as everything is connected in a complex network.

What is certain is that diets and lifestyle substantially contribute to health outcomes. Adhering to healthy dietary principles, along with physical activity (3.5 hours a week), non-smoking and a body mass index lower than 30 (calculated as weight in kilograms divided by height in meters squared), has been found to lower the risk of diabetes by 93%, heart attack by 81%, stroke by 50% and cancer by 36%[4].

Chronic non-communicable diseases (such as heart disease, diabetes and cancers) are on the rise worldwide and this coincides with increasing incidence of unhealthy diets and of toxic compounds accumulating in our food and environment, as well as an increase in life expectancy. These chronic diseases affect countries across all income groups[5]. A more recent pattern of concern comes from anti-microbial usage in agriculture which contributes to antibiotics-resistance in humans. The excessive and inappropriate use of antimicrobials in terrestrial and aquatic animal and plant production, for both treatment and non-therapeutic purposes, such as animal growth promotion, is a growing global concern because of increased failure to successfully treat infections and increased mortality. In 2010, global antimicrobial consumption in the livestock sector was 63 151 tonnes. The health consequences of antimicrobial resistance are estimated to 10 million human fatalities annually[6].

The World Health Organization (WHO) categorizes risk factors and health outcomes, without specifically addressing nutrition- or agriculture-related factors. Annex 1 categorizes food and agriculture systems exposure routes by expanding on the WHO framework.

With the exception of food-related pathogens where risk factors and health outcomes are somewhat directly linked, health is affected by a combination of risk factors. While acknowledging causation uncertainties and the fact that understanding linkages will never be unequivocal, the identification of the main exposure routes is crucial in designing interventions that might be appropriately targeted to promote health in the food and agriculture sector. In the paragraphs below, five main

[3] [3] Inferring food system impacts on health is complicated by multiple confounding factors and a sound methodology is needed to characterize the probability of disease causation. This Chapter is only a teaser that aims to illustrate the WV methodology described in Sections 2 and 3. For a debate on challenges surrounding understand of health impacts, see IPES, 2017. Unravelling the Food-Health Nexus: Addressing Practices, Political Economy, and Power Relations to Build Healthier Food Systems. International Panel of Experts on Sustainable Food Systems. October 2017.

[4] Ford E.S. et al, 2009. Healthy Living is the Best Revenge. Findings from the European Prospective Investigation into Cancer and Nutrition (EPIC). Postdam Study. Health Care Reform.

[5] WHO, 2009. Global Health Risks. Mortality and Burden of Disease Attributable to Selected Major Risks.

[6] FAO, 2016. The FAO Action Plan on Antimicrobial Resistance, 2016-2020.

routes of exposure are distinguished with regards food system linkages with chronic and degenerative diseases.

2.1.1. Hunger and malnutrition

Hunger and under-nutrition are caused by lack of access to food, or the means to produce food. Food security is an objective that requires policy action at all levels, from food availability, through food access and utilization, to stability of food systems to environmental and socio-economic volatility. FAO's annual reports on State of Food Insecurity in the World analyze historic trends, relevant policies and progress in this field: in 2016, the number of chronically undernourished people in the world was estimated to 815 million, with 155 million and 52 million children under five years of age suffering from, respectively, stunted growth and wasting[7]. Generally, undernourishment is declining faster than the rate for child underweight, suggesting room for improving the quality of diets, hygiene conditions and access to clean water, particularly for poorer population groups. Even where policies have been successful in addressing large food-energy deficits, dietary quality remains a concern; Southern Asia and sub-Saharan Africa remain particularly exposed to what has become known as "hidden hunger" – the lack of, or inadequate, intake of micronutrients, resulting in different types of malnutrition, such as iron-deficiency anemia and vitamin A deficiency.

2.1.2. Unhealthy diets

Unhealthy diets, including both over-consumption and under-consumption, as well as cooking habits, are behavioral risk factors modifiable by consumers, provided they have access to healthy food. Behavioral change is achieved through awareness campaigns and dietary guidelines that address nutritional balance (e.g. excess intake of fats, sugar, salt and animal proteins), as well as food preparation issues, including precaution in over-heating vegetable oils (frying) and meat (grilling), with a view to avoid the formation of carcinogenic compounds (e.g. heterocyclic amines). Nutritionally unbalanced diets (e.g. excessive consumption of animal products and ultra-processed foods) are major risk factors for chronic diseases, more than smoking and lack of physical activity. Considering that metabolic changes increase the risks of all non-communicable diseases, unhealthy diets (with raised blood pressure, obesity, hyperglycemia, hyperlipidemia) could be responsible for up to 80-90% of deadly diseases[8], even when inherited genes are not conducive to healthiness[9]. In fact, emerging epigenetics and nutrigenomics have demonstrated that food determines much of genetic expression, activating or deactivating cellular processes that determine health. In particular, natural inhibitors contained in food can compensate for inherited weaknesses and detrimental lifestyle factors (i.e. smoking, alcohol drinking, physical inactivity). Increasingly, dietary modifications (e.g. ketogenic diets) are explored as a possible adjuvant to disease treatments (e.g. to enhance metabolic stress in cancer cells, to control childhood seizures and epilepsy)[10].

[7] FAO IFAD, UNICEF, WFP and WHO, 2017. The State of Food Security and Nutrition in the World. Building Resilience for Peace and Food Security.
[8] WHO, 2015. Noncommunicable Diseases Fact Sheet. Updated January 2015.
[9] Ornish et al. Gene Expression Modulation by Intervention with Nutrition and Lifestyle (GEMINAL).
[10] Allen B.G et al., 2014. Ketogenic Diets as an Adjuvant Cancer Therapy: History and Potential Mechanism. Redox Biology, Vol. 2, 2014, 963-970.

What is today perceived as "healthy diet" is one of the most contrasted themes, including divergent views on the healthiness of single nutrients (e.g. saturated fats, red meat) and the explosion of the several "diet-less" trends (e.g. low-carb, gluten-free, vegan). In a food system approach, it is important to characterize food type benefits according to the different food production processes that will ultimately determine food quality and health outcomes; e.g. refined flour-based products versus whole flour products, or grain-fed versus grass-fed livestock products. Ultimately, the over-riding principle of a healthy diet is not only about the quantity of macro-nutrients (i.e. fat, carbohydrate and protein) and micro-nutrients (i.e. vitamins and trace metals) but the quality of the food eaten (e.g. level of pesticide residues), as well as the associations of different foods in a meal (e.g. enough anti-oxidants to counteract the pro-oxidant effect of heme iron in beef), dietary sources of non-nutritive constituents (e.g. isoflavonoids, fibers) and the enzymes produced by the intestinal microflora that build-up with each meal and determine much of the metabolic activities and infections' occurrence.

2.1.3. Low quality food

Low quality food refer to fewer nutrients and more contaminants in food, resulting from poor growing, post-harvest handling, processing and packaging practices. Quantifying health hazards of low quality food helps modifying policy measures and shopping habits towards healthier food production practices. Generally, the negative impact of agri-food inputs (e.g. synthetic pesticides, mineral fertilizers, genetically-engineered seeds, ionizing radiation and additives) on food quality and health is disputed in terms of safety thresholds. Many impacts remain controversial and scientific reviews are not always converging, especially because "current toxicity testing and exposure limit-setting methods fail to accurately represent the nature of human exposure to potential harmful chemicals"[11]. Competent authorities and various international risk assessment bodies regulate residues or toxicity in food (e.g. FAO/WHO Joint Meeting on Pesticides Residues, Joint Expert Committee on Food Additives).

2.1.4. Agri-environmental risks

Agri-environmental risks refer to conditions created by agriculture that expose rural residents, as well as the wider community, to farm-generated pollution. Public health could be safeguarded through prevention and mitigation measures that address: air pollution from pesticide spraying and factory farms; transboundary animal diseases and zoonosis; soil contamination with Cadmium and other heavy metals; nitrates and pesticides leaching in drinking water; greenhouse gas emissions, climate change and ozone loss. Predictions of climate change impact on health include: direct effects (e.g. floods, ischemic stroke from heat exposure), ecosystem mediated health effects (e.g. reduced food yields, epidemics from vector borne diseases driven by rainfall, re-emergence of infections such as TB or cholera and the development of new infections) and indirect effects (e.g. health consequences of livelihood loss).

[11] National Cancer Institute, 2010. Reducing Environmental Cancer Risk: What we Can do Now. 2008-2009 Annual Report of the President's Cancer Panel. US Department of Health and Human Services, National Institute of Health, National Cancer Institute. April 2010.

2.1.5. Occupational hazards

Occupational hazards mainly result from on-site exposure to hazardous chemicals (i.e. pesticides) and machinery, or poor working conditions (e.g. repeated motion in processing factories) that could be redressed with improved workers' protection and rights. Statistics from many countries or regions show that agriculture consistently has one of the highest accident and injury rates of the industrial sectors[12]. These range from minor (cuts, bruises) to more severe (deep wounds, fractures), permanent (amputation, spinal cord injury) and fatal injury. Ill-health as a result of contact with animals, micro-organisms, plant material dusts or chemicals are associated with certain types of agriculture. Pesticides permitted for current use in agriculture, when incorrectly handled (e.g. without protective gear), could be a source of occupational hazards to people working in the agriculture sector; millions of acute poisoning cases are reported for pesticide handlers (formulators, manufacturers, applicators), of which 300 000 death are estimated to occur annually at the global level[13]. Many approved agriculture pesticides are important toxicants: in fact, US/EPA and EU-approved active substances include several pesticides with ingredients classified as carcinogenic.

2.1.6. Multiple exposures to agricultural inputs

Although regulatory authorities report a low proportion of pesticide residues in food exceeding the Maximum Residue Levels (1.6% of EU samples[14]), small amounts of certain synthetic chemicals and the combined effect of pesticides' active ingredients found in food, drink, dust and air act synergistically, leading to high toxicity and damaging health effects for current and future generations. As knowledge progresses on health effects of chemicals, allowed residues limits in food keep being lowered, while life cycle impact assessment frameworks are being developed to better assess human exposure to pesticides[15]. The challenge of the FAO/WHO Codex Alimentarius Commission and other standard-setting authorities is to address cumulative effects, or mixture toxicity, of different compound residues on health.

Awaiting for conducive policies towards healthier food systems, exposure pathways could be drastically reduced by individual small actions, such as decreased exposure to pesticides "by choosing, to the extent possible, food grown without pesticides or chemical fertilizers and washing conventionally grown produce to remove residues. Similarly, exposure to antibiotics, growth hormones, and toxic run-off from livestock feed lots can be minimized by eating free-range meat raised without these medications if it is available. Avoiding or minimizing consumption of processed, charred and well-done meats will reduce exposure to carcinogenic heterorocyclic amines and polyaromatic hydrocarbons"[16].

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[12] Litchfield Melville, 1999. Agricultural Work Related Injury and Ill-Health and the Economic Cost. Environmental Science and Pollution Research, 6:175. doi:10.1007/BF02987623

[13] PANNA, 2004. Chemical Trespass: Pesticides in our Bodies and Corporate Accountability. Pesticides Action Network America.

[14] EFSA, 2017. The 2015 European Union Report on Pesticide Residues in Food. European Food Safety Authority.

[15] Fantke Peter and Olivier Jolliet, 2016. Life cycle Human Health Impacts of 875 Pesticides. Environmental Health Sciences. International Journal of Life Cycle Assessment, 21(5), doi 10.1007/s11367-015-0910-y

[16] National Cancer Institute, 2010. Reducing Environmental Cancer Risk: What we Can do Now. 2008-2009 Annual Report of the President's Cancer Panel. US Department of Health and Human Services, National Institute of Health, National Cancer Institute. April 2010.

2.2. Selected diseases associated to some extent with food and agriculture systems

The four leading non-communicable diseases (NCDs) that are responsible for the bulk of NCD premature deaths are: cardio-vascular diseases (37%), diabetes (4%), cancer (27%) and respiratory diseases (8%)[17]. With regards the food system, these NCDs could be diet-related (i.e. nutrition-related NCDs) or linked to contaminants in food and the environment (i.e. agriculture-related NCDs). It is to be stressed that agriculture-related NCDs include both environmental exposures (with lower dose of agricultural contaminants exposing a larger population) and occupational exposures (with higher dose of agricultural contaminants exposing the smaller population).

Most policy actions and related mitigation targets address nutrition-related NCDs, such as malnutrition and poor diets (both stunting/wasting and overweight/obesity). These are recognized as the number one driver of the global burden of diseases, affecting one in three people, with an annual economic loss of 11% of GDP in Africa and Asia. Nutrition-related NCDs account for nearly half of all deaths and disability in low- and middle-income countries[18].

Much less is known about agriculture-related NCDs, as the exact linkage between agriculture and health has not been scrutinized enough. Occupational exposure in particular is virtually not considered and regulations for workplace environments are focused more on safety than on health. Thus, when analysing food system impacts on health, it is worth considering also disease groups such as: antibiotic-resistant infections, neuro-developmental diseases and neuro-degenerative diseases, along with the well-studied foodborne infections. These are all associated to different extent with the quality of agricultural management, as well as with the extent of synthetic agricultural inputs and residues found in food and the environment.

While the number of diseases that could to some extent be associated with the food system is varied, what follows is a brief presentation of the selected health conditions used to illustrate the MARCH valuation method, and more specifically MARCH' application of a probability of food system causation that excludes other risk factors in the causal chain (e.g. physical inactivity, alcohol consumption and smoking). While the causation ratios applied should not be considered definitive (and must be improved), they illustrate MARCH's potential outcomes.

2.2.1. Cardio-vascular diseases

Cardio-vascular diseases (CVDs) are the leading cause of death globally: 17.7 million deaths in 2015[19]. Coronary artery disease and stroke account for 80% of CVD deaths in males and 75% of CVD deaths in females in USA. The American Heart Association reports that CVDs cost over USD 320 billion per year in terms of health care and reduced productivity[20]. Unhealthy diets are

[17] WHO, 2014. Global Status Report on Non-communicable Diseases 2014. Attaining the Nine Global Non-communicable Diseases Targets: a Shared Responsibility.
[18] International Food Policy Research Institute, 2016. Global Nutrition Report 2016. From Promise to Impact: Ending Malnutrition by 2030. Washington D.C.
[19] WHO, 2017. Cardiovascular Diseases Fact Sheet.
[20] Mozaffaraian et al, 2015. Heart Disease and Stroke Statistics: 2015 Update. A Report of the American Heart Association, American Heartt Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 131, e29-322. Doi: 10.1161/CIR.00000152

an important risk factor[21]. Globally, 33% of ischemic heart disease is attributable to high blood cholesterol. Raised blood sugar is associated with 22% of ischaemic heart disease and 16% of stroke deaths[22].

2.2.2. Colorectal cancer

Neoplasms (or cancers), figure among the leading causes of human morbidity and mortality worldwide, with approximately 14 million new cases and related 8.2 million deaths in 2012. The number of new cases is expected to rise by about 70% over the next 2 decades, up to 22 million. Around one third of all cancer deaths are due to the 5 leading behavioural and dietary risks: high body mass index, low fruit and vegetable intake, lack of physical activity, tobacco use, alcohol use[23]. The American Association for Cancer declared that 60% of cancers can be avoided by simply changing diet and lifestyle. The American Institute for Cancer Research examines evidence linking diet, physical activity and weight to 17 cancer types. Colorectal carcinoma is the third leading cause of cancer deaths, especially among men in high-income countries. Experts of the International Agency for Research and Cancer report that for each 50 gram portion of processed meat eaten daily, the risk of colorectal cancer increases by 18%[24]. Acknowledging contradicting science in dietary regimes, colorectal cancer is reported as one of the most preventable types of cancer (50%), especially by reducing alcohol and red and processed meat intake[25].

2.2.3. Obesity

Globally, 2 billion people have nutritional deficiencies, including both those under- or over-nourished. Overweight and obesity cause millions of premature deaths, more than for people underweight. In 2014, over 600 million people (or 13% of adults over 18) were obese and 41 million children under the age of 5 were overweight or obese. Obesity is responsible for 4.8% of deaths globally and 8.4% in high-income countries[26]. In USA, when one person in a household is obese, the household faces additional health care costs equivalent to 8% of its annual income[27]. Obesity is reported to have the same economic impact as armed violence, war and terrorism, about USD 2 trillion or 2.8% of global GDP. Should current trends continue, almost half of the world population will be overweight or obese in 2030[28]. The risk of coronary heart disease (23%), ischaemic stroke and Type 2 Diabetes (44%) grows steadily with increasing body mass, as do the risks of cancers of breast, colon, prostate and other organs (7-41%). Obesity is among the main reasons of gene mutation, causing 15-20% of all cancer deaths.

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[21] WHO, 2011, Global Atlas on CVD Prevention and Control.
[22] WHO, 2009. Global Burden of Disease.
[23] *WHO Fact Sheet no. 297, 2015*
[24] IARC, 2015. Press Release no. 240. IARC Monographs Evaluate Consumption of Red Meat and Processed meat. 26 October 2015. International Agency for Research on Cancer. WHO.
[25] World Cancer Research Fund International, Continuous Update Project website (accessed in March 2017).
[26] WHO, 2009. Global Health Risks. Mortality and Burden of Disease Attributable to Selected Major Risks.
[27] International Food Policy Research Institute, 2016. Global Nutrition Report 2016. From Promise to Impact: Ending Malnutrition by 2030. Washington D.C.
[28] Mc Kinsey Global Institute, 2014. Overcoming Obesity: an Initial Economic Analysis.

2.2.4. Diseases of the digestive system

Stomach, liver and kidneys are the prime metabolic organs that breakdown carbohydrates, proteins and fats in food, transform excess nitrogen into waste products and break-down chemicals. Besides alcohol-related diseases, the main chronic liver diseases are closely related with diabetes and obesity, while kidney failures are associated, among others, with toxic exposure to environmental pollutants, especially overloads of toxins from heavy metals. Adequate diets, including enzymes that support metabolic processes, are key to improving metabolic functions, including both prevention and treatment of several disorders. Kidney diseases are partly due to phosphate additives (pyrophosphate and sodium polyphosphate) in meat and soft drinks[29], as well as to Cadmium from mineral phosphorus fertilizers (especially in barley, wheat and vegetables)[30] and certain herbicides and insecticides residues in food[31].

2.2.5. Respiratory diseases

Chronic respiratory diseases include the most common chronic obstructive pulmonary disease, asthma, occupational lung diseases and pulmonary hypertension. In low-income countries, the leading cause of disease is pneumonia, while in high-income countries, pneumonia and chronic bronchitis are the third cause of death, after coronary artery diseases and cancer. In addition to tobacco smoke and frequent lower respiratory infections during childhood, risk factors include atmospheric pollution from factory farms that increases by 20% respiratory diseases[32]. Atmospheric pollution from factory farms and pesticide drifts from aircraft spraying are particularly associated with respiratory diseases; exposure to chemicals and dusts (fine particulate matter) is estimated to cause 12% of deaths due to chronic obstructive pulmonary disease[33]. A child's immune system may be weakened by malnutrition or undernourishment (especially zinc deficiency), especially in infants who are not exclusively breastfed[34].

2.2.6. Reproductive disorders

Endocrine-disrupting chemicals (EDCs), widely used in consumer products, electronics and agriculture, have been associated with a diverse array of health effects. Simulations produced a median EDC-related health cost of €157 billion annually in the European Union (i.e. USD 217 billion), corresponding to 1.28% of EU gross domestic product[35] and USD 340 billion annually in

[29] Amato and Maravilla, 1998. Acute Effects of Soft Drink Intake on Calcium and Phosphate Metabolism in Immature and Adult Rats. Rev. Invest. Clin. May-June 1998, vol. 50(3).
[30] EFSA, 2009. Scientific Opinion of the Panel on Contaminants in the Food Chain on a Request from the European Commission on Cadmium in Food. EFSA Journal 2009 (980).
[31] Lebov et al, 2016. Occupational Environment Med 2016;73:3-12
[32] May S., D.J. Romberger and J.A. Poole, 2012. Respiratory Health Effects of Large Animal Farming Environments. Journal of Toxicol Environ Health B Crit Rev. 2012; 15(8): 524–541.
33 WHO, 2009. Global Health Risks.
[34] WHO, 2016. Pneumonia Fact Sheet.
[35] Trasande et al, 2015. Estimating Burden and Disease Costs of Exposure to Endocrine-Disrupting Chemicals in the European Union. J. Clin. Endocrinol. Metab. 2015, April; 100(4).

USA, corresponding to 2.33% of GDP[36]. Exposure to EDCs (e.g. phthalates, bisphenols and per-fluoro-otanoic acid) used in plastic bottles, tins, cans, foodware and cookware (Teflon)[37] is associated with 40-69% of anomalies of male reproductive hormone balance (infertility, cryptorchidism, hypospady) and 0-19% incidence of testicular cancer[38].

2.2.7. Alzheimer's Disease

The cause of neuro-degenerative diseases, such as Parkinson and Alzheimer's Disease (AD), is generally unknown, though believed to involve both genetic and environmental factors. In France, neuro-degenerative diseases are recognized as professional diseases of agricultural pesticide users, especially viticulture workers[39]. There is also an increased risk in people with hypertension and those exposed to certain pesticides[40]. In 2015, there were approximately 48 million people worldwide with Alzheimer's and in developed countries, AD is one of the most financially costly diseases[41]. The incidence of neuro-degenerative diseases is doubling every 4 years. Its association with atherosclerosis and other blood flow in the brain could classify it as a vascular pathology.

2.3. Probability of disease causation

The number of disease outcomes is substantial and most health conditions are somewhat linked to the food system, whether nutrition- or agriculture-related NCDs. Food system-related risk factors and the incidence of disease must be better understood in order to guide decision-makers towards disease prevention. Most risk factors are associated with more than one disease and targeting those factors can reduce multiple causes of disease. On the other hand, a particular disease is often caused by more than one risk factor and linkage ratios cannot simply be added to quantify the impact of the food system on specific diseases because of the risk of double-counting the impact. For example, 45% of cardiovascular deaths of those older than 30 years can be attributed to raised blood pressure, 16% to raised cholesterol and 13% to raised blood glucose, yet the WHO estimated combined effect of these three risks is about 48% of cardiovascular diseases[42].

A significant challenge is to isolate causal links between agricultural and food inputs and health impacts. Health studies are inherently insufficient or equivocal for any precise decision-making. In fact, scientific "evidence" is not settled on most important issues. Besides inconclusive and/or biased studies, scientific literature on health risk assessment uses different measurement methods and data collection approaches, with more often than not, contradicting results. A notable example is the current debate around glyphosate herbicide, labelled in 2015 by the International Agency for Research on Cancer as "probable carcinogen", while doubt, evidence and counter-evidence keeps

[36] Attina et al, 2016. Exposure to Endocrine-Disrupting Chemicals in the USA: a Population-Based Disease Burden and Cost Analysis. Lancet Diabetes Endocrinol. 2016 Dec;4(12):996-1003. Epub 2016 Oct 17.

[37] European Food Safety Authority, 2014. Official Declaration: Bisphenol A.

[38] Trasande et al, 2015. Estimating Burden and Disease Costs of Exposure to Endocrine-Disrupting Chemicals in the European Union. J. Clin. Endocrinol. Metab. 2015, April; 100(4) pp.1245-55

[39] French Decree no. 2012-665, May 2012. In: Le lien entre la maladie de Parkinson et les pesticides officiellement reconnus. Le Monde, 9 mai 2012.

[40] Plassman B.L. et al, 2016. Design of the Agricultural Health Study of Memory in Aging. The Journal of Alzheimer' Association. DOI: http://dx.doi.org/10.1016/j.jalz.2016.06.2035

[41] WHO, Global Burden of Disease.

[42] WHO, 2009. Global Burden of Disease.

being discussed by concerned manufacturers and regulatory agencies and in federal courts (by thousand farmers affected with non-Hodgkin lymphoma), citing gaps regarding the assessment methods (e.g. human epidemiology vs, animal bioassays vs. genotoxicity), statistical validity of data (including of meta-analyses pooling human data from multiple studies to identify trends) and interpretation of the "weight of evidence".

The determination that an association is causal signals the need (or at least the possibility) to take action to reduce exposure to hazardous agents: thus, causal inference is needed for public health practice, policy formulation and regulatory processes. However, the notion of disease causation has always been a matter of controversy, as a single clinical phenomenon can have quite different causes, and one cause can have quite different clinical consequences. Every verdict of causation is provisional due to insufficient evidence regarding temporal relation, association, environmental equivalence and population equivalence - so it is impossible for disease processes to draw an ontological demarcation within the indefinite stream of events between causal and non-causal associations[43].

Excluding evidence from experimental animal bioassays and in-vitro studies, human studies follow two main approaches to attribute causation:

- Epidemiological or observational studies: usually a cohort group that provides ex-post evidence, that is, when the health impairment has already occurred in a significant fraction of the exposed population. Epidemiological evidence does not reflect the importance of participants' genetic susceptibility and their response to cofactors, while failing to demonstrate environmental equivalence to a sufficient degree to support the notion of a causal relation between and agent and the target disease.
- Clinical or randomized studies: usually a randomized, placebo-controlled double blinded group, that tests whether the change in treatment/intervention leads to a change in disease over a defined period. Although this randomized process (which produces and control all relevant conditions) removes bias, it is almost always performed in tightly defined groups, which narrows the possibility of generalising results. Considering the width of the food system (i.e. how it gets from field to plate, and to whom), it is very difficult to imagine a counter-factual. Furthermore, clinical intervention trials cannot be applied to potentially debilitating or lethal factors, while being in any case impossible if the latency is long, as it is for chronic diseases. For example, understanding certain pesticides effects require longitudinal studies including parental exposure prior to conception, in utero exposures, and direct exposures throughout childhood to pesticides.

Although clinical intervention trials are considered superior to observational studies, their limits and costly implementation requires enhancing epidemiological studies by adopting a multi-variable approach (e.g. use of propensity scores and matching, with the help of statistical models), as well as designing observational analyses that emulate data from hypothetical randomized experiments with relatively well-defined interventions.

In order to avoid subjectivity in the evaluation of evidence or the manipulation of evidence, broader frameworks for formulating causal questions require developing analytical tools that reduce

[43] Kundi Michael, 2006. Causality and the Interpretation of Epidemiological Evidence. Environmental Health Perspectives. 114(7): 969-974.

uncertainty associated with causal determinations. For example, the global challenge of obesity necessitates a multi-level framing of underlying causal processes (or multiple exposure effects on disease initiation and outcome) - extending from pre-natal exposure to "obesogens", through the genes of individuals and dietary habits, to the food sold by multinational corporations - as the basis for formulating interventions.

3. The wellbeing valuation approach and other valuation metrics

It is highlighted that the valuation approach of this study does not consider mortality but only the burden of disease on individuals, measured in terms of subjective wellbeing. However, these costs will include the threat of a higher probability of an early death.

3.1. Introduction

Chapter 2 introduced the medical aspects to this study, recommending that a dedicated effort be undertaken to establish the range of causation between the agri-food system impacts on health. This Chapter turns to the economic aspects of the study to enable the user to value the impact of the diseases on the individual.

In valuation methodology, three key **economic agents** (i.e. groups) in society are recognized. This is typical in cost-benefit analysis (CBA) methodology and is the global best-practice method for estimating and understanding value:

- Individuals;
- Businesses;
- Government.

A given health outcome can impact on a number (or all) of the agents. For example, a health problem may impact on a private individual through the experience of living in pain and discomfort, or being unable to achieve some normal daily activities. This health problem may also mean that the individual needs to take a substantial amount of time off work which could impact on businesses and on the individual through loss of earnings. And finally, absenteeism from work would mean lower tax receipts and the individual may need to use public health services, both of which have detrimental effects on government finances.

These impacts can be financial (monetary) or non-financial (non-monetary). Financial values are impacts on cashable resources such as tax revenue, income and government expenditure. Non-financial values are the value of more intangible non-financial outcomes, such as pain and discomfort. Impacts on (and costs for) businesses and government are usually financial impacts with a cashable implication, whilst impacts on individuals can be both financial (e.g. loss of income due to unemployment) and non-financial (e.g. pain) for health problems. Understanding the full food system-related costs of health requires understanding the impacts on all three agents, both in the form of financial and non-financial impacts. Although there are some areas where there are issues related to double-counting, by and large these impacts are independent and should all be estimated and valued separately.

The focus of this study is on the food system-related (i.e. diets, food, agri-environmental and occupational quality) impacts of health for **individuals**, with a specific focus on **non-financial impacts**. Whilst there are financial costs of health for individuals, such as loss of earnings or expenditure on medication, the focus is on non-financial impacts such as pain, discomfort, depression and other mental health issues. These non-financial impacts are harder to measure and value and, as much research has shown, they also far outweigh the financial costs of health problems[44]. From a policy perspective, non-financial impacts can be interpreted as indicating the magnitude of the social cost associated with health conditions, and hereby refer to them as non-financial costs or wellbeing costs.

3.2. Valuing non-financial costs of health for individuals

3.2.1. Theory

There has been an extensive body and history of research in health economics on valuation methods for non-financial costs of health. This literature has grown-out of the more general valuation literature in microeconomics, which has become the standard and best-practice approach to valuing outcomes. At the heart of valuation of intangible (non-financial) outcomes is the concept of two welfare measures developed by Hicks and Allen (1934)[45]:

- **Compensating surplus (CS)** is the amount of money, paid or received, that will leave the individual in his/her initial welfare position following a change from the *status quo*. For example, the CS for an improvement in health (which improves an individual's overall welfare) is the maximum amount of money that the individual is willing to pay for the health improvement.
- **Equivalent surplus (ES)** is the amount of money, to be paid or received, that will leave the individual in his/her subsequent welfare position in the absence of a change from the *status quo*. For example, the ES for an improvement in health is the minimum amount of money that an individual would be willing to accept as compensation for foregoing the health benefit.

As applied to health, the change from the *status quo* is a change in health from the *status quo*, or current health status. It is common to use the CS measure in valuation and doing so here, the cost of a food system-related health problem is defined as the amount of money that would need to be received by the individual to return the individual to his/her **initial** welfare position after the deterioration of his/her health. In this context, it resembles a compensation amount for the individual to live with the health problem, such that his/her overall level of welfare is unaffected.

It is known as a "welfarist" or "welfare-based" approach because the ultimate concept being measured is how the change impacts on the welfare of an individual, or quality of life in the broadest sense of the word. In this framework, a change is valuable to an individual **if and only if (*iff*)** it impacts on the individual's welfare, either for a part of or the rest of their life (thus including

[44] For example, see the non-financial impact/cost of depression in Fujiwara, D. & Dolan. P. (2014). Valuing Mental Health: how a Subjective Wellbeing Approach can Show Just How Much it Matters. UK Council for Psychotherapy.
[45] J. R. Hicks and R. G. D. Allen, 1934. A Reconsideration of the Theory of Value: Part I. Economica, vol. 1, no. 1, pp. 52–76, 1934.

both curable and non-curable conditions). This is the framework used as best-practice across the OECD and within international organizations.

The key to valuation of individual impacts is therefore in how welfare (or wellbeing) is **defined** and **measured.** The key two candidate measures of welfare that are discussed here (and which are the basis of much research in economics) are: preference-based measures of wellbeing; and experience-based measures of wellbeing.

Preference accounts of wellbeing are based on the premise that welfare can be inferred from people's choices because "what is best for someone is what would best fulfil all of his desires"[46]. Modern-day economic theory is based on this account of welfare and in economics the 'information' that preferences reveal is called **utility**.

Experience-based measures of wellbeing - also referred to as mental state accounts of wellbeing and **subjective wellbeing** (SWB) - refer to people's subjective experiences of their own wellbeing, which is usually measured through a self-reported survey. It looks at how the individual feels and thinks about his/her life and there is a large range of SWB questions which include questions on happiness, emotions, life satisfaction, purpose in life, sadness, anxiety and goal attainment. Each SWB measure taps into different theoretical concepts of wellbeing.

Valuation methods have been developed for both preference and SWB measures of welfare. These are discussed below with respect to health.

3.2.2. Preference-based valuation methods

Two methods have been developed to measure values based on preference and these have become the two core traditional methods within economics[47].

i. Revealed preference valuation

Revealed preference methods uncover estimates of the value of non-market goods by using evidence of how people behave in the face of real choices. This can be in the direct market or an indirect market. A direct market is where people are observed to make purchases directly in respect to health. For example, the cost of a health condition could be measured by how much people are prepared to spend on rectifying the problem or how much people are prepared to spend on insuring against the problem (**defence expenditure method**).

An indirect market approach is where the value of health is revealed in other market transactions, such as how much people are willing to spend on equipment (e.g. pesticide protective gear, water purifiers) to reduce the risk of a health problem, or how much people are compensated in their salary for jobs that contain health risks (**hedonic pricing**). Part of the amount they pay or receive

[46] Parfit, 1984. Reasons and Persons. Oxford University Press.
[47] For more details, see Fujiwara Daniel and Ross Campbell, 2011. Valuation Techniques for Social Cost-benefit Analysis: Stated Preference, Revealed Preference and Subjective Well-being Approaches. A Discussion of the Current Issues. HM Treasury. Department for Work and Pensions.

for these goods/services is related to health although not directly and completely so, hence they are known as indirect market methods.

The application of these methods is limited because very often, well-functioning direct or indirect markets do not exist for the outcomes to be measured and this is likely to be the case for health. Consequently, valuation of health outcomes has tended to rely on other methods, which are discussed below.

ii. Stated preference valuation

Stated preference techniques are survey-based methods that elicit monetary values of non-market goods and services by directly asking people what value they attach to specified changes in those goods and services. Two main types of stated preference methods exist: **contingent valuation methods** and **choice modelling techniques**, such as choice experiments.

Contingent valuation (CV) asks respondents directly to report their maximum willingness to pay (WTP) (for positive outcomes), or minimum willingness to accept (WTA) (for negative outcomes) for the hypothetical policy change, or change in an outcome like health. The main advantage of CV is that it is extremely flexible and capable of valuing a wide range goods and services, including future or planned changes.

Choice modelling (CM) is a multi-attribute preference elicitation technique used extensively in marketing, transportation and environmental valuation. Respondents are presented with a series of scenarios, each composed of different attributes, varying at different levels. Respondents are then asked to choose their most preferred scenario. If a monetary cost is included as one of the attributes, it is possible to value of the component attributes, in other words the implicit value of each of the attributes (i.e. the marginal WTP).

Stated preference valuation methods suffer from a number of problems: a large literature from the decision science has shown that preferences can be highly context-dependent[48]. They can often be biased by irrelevant factors, which means that what people want may not always align well with what is best for them and their WTP/WTA responses may be biased. In light of this, CV and CM survey instruments must be designed with care in order to reduce biases.[49]

Whilst CM is rarely applied to health valuation (it is difficult to define distinct attributes of health and placing a monetary value on attributes of health is considered by many to be controversial), numerous attempts have been made to use CV to value health states. Issues concerning bias in the surveys aside, the key problem for CV in health has been the tendency for people to object to the idea of placing a monetary value on their own health. Whilst CV has been demonstrated to work well in areas such as transport (e.g. WTP for different road options) and culture (e.g. WTP for museum entry), the appropriateness of using WTP to value health raises ethical concerns. For example, because value will be related to the ability to pay (and the prevailing income distribution

[48] See Lichtenstein, S. & Slovic,P. (2006). The Construction of Preference. Cambridge University Press.

[49] For instance, NOAA sets a protocol on survey design so as to get solid, reliable estimates using this type of instrument. Available at: http://www.economia.unimib.it/DATA/moduli/7_6067/materiale/noaa%20report.pdf

may be seen as inequitable) and because of the signal that using money to value health may send (implying health is just like any other commodity bought and sold in the market place).

As a result of these concerns over using CM or CV to evaluate health, health policy analysis has become a notable exception in many countries which do not use CM or CV to evaluate policy interventions. Health valuation commonly uses the Quality Adjusted Life Year (QALY) approach, in which health conditions are valued in health quality rather than in monetary terms.

3.2.3. The Quality Adjusted Life Year (QALY) approach in health

The QALY approach converts different health states onto a scale of 0 (death) to 1 (perfect health), which provides a 'value' of the non-financial health costs in a non-monetary format, where more severe/worse health conditions have a lower value (closer to 0). There are two stages in the process of estimating QALYs.

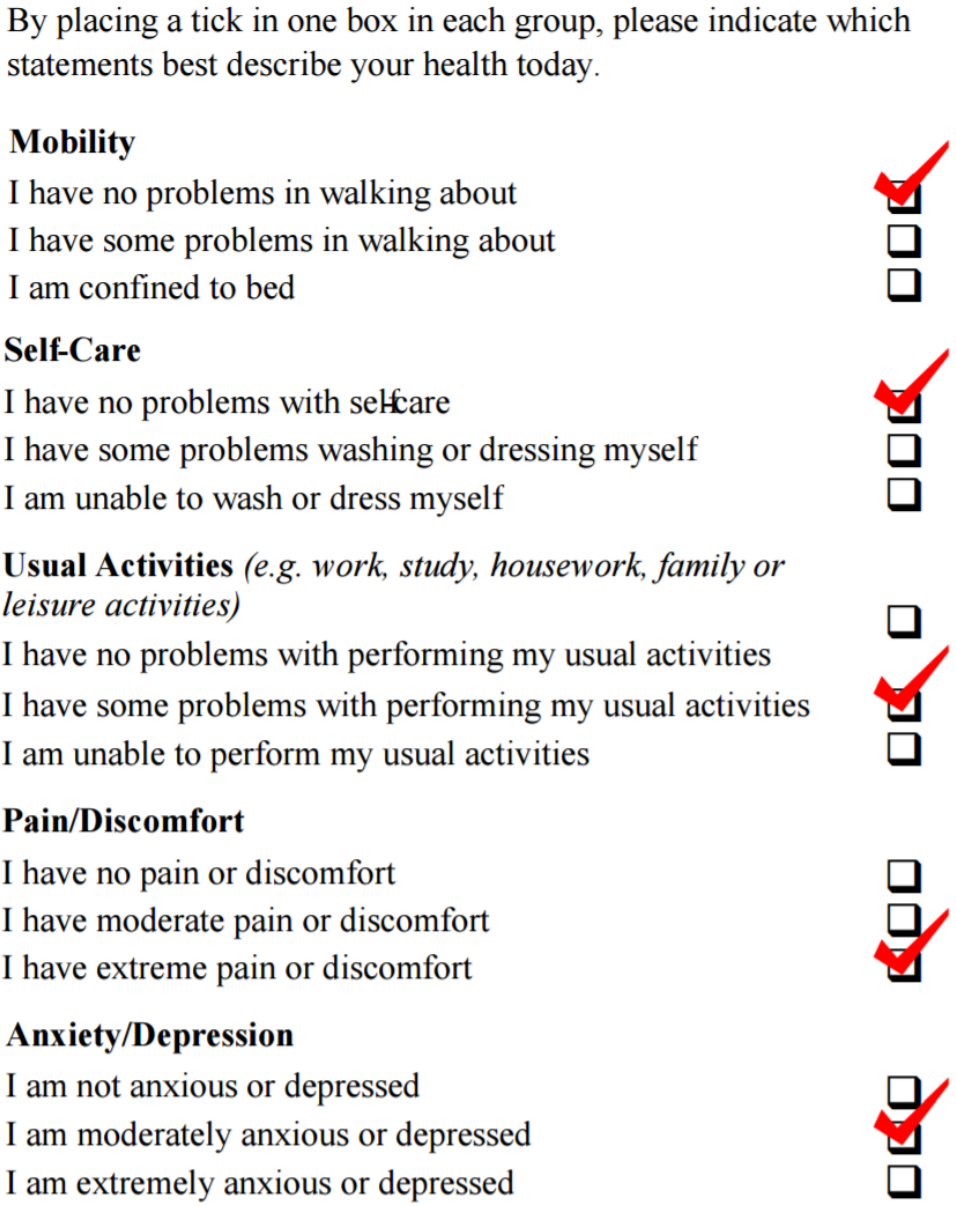
- A health state descriptive system is used to describe health conditions in a consistent way on a number of dimensions. In the UK, the National Institute for Health and Care Excellence (NICE) currently recommends the EQ-5D. The EQ-5D has also been used by the World Health Organisation for measuring the severity of health conditions[50], as it provides a standard measure for inputs into QALY and the very similar Disability Adjusted Life Year (DALY). EQ-5D defines health in terms of five dimensions (mobility, self-care, usual activities, pain and depression/anxiety), with three levels of severity for each dimension (level 1 = no problems; level 2 = some problems and level 3 = extreme problems) (see Figure 1)[51]. Health conditions, such as back pain or heart disease, are rated on this scale using the EQ-5D: for example, an index of (21121) would represent a health state with some mobility problems and moderate pain, but no problems in the other three domains. Patients that experience the health condition assess their health using the EQ-5D. There are other health state descriptive systems, such as the SF-36[52], but the focus here is on the EQ-5D.

- In the second stage, the general public is asked to value the health states. Given the problems with eliciting monetary values for health, a different approach has been adopted. This involves retaining the preference-based component of willingness to pay but replacing money as the currency with the risk of death or life years. The **standard gamble (SG)** approach to estimating QALYs requires respondents to consider the combination of the risk of full health (p) and the risk of death (1-p) that is equivalent to the certainty of a poor health state. If full health is assigned a value of 1, then the value of the poor health state is taken to be p. The time **trade-off (TTO)** approach to estimating QALYs requires respondents to consider how many years of life in full health, x, are equivalent to a longer time, t, in a poor health state. With full health = 1, the value of the poor health state is x divided by t. The TTO and SG can be used to estimate QALYs: both methods assign a

[50] See: http://www.who.int/bulletin/volumes/90/7/11-095109/en/
[51] There is also a version of the EQ-5D with 5 levels of severity.
[52] The SF-36 is a measure of general health used in clinical studies: it has eight dimension scores and which lead to a two summary scores for physical and mental health.

figure between 0-1 to health states, where more severe/worse health conditions have a lower value (closer to 0). A QALY value of 1 represents one year of life in perfect health and a QALY of zero represents death. There has been considerable debate among health economists about the relative merits of these methods. As it currently stands, NICE in the UK has a preference for the TTO.

Figure 1. The EQ-5D health state descriptive system (with example responses) [53]



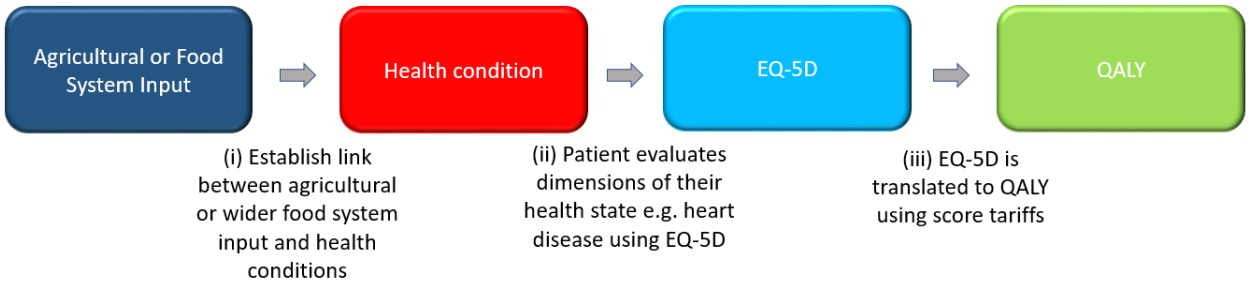
[53] EuroQol Group, 2015. EQ-5D-3L User Guide: Basic information on how to use EQ-5D-3L instrument, Ver. 5.1

The result of these two stages is that a health condition is converted into an EQ-5D score (e.g., 21121), which in turn is converted into a QALY score (e.g., 0.3 on the 0 to 1 scale). The QALY represents the severity or the non-financial 'cost' to individuals of the health condition. QALYs retain the preference element from traditional economic analysis – that is, it uses preference as the overall gauge about how important and valuable health is - but the final value metric is non-monetary, hence avoiding the issues around placing a financial figure on one's health.

3.2.4. Application of the QALY to food system-related costs of health

The QALY approach, which represents the traditional and most widespread approach to health assessments, can be applied to estimate food system-related costs of health as set-out in Figure 2.

Figure 2. Application of QALYs to food system-related costs of health



Through this process, it is possible to estimate the impact of food system-related health condition on QALYs. The two key parameters that require estimation are (i) the impact of the agricultural food system-related input on the health condition and (ii) the translation of the health condition onto the EQ-5D score. From this, it is possible to derive the QALY in process (iii) where the EQ-5D-to-QALY conversion tariff has been pre-estimated and is available for a number of countries, including the UK.

3.2.5. Advantages and disadvantages of the QALY approach

There are a number of pros and cons related to using QALYs to measure agriculture and the wider food system-related costs of health. The main advantage is that this is a standard approach in health economics and for the majority of food system-related health conditions, the EQ-5D and QALY scores are already known. Hence, the main task is to estimate the impact of the food or agricultural issue on the health condition. Another key benefit of this approach is that health states are measured in non-monetary terms using the QALY, which avoids the problems discussed above.

There are, however, a number of key problems with this approach. First, since money is not used as the numeraire in the methods for eliciting the QALY (i.e. the TTO and SG), the QALY does not have any *natural* monetary value. It is possible to calculate implicit values for QALYs. These are estimated using thresholds for cost-effectiveness (i.e. what health care systems find as acceptable levels of payment for improving a QALY). The National Institute for Health and Care

Excellence (NICE) regards cost-effectiveness ratios of up to £40 000 per QALY as reasonable [54]. Whilst this method allows us to estimate an implicit value, it is not a particularly robust way to value health conditions as there is no data-driven way to set the threshold. NICE currently use a one-to-one ratio of per capita GDP to the QALY whilst the WHO recommends valuing Disability Adjusted Life Years DALYs (which are similar to the QALY) at three times per capita GDP[55].

The derivation of the value from a somewhat arbitrary threshold means that the values attributed to the health conditions are less defensible than in the WV approach where the valuation is derived from people's experience of positive income shocks. Further, other studies have found that the British public's willingness to pay for an incremental QALY is around £60 000[56] using stated preference methods. However, this approach is limited by the issues described in section 3.2.2. Due to the inherent difficulties of placing a monetary value on QALY, they tend to be used is in health related cost-effectiveness analysis (CEA) (often termed cost-utility analysis (CUA)), rather than cost-benefit analysis (CBA). Health related CEA/CUA assesses the cost-per-QALY of an intervention (i.e. how much it costs to generate one additional QALY). This means that the financial costs of reducing the risk of an agriculture and wider food system-related health condition cannot be compared to the benefits in the same monetary terms unless the QALY is monetized. In sum, QALYs can only be used to make relative assessments in health, where different health interventions are compared but it is not clear whether the benefits of the intervention outweigh the costs.

The second problem area relates to using preference as the measure of welfare in health valuation. Responses to methods, such as the SG and TTO, are subject to various biases that mean they (and the subsequent QALY scores) rarely reflect real experiences. In many ways, health state preferences (as elicited in the TTO and SG) more accurately reflect affective reactions to – or fears about – particular health states, rather than a considered assessment of what life would actually be like with those conditions. While fear is certainly an important thing to consider in healthcare, it is not what the SG and TTO are designed to tap into; rather, they are intended to reflect a cognitive assessment of the impact that a particular health state will have in the future, including how that impact may change over time.

The fundamental problem in methods like the TTO and SG is that the focus is on a preference question that is not often the real focus of attention in the actual experience of life. The TTO in the UK is administered from the general public. Compared to those who have experienced the health conditions, in the TTO the general public tends to overestimate the severity of many health conditions, partly because the survey context exaggerates the extent to which people attend to their health state. Imagine being asked to value walking with a cane. It is almost impossible to avoid imagining that as you walk you will be thinking about the cane much of the time when, in fact, the cane will rarely be the focus of one's attention, especially as time passes. Such focusing effects are an issue for any preference elicitation question for any population, including patients, since the

[54]UCL School of Pharmacy. (2016). Affording the Future? The role of cost effectiveness thresholds in determining NHS patient access to high quality care in the post-Brexit era. Retrieved 18th April 2017 from http://www.ucl.ac.uk/pharmacy/departments/practice-policy/affording-the-future.pdf

[55] Ibid.

[56] Glover, P. Henderson, J., 2010. Quantifying Health Impacts of Government Policies: A How-to Guide to Quantifying the Health Impacts of Government Policies. Department of Health, United KIngdom.

focus is on the extent of the experience. Furthermore, some people are able to adapt to some health conditions very well, whilst others may never adapt, and this is almost impossible for someone to know when stating their preferences over future health states. In sum, QALY scores may not reflect the real impact of health conditions on people's lives.

A third problem with QALYs relates to the usage of health state descriptive system, such as the EQ-5D. The EQ-5D is a narrow set of health dimensions (mobility, self-care, usual activities, pain and depression/anxiety) and there may be many other ways in which an agriculture and wider food system-related health problem impacts on an individual, for example through other forms of mental health problems, or impacts on feelings of energy and vitality and self-image, which would not get captured through the current EQ-5D and QALY method. Also, since the EQ-5D was designed for use among patient populations, it does not capture the impact that health conditions have on the families of patients. The impact on others affected by the condition is increasingly recognized as an important consideration in health technology assessments, there is a need to do more in order to accurately capture those effects.

All of this raises the question of the suitability of the QALY approach for assessing the agriculture and wider food system-related costs of health. Using the QALY in this area may lead to health agencies and other organizations to make the wrong policy decisions: 'wrong' in the sense that more benefit could be gained by using other valuation methods and in turn by making different policy decisions. Many economists recognize the problems with preference-based approaches and are looking for ways of refining conventional QALY methods (see for example Dolan & Kahneman, 2008[57]).

In the following sections, the Wellbeing Valuation approach is introduced, using Subjective Wellbeing (SWB) measures to value outcomes like health. This moves away from using preference and the QALY framework for health valuation, thus offering a number of key benefits. The introduction to the Wellbeing Valuation approach is followed by a case study using national health data from the UK.

3.2.6. The Wellbeing Valuation approach to measuring agriculture and wider food system-related costs of health

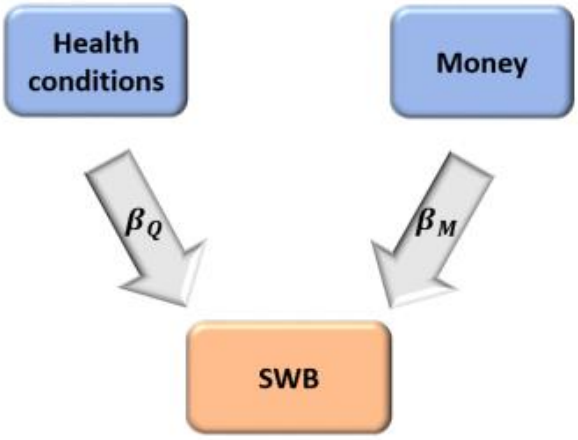
3.2.6.1. Introduction to the Wellbeing Valuation approach

The Wellbeing Valuation approach uses measures of SWB, such as life satisfaction and happiness to derive monetary values of non-market goods. In the case of health, the negative impact of a health condition on people's SWB (e.g. life satisfaction) is assessed, followed by an estimate of how much money would be needed to give to (compensate) people to return their wellbeing to their original level (the level without the health condition, that is the *status quo*). This provides an estimate of value that is consistent with the theoretical gold standard welfare measures of CS and

[57] Dolan, P. & Kahneman, D. (2008). Interpretations of Utility and their Implications for the Valuation of Health, The Economic Journal, 118 (January), 215–234.

ES (in this case CS)[58]. Figure describes the stages of the Wellbeing Valuation approach when applied to health.

Figure 3. Graphical representation of the Wellbeing Valuation approach



As displayed in Figure , the Wellbeing Valuation (WV) approach, measures two effects: first, the impact of the non-market good (here, health) on SWB (β_Q) and second, the impact of income or money on SWB (β_M). Using these two estimates, the method is able to consider how much income would have the same impact on SWB as the non-market good; usually, it considers the change in household income required from the national average level of household income. Specifically, the Marginal Rate of Substitution (MRS) between the non-market good and money provides the value of the non-market good estimated as:

(1) $$MRS = -\frac{\beta_Q}{\beta_M}$$

When the non-market good (Q) is a health condition, equation (1) shows that the cost of the health condition increases with the (negative) impact that the health condition has on SWB (i.e. as β_Q gets larger). In practice, β_Q and β_M are estimated empirically through statistical analysis based on a model of SWB such as:

(2) $$SWB_i = f(M_i, Q_i, X_i)$$

Where

SWB = a measure of wellbeing like life satisfaction or happiness
M = income
Q = the non-market good being valued (here health) and
X = other determinants of SWB.

[58] HicksJ.R. and R. G. D. Allen, 1934. A Reconsideration of the Theory of Value: part I," Economica, vol. 1, no. 1, pp. 52–76, 1934.

Here f'_Q (the first partial derivative of SWB with respect to Q) and f'_M (the first partial derivative of SWB with respect to M) would respectively provide proxies for β_Q and β_M.

There are two key issues or challenges related to the WV method. The first relates to the measurement of SWB; whether there is a suitable and robust measure of SWB and whether the SWB measure can be measured accurately and without bias.

SWB can be measured as 'evaluation' or 'experience'. SWB is measured as an evaluation when people are asked to provide global assessments of satisfaction with their lives overall. Economists have been using 'life satisfaction' for some time (for example, it is included in the UK's Understanding Society survey). Experience is closely associated with Jeremy Bentham's view of wellbeing, where pleasure and pain are the only things that are good or bad for people and they are measured repeatedly through an individual's day to build-up a picture of their wellbeing.

This paper focuses on life satisfaction, since it has been the default wellbeing measure used in the WV literature and the wellbeing literature more widely (Diener, 2000)[59]. Whilst it is impossible to 'verify' the measurement in that one cannot compare an individual's subjective wellbeing evaluation to anything objective; it is possible to evaluate the measure in other ways. The test-retest correlation is 0.59 over two weeks (Kahneman & Kreuger, 2006[60]), and has been found to be affected by current mood and context to some extent (see for example, Schwarz, 1987[61]). However, the bias due to current mood is likely to average out in large representative samples. Given these considerations, SWB evaluations may be considered reliable enough for the purpose of estimating the relationship between health conditions and SWB in large representative samples. It can also be seen as a good guide to what matters to people as they reflect on their lives, and there is a *prima facie* case for counting this in policy appraisal (Sumner, 1996)[62].

The second challenge is concerned with the technical aspects of the approach: that is, whether the statistical methods are suitable and robust. Econometric analysis such as multivariate regression analysis (which is the typical method used) generally identifies the relationship between a set of variables (such as life satisfaction, health and a set of control variables relating to the person's demographic characteristics and other circumstances). A statistically significant association which indicates that there is a notable statistical relationship between one factor (e.g. health) and the outcome (e.g. life satisfaction) is not enough *per se* to demonstrate the existence of a causal effect. What it means is that an increase in health of one unit on the scale is associated with an average increase of β_Q units in life satisfaction, but it does not imply that making someone healthier by one unit on the scale will cause his/her life satisfaction to increase by that much, since the estimated relationship may be due to other factors that jointly drive and influence health and life satisfaction, such as age or hereditary factors (known as confounding factors), and it may be that people with higher levels of life satisfaction become healthier (the issue of reverse causality).

[59] Diener, E., 2000. Subjective Wellbeing. The Science of Happiness and a Proposal for a National Index. Am Psychol. 2000 Jan;55(1):34-43.
[60] Kahneman, D., & Krueger, A.B. (2006). Developments in the Measurement of Subjective Well-Being. Journal of Economic Perspectives, 20 , 3-24.
[61] Schwarz, Norbert. 1987. Stimmung als Information: Untersuchungen zum Einfluß von Stimmungen auf die Bewertung des eigenen Lebens. Heidelberg: Springer Verlag.
[62] Sumner, L., 1996. Welfare, Happiness, and Ethics. Oxford University Press.

In order to address these issues in WV, a wide range of confounding factors are controlled for in multivariate regression analysis. However, it should always be noted that some variables are unobservable or hard to measure (such as hereditary factors) and so may not be controlled for in the model, which could bias the results. Bearing this caveat in mind, multivariate regression analysis of this kind is nevertheless the favoured approach in policy evaluation and cost-benefit analysis, as well as the academic empirical literature on wellbeing.

3.2.6.2. Challenges associated with other health valuation methods that Wellbeing Valuation can overcome

The key challenge related to preference valuation methods, such as the SG and TTO which are asked of people who do not actually have the conditions, are focussing effects[63]. This is where when asked to predict how one's life would be living with a particular health condition, people over-focus on the health condition and do not realize that they can adapt to many health issues. This is overcome in the WV approach, as the SWB approach allows us to infer what is important in people's lives when they are not thinking about how important those things are. In the area of health valuation, one cannot overstate how vital this is. Using statistical analysis, the effects of health problems on wellbeing can be examined without asking people how they think they would feel with the said health condition. In other words, one can find-out how important walking with a cane really is in the actual experience of people's everyday lives, alongside all the other things that affect people's wellbeing. Values derived from WV for health will fully account for how people adapt to different health conditions, an issue that is hard to capture in preference methods for health valuation. In sum, the WV method gives us a better understanding and is a reflection of the *real impact* and *real costs* of health conditions on people's lives.

A second key challenge that WV overcomes is that it can derive monetary values of health conditions. In preference valuation methods like CV, people have tended to refrain from (or be uncomfortable with) putting a value on their health. Subsequently, the QALY was designed to understand the value of health conditions without having to ask people the difficult question of placing a monetary value on health, but there is no natural monetary value for a change in QALYs. Since WV can estimate the value of health conditions solely from people's SWB responses, it does not directly ask people to place a value on their health and hence, is able to avoid these problems. The WV approach allows us to value health conditions in monetary terms and consequently, to conduct CBA, rather than the more restrictive CUA.

A third challenge is that preference-based health valuation methods require the use of health state descriptive systems, which have to define health as a pre-defined set of outcomes, such as pain and mobility, as in the EQ-5D. The WV approach for health avoids this. In equation (1), β_Q (estimated as the first partial derivative of SWB with respect to Q in equation (2) (f'_Q)), represents the full impact on SWB of the health condition. This can be through any channel through which health conditions impact on an individual's wellbeing such as pain and mobility, but also other mechanisms that are not picked up in the EQ-5D, such as self-image and energy.

[63] Fujiwara, D. and Dolan. P., 2014. Valuing Mental Health: how a Subjective Wellbeing Approach can Show Just How Much it Matters. UK Council for Psychotherapy.

A fourth challenge to preference-based health valuation methods is that they cannot pick up the impact of health conditions on others. The WV method can also pick up any burden on others through two mechanisms. First, if individual i's health condition impacts on j's wellbeing and i cares about this impact on j's wellbeing (e.g. poor health of a father creates worry for a daughter, which in turn negatively impacts on the father's wellbeing), then this will naturally be captured in β_Q for i. Second, it is possible to estimate the impact of i's poor health on j's SWB (e.g. poor health of a father creates a negative impact on a daughter's SWB) by running equation (2) for j and including i's health in equation (3).

(3) $$SWB_j = f(M_j, Q_i, X_j)$$

3.2.6.3. The challenges of the Wellbeing Valuation Approach

The key challenges regarding the WV approach relate to the rigour of the statistical methodology, which have already been touched upon in the section above. Equation (2) needs to be estimated such that f'_Q and f'_M are unbiased. That is, there is need to estimate the **causal impact** of health and money on SWB, which can be problematic. If health conditions and money are not randomly assigned, there is always the possibility that other confounding factors are driving any observed statistical relationship between health, money and SWB. It is, therefore, important to control for confounding factors, such as the socio-economic background.

In terms of control variables, Fujiwara and Campbell (2011)[64] provide a list of the main determinants of life satisfaction found in the literature to date:

- Income
- Age
- Gender
- Marital status
- Educational status
- Employment status
- Health status
- Social relations
- Religious affiliation
- Housing and environmental conditions and crime levels in the vicinity
- Number of children and other dependents (including caring duties)
- Geographic region
- Non-market good being valued
- Personality traits (such as extroversion)

Controlling for these potential confounders allows us to get closer towards a causal estimate. The issue of reverse causality is particularly important to consider in the estimation of the effect of income on life satisfaction. The causal estimate of income on life satisfaction is thus estimated

[64] Fujiwara, D. & Campbell, R. (2011). Valuation Techniques for Social Cost-Benefit Analysis: Stated Preference, Revealed Preference and Subjective Well-Being Approaches. HM Treasury and Department for Work and Pensions.

through an instrumental variable approach. The details of this technique are discussed in more depth in section 4, when conducting the case study for the UK.

3.2.6.1. Examples of use of wellbeing valuation of health in a policy context

Subjective wellbeing valuation has been used to value health conditions in a range of contexts. It can be fed into cost-benefit analysis as a benefit.

Box 1. Depression / Anxiety

Fujiwara and Dolan (2014) estimate the monetary equivalent cost for suffering from depression or anxiety to be £44 237 per capita per year. This value is the annual cost to the individual, and should be interpreted as an individual needing an additional £44 237 in income per year to return to the same level of life satisfaction if she or he did not suffer from depression or anxiety. Such a value can be used in cost-benefit analysis to value the impact of a policy. For example, Richards and Borglin (2011) found that 40-46% of patients participating in the "Improving Access to Psychological Therapies" service recover from depression and / or anxiety. Assuming that none of the participants would recover in absence of therapy, the expected annual benefit of the service per participant is 43% (the midpoint estimate of the percentage of patients that recover) multiplied by the value: £19 022.

Box 2. Diabetes

The Australian Social Value Bank (ASVB) covers a wide range of policy outcomes including some health conditions. The ASVB values the wellbeing impact of diabetes at around –USD 3000 (Australian Dollars, the exact values are restricted under license). Again, the value should be interpreted as the individual needing an additional USD3 000 in income per year to return to the same level of life satisfaction if she or he did not suffer from diabetes. Such a value may be used in a cost-benefit analysis for an intervention which prevents people from developing diabetes. For example, 100 people in a suburb of Sydney, New South Wales are diagnosed with pre-diabetes (characterised by the presence of blood glucose levels that are higher than normal but not yet high enough to be classed as diabetes) and 50 undertake a behavioural change course and 50 do not. Within the same time period, 40 of the people that take the course return to normal blood glucose levels and 10 of those who don't take the course return back to normal blood glucose levels. This shows that 1/4 of the people would have achieved the outcome without the course. As a result, the annual benefit of the course is USD3 000 multiplied by 40, multiplied by 3/4; USD 90 000. This can be compared to the costs of the course to conduct a cost benefit analysis. For more information on the Australian Social Value Bank, please see https://asvb.com.au/.

4. Methodology for Agriculture and the wider food system-Related Costs of Health (MARCH), using the UK case study

4.1. Step-by-step guide

In this Chapter, a step-by-step approach is set-up to value the agriculture and wider food system related costs of health, using the WV approach and illustrating it with actual UK data. The UK focus was chosen because the UK has extensive data on health in a number of national surveys. The analysis here provides a test of the WV approach as applied to valuing the agriculture and food system-related costs of health. From the results, it will be assessed whether the WV approach is a viable method in this field, compared to other methods such as the QALY approach. The objective here is to develop, a framework for the WV of agriculture and food system-related costs of health, similar to the QALY-based approach set-out in Figure 2. This is best described as a step-by-step Method for valuing the Agriculture and the wider food system Related Costs of Health, or MARCH:

A. Model and data preparation

A.1. Identify the health conditions that are to some extent affected by the food system. A preliminary framework must be set, as explained in Chapter 2. For example, colorectal cancer has been found to be linked to a deficit of fibre in the diet and excess meat intake.

A.2. Establish the quantitative link between the food system and resulting health conditions. This results in a probability that the health condition (or risk factor) is caused by the food system. Some examples are mentioned in Chapter 2. In the example, the probability of colorectal cancer being caused by the food system could be roughly estimated to be 50-75%.

A.3. Find or collect the data required for wellbeing valuation of the health condition. This requires data on SWB (e.g. life satisfaction), the health conditions, income and control variables and this step is explained in more detail in Section 4.2.1. For instance, the Health Survey Northern Ireland gives data on colorectal cancer and the control variables.

B. Model derivation and value estimation

B.1. Estimate the impact of the health conditions identified in Step A.1 on life satisfaction, using data from Step A.3, using for example regression analysis. In the example, the impact of having colorectal cancer is associated with a 1.054 lower life satisfaction on a scale of 1 to 7 with 1 being "completely dissatisfied" and 7 being "completely satisfied"[65].

B.2. Estimate the impact of income on life satisfaction, using data from Step A.3, using for example regression analysis. For example, this study uses an instrumental variable approach on

[65] The life satisfaction question is on a 1-5 scale in the HSNI but 1-7 in BHPS. The coefficient on colorectal cancer is rescaled to make it comparable to the income coefficient which comes from BHPS.

data from the British Household Panel Survey to estimate that a 100% increase in income would increase life satisfaction by 110%.

B.3. Use the results form steps B.1 and B.2 to estimate the monetary costs of the health conditions using equation (1). This produces the wellbeing value of the costs of the health conditions in per person, per year values. For example, the wellbeing value of the cost of colorectal cancer is -£48218 per individual per year.

Steps B.1 to B.3 are explained with examples from the UK in Section 4.2.2 and wellbeing values of health conditions based on UK data are shown in Section 4.2.3.

C. Aggregating values

C.1. Estimate the number of people who have the health condition in the country of interest. For example, the number of people affected by colorectal cancer in the UK is 41 265.

C.2. Multiply this number of people by the per person costs of health condition estimated in B.3. This will result in the annual cost of health of the population in the country of interest. For instance, this gives a total cost in terms of wellbeing as USD2.49 billion per year for colorectal cancer in the UK.

C.3. In this step, the results in C.2. are modified to derive costs related mainly to the food system by multiplying the cost of the health condition from C.2. by the probability that the health condition is due to agricultural and food system inputs estimated in A.2. This is the annual cost of the health condition due to agricultural and food system inputs of the total country population. For example, the final estimation of the cost of the agriculture and food system in terms of the wellbeing cost of colorectal cancer is USD1.55 billion per year in the UK.

These steps are considered in more detail within Section 4.3 where the food system-related costs of health in the UK are estimated.

4.2. Valuing health conditions using the wellbeing valuation approach

4.2.1. Data required for wellbeing valuation (A1 - A3)

The WV approach requires data on SWB and the outcomes being valued (in this case health conditions). In addition, it requires a rich set of demographic and socio-economic variables, so that confounding factors are controlled in the analysis, in order to better understand the impact of the outcome and money on SWB. In particular, the data requires at least the following variables: life satisfaction, the health condition being valued, income, age, gender, marital status, employment status, number of children/dependents, geographic region. The full set of desired control variables is set-out in Section 3.2.6.3.

These variables and data can be used in multivariate regression analysis to estimate the impacts of health conditions and income on life satisfaction. If additional data is available, then more sophisticated statistical approaches for measuring causal impact can also be employed. These

include methods such as the difference-in-difference method, natural experiments and instrumental variables methods. In the UK case study, an Instrumental Variable (VI) model is used to estimate the impact of income on life satisfaction.

There are three options for data sources to estimate the food system related costs of health. It is recommended to use option 1 or 2:

i. **Existing data sets:** using existing data from the relevant country that contains data on SWB and health, as well as the necessary control variables, is typically the least expensive option, but not all of the required variables may be available in the data. Possible sources of cross-country data include: the World Values Survey[66], which asks individuals from almost 100 different countries about their general health and their life satisfaction; the EBRD Life in Transition survey[67], which covers mainly transition countries from central and Eastern Europe; or the Gallup World Poll[68], which includes more than 160 countries. These datasets typically do not include detailed data on particular health conditions; therefore, as discussed in point iii. below, the link between a particular health condition and general health might have to be established using a different data set). Where data is not available or sufficient, there are the following two options.

ii. **Primary data collection through bespoke surveys:** the required data can be collected using the example survey instrument in Annex 3. This will need to be administered by organisations/individuals with a relevant background in statistics, in order to ensure that the sample is representative of the population in attempting to draw inferences, and ensuring that the data is collected in a robust way. The sample size will also need to be sufficient to capture enough people with the health conditions being valued. Most WV analysis is conducted on data sets with over 100 000 responses, although depending on the condition, smaller samples can be used. Whilst there is no hard and fast rule on sample sizes, typically, there should be at least 500-1 000 individuals in the data with the health conditions. Whilst this approach is more costly and time-consuming, it permits in-depth analysis of detailed health conditions and hence, more information about health costs can be gleaned from this approach.

iii. **Use of surveys from other countries.** In the case where data for the specific country is not available and primary data collection cannot be conducted, it is possible to derive and 'transfer' wellbeing values from other country data sources[69]. It will need to be caveated that such values are based on data collected in another country where the impact of health conditions on wellbeing could be notably different. These differences can be minimised (and hence the values made more transferable) if data comes from similar countries. It is important, therefore, to choose countries that are most similar in terms of economic, political and cultural background. Analysis of previous studies conducted using Australian

[66] http://www.worldvaluessurvey.org
[67] http://www.ebrd.com/what-we-do/economic-research-and-data/data/lits.html
[68] http://www.gallup.com/services/170945/world-poll.aspx
[69] For more information on the benefit transfer method, please see Ready, R., Navrud, S., Day, B. et al., 2004. Benefit Transfer in Europe: How Reliable are Transfers Between Countries? Environmental and Resource Economics, 29(1): 67-82.

data has found that results and values are similar for the UK and Australia[70]. It would be possible to 'transfer' the relationship between the specific health conditions and the general evaluation of health from a country with available data, and to use the relationship between general health and life satisfaction for these countries. It is also important to change the reference income to the median income of the country of interest to account for differences in income and purchasing power parity.

Data used in the UK case study on wellbeing valuation

In this study, the WV analysis conducted for the UK is based on four existing national data sets that include the required variables for WV. It is noted that, due to differences in the data sets, there is some variation in the number and types of control variables that were included in the analysis, but the core control variables in all models are covered as a very minimum. The data sets and control variables are discussed in more detail below.

It is important to note (as discussed above) that whilst all of the key drivers of life satisfaction are controlled in the models, it remains prudent to caveat this approach - as there may still be some confounding variables that are not measured and hence are omitted from the models, which may bias the estimates of the association between the health condition and life satisfaction. However, as discussed, this approach represents one of the best methods for estimating impacts using observational data (i.e. data where the outcome has not been randomly assigned) and is the main method used in social science research on wellbeing.

In order to estimate the impact of health conditions on life satisfaction (step B.1), the following UK data sets were used:

(i) Understanding Society (U Soc) is a longitudinal study of a large number of households in the UK. It incorporated and replaced the British Household Panel Survey (BHPS) in 2010. It follows the same individuals as the BHPS, plus about 60 000 new participants and it has added a new set of variables. It is a panel data set that surveys over 70 000 individuals each year on all aspects of people's lives. It is representative of England, Scotland, Wales and Northern Ireland and there are currently six waves of data available. The BHPS, and now Understanding Society, is the largest panel (longitudinal) data set of households and individuals in the UK.

This data set includes in-depth information on individuals' health conditions. The main data set includes questions on self-reported health, such as whether the individual reports having a particular health condition and their self-assessed level for general health (e.g. excellent, very good, poor). In addition to this, U Soc also contains a Nurses' Assessment module which offers further information on respondents' health conditions measured objectively through various tests. This data is available for the period 2010-2012 in U Soc. The Nurses' Assessment includes of blood sample screening, gene analysis and bio measures analysis. Further information about both

[70] Fujiwara, D., Vine, J. (2015). The Wellbeing Value of Tackling Homelessness: Identifying the Impact on Life Satisfaction Using the Journeys Home Dataset. Affinity Sutton, Family Mosaic and Midland Heart.

U Soc data sets can be found on the dedicated website[71]. The analysis of the U Soc data uses the following control variables:

- Income
- Age
- Gender
- Marital status
- Educational status
- Employment status
- Number of children and other dependents (including caring duties)
- Geographic region
- Ethnicity
- Housing status and satisfaction with housing
- Religious status
- Wave of survey

(ii) Health Survey for England (HSE) is a major monitoring tool looking at the nation's health. In particular, it includes questions about a large number of health conditions, as well as demographic factors. It is used by the Government to plan health services and make important policy decisions. Around 8 000 adults and 2 000 children take part in the survey each year. Information is collected through an interview, and if participants agree, a visit from a specially trained nurse. The surveys have been carried-out since 1991 in repeated cross-sections (i.e. the same individuals are not followed over each wave). More information about the HSE can be found on its website[72]. The analysis of the HSE data uses the following control variables:

- Age
- Gender
- Socio-economic status (as a proxy for income)
- Educational status
- Employment status
- Geographic region
- Ethnicity
- Smoker status
- Body Mass Index

(iii) Health Survey Northern Ireland (HSNI) is a Northern Ireland Department of Health survey that runs every year on a continuous basis. The survey covers a range of health topics that are important to the lives of people in Northern Ireland today. It has been running from April 2010 with separate modules for different policy areas included in different financial years**.** In 2014-15, 4 603 individuals answered the survey. Further information on HSNI can be found on its website[73]. The analysis of the HSNI data uses the following control variables:

- Age
- Socio-economic status (as a proxy for income)

[71] https://www.understandingsociety.ac.uk/
[72] http://content.digital.nhs.uk/healthsurveyengland
[73] https://www.health-ni.gov.uk/articles/health-survey-northern-ireland

- Educational status
- Employment status
- Number of children
- Marital status
- Housing status
- Smoker and drinker status (due to the condition being valued)
- Wave of survey

Using these three data sets, 13 health conditions were analysed in relation to agriculture or the wider food system impacts, as set out in Table 1. Each of these conditions are coded as "dummy" variables whereby a value of 1 indicates that a respondent has the condition, 0 otherwise[74]. These conditions were selected based on the quality of evidence linking them to agricultural activity, as well as to survey data availability.

Table 1. Health conditions covered in the UK case study

Health condition	Definitions in the data	Data set used
Coronary heart disease	Currently has coronary heart disease	U Soc (Waves 1-6)[75]
Heart attack	Had a heart attack the last year	U Soc (Waves 1-6)
Stroke	Had a stroke in the last year	U Soc (Waves 1-6)
Emphysema	Currently has emphysema	U Soc (Waves 1-6)
Chronic bronchitis	Currently has chronic bronchitis	U Soc (Waves 1-6)
Liver dysfunction	Currently has any kind of liver condition	U Soc (Waves 1-6)
Kidney dysfunction	Currently has kidney complaints	HSE (1993-2011)
Stomach dysfunction	Currently taking gastrointestinal medicine	U Soc (Waves 2-3) Linked to U Soc Nurse (Waves 2 & 3)
Colorectal cancer	Diagnosed in the last year with colorectal cancer	HSNI (2010-11 - 2014-15)
Obesity BMI 30-40	Currently has a BMI score of 30-40	U Soc (Waves 2-3) Linked to U Soc Nurse (Waves 2 & 3)
Severe Obesity: BMI 40+	Currently has a BMI score of 40 or above	U Soc (Waves 2-3) linked to U Soc Nurse (Waves 2 & 3)
Male reproductive disorders	Currently has a male reproductive system disorder	HSE (1993-2011)
Alzheimer's disease	Currently has senile dementia	HSE (2000-2001)

[74]Where possible within the data, we also ensure that respondents with long term health conditions are excluded from the analysis to ensure that we compare respondents with a health condition to a relevant control group.
[75] Understanding Society waves 1-6; 2009-2015.

Evidence on adaptation suggests that the costs of health conditions will change depending on how long the individual has been suffering from the condition since people tend to adapt to many types of health issues. In order to better understand this **duration** element, for the health conditions that are available in U Soc waves 1-6, the possibility of testing for adaptation was considered by also including a variable which stated that an individual had the condition in the last seven years and comparing it to the value found for currently having the condition. However, this variable was unsatisfactory as a test for the impact of adaptation as it could include people who no longer have the condition. An appropriate test for adaptation would compare the wellbeing values for people who have had the condition for some period of time (e.g. three years) and who still have the condition to those who have recently been diagnosed with the condition (e.g. in the last year). The survey instrument in Annex 3 has been designed to pick-up the duration dimension and to test for adaptation to health conditions.

The data assessed here also do not include a **severity** dimension, that is, how severe or serious the health condition might be. This will affect the size of the health costs. Questions on severity of the health condition are also included in the survey instrument.

In order to estimate the impact of income on life satisfaction (step B.2), the following UK data set was used:

(iv) **British Household Panel Survey** (BHPS) is a household survey ran from 1991-2009 by the University of Essex that follows the same people over time (Panel data). It surveyed 10 to 15 thousand people each year and there are 18 years (waves) of data. It includes (and is representative of) England, Scotland, Wales and Northern Ireland and consists of a large range of variables covering all aspects of people's lives, including life satisfaction and income. The BHPS was employed because it contains data on lottery winnings, which represent exogenous shocks in people's income. This allowed the derivation of more robust estimates of the causal effect of income on life satisfaction using an instrumental variable (IV) approach (see Annex 2).

4.2.2. Methodology for estimating wellbeing values of costs of health conditions (B.1 – B.3)

Annex 2 sets-out a detailed methodological process for estimating the wellbeing costs of health conditions. This covers steps B.1 to B.3 from section 4.1. With Annex 2 describing the technical details, here a more accessible, non-technical summary of the approach is provided. This section should be read in conjunction with Annex 2 by anyone wishing to use or evaluate this methodology.

4.2.2.1. Estimating the impact of health conditions on life satisfaction (B.1)

The most common way to assess impacts on life satisfaction is through regression analysis. **Regression analysis** is a statistical process for estimating relationships among variables and is used throughout policy evaluation to identify relationships using observational data. In the UK case study, it is necessary to regress life satisfaction on the controls described in section 4.2.1 and

a dummy variable which takes the value of 1 if the respondent in the survey data has the health condition and 0 if they do not have the condition. By including the controls, the impact of these factors on life satisfaction is excluded and therefore results in more confidence in the estimated association between life satisfaction and the health condition. In effect, levels of life satisfaction are compared for people with and without the health condition after accounting for the impacts of control factors, such as age and gender. The coefficient on health conditions in the regression model provides an estimate of the impact of the health condition on life satisfaction.

Regression models should be tested using a number of diagnostic tests, including variance inflation factors (VIFs) to test for multicollinearity, tests for heteroscedasticity[76] and for the normality of the distribution of the residuals. These models provide the best estimates of the impact of health conditions on life satisfaction given this type of data.

It should be noted that in the HSE data, there is no measure of life satisfaction, so a two-step (indirect) procedure was employed, as set-out in FAO, 2014[77], whereby the impact of the general health condition was first measured on a 1-5 Likert scale (1 = very good to 5 = very bad) (general health is included in the HSE data set), and then, the product of this estimate and the impact of general health on life satisfaction are taken (estimated in the U Soc data)[78], which provides an estimate of the impact of health conditions in the HSE data set on life satisfaction. This is under the assumption that these health conditions only impact on life satisfaction through their impact on general health.

Recalling equation (1) here: $$MRS = -\frac{\beta_Q}{\beta_M}$$

This process derives estimates of β_Q (the impact of the issue – here, health conditions – on life satisfaction). As stated above, β_Q is estimated using the regression coefficient for health conditions.

4.2.2.2. Estimating the impact of income on life satisfaction (B.2)

A common approach in the WV literature has been to estimate the impact of income on life satisfaction (β_M from equation (1)) within the same regression model as the health condition. This is a viable approach and if undertaken it would be a case of deriving both β_Q and β_M from the same model, which would be the coefficients on health conditions (β_Q) and on income (β_M).

However, as stated above, where more robust methods are possible they should be used. In this UK case study, lottery wins are used in an instrumental variable (IV) approach. Lottery wins are exogenous (randomly assigned) and hence, allow determining the causal effect of income on life satisfaction. The details of the IV approach are set-out in Annex 2.

[76] Multicollinearity is where two independent variables in a multiple regression model are highly correlated. Heteroscedasticity is where the variance of an independent variable is unequal across the range of values for the dependent variable.
[77] FAO, 2014. Food Wastage Footprint: Full-Cost Accounting. Final Report (http://www.fao.org/3/a-i3991e.pdf).
[78] Although it is measured on the same five-point scale, the general health question is worded slightly differently in HSE and U Soc.

If data on exogenous changes in income are available, they should be used in methods like IV or natural experiments. Other possibilities for exogenous income shocks would include for example, unexpected inheritances or unexpected tax rebates. The example survey instrument contains questions on lottery wins for this purpose.

4.2.2.3. Estimating the monetary costs of the health conditions (B.3)

The processes set-out above demonstrate how β_Q and β_M can be estimated. Any health condition that is statistically significant at at least the 10% level can be valued using equation (1):

(1) $$MRS = -\frac{\beta_Q}{\beta_M}$$

In the UK case study, a slightly more complex methodology is applied, whereby non-linear relationship between income and life satisfaction (higher income creates more life satisfaction but at a smaller rate as people get richer) is accounted for. This is achieved by using logarithmic functional form for the income variable. This is set-out fully in Annex 2.

4.2.3. UK case study results

4.2.3.1. Estimating the non-financial costs of health conditions using wellbeing valuation

Table 2 sets out the coefficients on the health outcome ("Association with Life Satisfaction") and the associated WV of the health outcome for the 13 health conditions which are analysed in this study. The coefficients in the column entitled 'Estimated relationship with life satisfaction' represent the change in life satisfaction on a scale of 1-7 associated with having the health condition. For example, people with coronary heart disease on average have a life satisfaction score of 0.469 points lower (on the seven-point scale) than those without coronary heart disease, once a range of control variables are taken into account. The values in the columns entitled 'Wellbeing valuation of non-financial health cost' convert the coefficients into a monetary amount based on equation 1. The values, which are presented in both pounds sterling and US dollars, represent the average non-financial cost of each health condition per person per year in the analysed sample.

Eleven of the 13 health variables produced statistically significant associations with life satisfaction; Alzheimer's disease was found to be particularly insignificant, whilst male reproductive disorders were very close to the 10% statistical significance threshold. Any outcomes that are not statistically significant are not valued as the evidence would indicate that there is no effect on life satisfaction within this sample[79]. However, it should be noted that this could be for a number of reasons, including a small number of individuals with a particular condition in the sample and the possibility that the disease itself prevents the respondent from fully engaging with

[79] A value to "male reproductive disorders" is applied, as the coefficient on it is close being significant at the 10% level (p value = 0.156 which indicates that it is significant at the 16% level). This means that the quality of evidence on male reproductive disorders is lower than the other conditions which are assigned a monetary value.

the survey questions. One of the lessons from this example is therefore that it may not be possible to use the WV approach in cases where certain conditions, related to mental health and cognition, affect the reliability of survey responses [80]. Naturally, however, these issues would also provide a constraint on other traditional methods of health valuation such as the QALY.

Table 2 Well-being valuation results for selected health conditions in the UK

Health condition	Estimated relationship with life satisfaction (A * next to the number indicates statistical significance at the 10% level)	Well-being Valuation of non-financial health cost (GBP)	Well-being Valuation of non-financial health cost (USD)
Coronary heart disease	-0.469*	-19 954	-24 943
Heart attack	-0.449*	-22 779	-28 474
Stroke	-0.528*	-24 939	-31 174
Emphysema	-0.727*	-33 271	-41 588
Chronic bronchitis	-0.636*	-26 671	-33 339
Liver dysfunction	-0.544*	-23 323	-29 154
Kidney dysfunction	-0.201*	-6 029	-7 536
Stomach dysfunction	-0.29*	-9 052	-11 315
Colorectal cancer	-1.054*	-48 218	-60 272
Obesity: BMI 30-40	-0.135*	-3 930	-4 913
Severe obesity: BMI 40+	-0.34*	-10 870	-13 587
Male reproductive disorders	-0.135	-3 931	-4 914
Alzheimer's disease	-0.219	-	-

Notes on the table: (i) Association with life satisfaction converted to monetary amount estimated using equation (10) from Annex 2 with average UK household income set at £30 000 (USD37 500); (ii) GBP converted into USD based on market rate at 13:20 GMT 24.03.2017 £1 = $1.25; (iii) All models used heteroscedasticity-robust standard errors; (iv) The full results of the regression analyses can be found in Annex 4.

For all of the regression analyses presented in this study, a number of validity tests were conducted. In general, the R^2 values were in line with the wellbeing literature (around 10-20%), which means that 10-20% of the variation in life satisfaction is explained by the variables in the model.

[80] Note that it has previously been possible to obtain robust wellbeing values for mental health conditions such as depression, anxiety and PTSD (for example, see http://www.hact.org.uk/value-calculator and https://asvb.com.au/how-asvb-can-help/what-is-the-asvb/).

Multicollinearity as tested through the variance inflation factor (VIF) was not found to be a problem in the models (VIFs for most variables were around 1, which represents no inflation of standard errors). Residuals from the models looked normally distributed.

It is important to note that these results represent the costs of these health conditions to individuals, irrespective of their causation. That is, the health conditions will be due to many different factors, of which agricultural issues will be one reason. To understand the amount of these health costs that is due to agriculture or the wider food system, there is a need to derive a proportion of these costs, based on the link between the food system and health conditions.

4.2.3.2. Validation of results

Whilst it is not possible to assess the values in an absolute or objective sense because there is no 'true' cost of health conditions to begin with, their validity and plausibility of the results can be assessed through relative assessments.

The first type of relative assessment that can be made is an **internal** (or **within study**) comparison, by assessing whether the costs of the 12 health conditions considered make sense in relative terms: do more severe health conditions have a higher cost? Generally speaking, the costs tend to increase with seriousness of the condition: for example, heart disease and stroke have a higher cost than obesity. It is also found that related conditions have similar costs. For instance, coronary heart disease and heart attack have similar costs. And severe obesity has a higher cost to individuals than obesity. Cancer and lung related diseases tend to have the highest costs.

The second type of relative assessment is an **external** (or **between study**) comparison, whereby results of this study are compared to results from other studies. Due to the difficulties of valuing health outcomes (which is one of the rationales for WV in health), there are not really any studies with which this study monetary value results can be directly compared. However, in Table 3, the literature on QALYs is assessed as an external reference point for the WV results.

Average age-adjusted QALY values representative for the population of England have been calculated in the literature for a number of health conditions including coronary heart disease, heart attack, stroke and obesity (defined as BMI $\geq$ 30). Stafford *et al*. (2012)[81] estimate a regression model to isolate the impact of each condition on the QALY score (see Association of health condition with QALY). These results should be used in the comparison to this study results.

[81] Stafford et al., 2012. Socio-Economic Differences in the Health-Related Quality of Life, Eur J Public Health (2012) 22 (3): 301-305. This study is based on data from Health Survey for England 2003 and 2006.

Table 3. QALYs reported in the literature for selected health conditions in the UK

	Average age-adjusted QALY	Association of health condition with QALY	QALY value in Pounds (based on £ 60 000 threshold)
Coronary heart disease	0.711	-0.090	-5 400
Heart attack	0.636	-0.060	-3 600
Stroke	0.680	-0.101	-6 060
Obesity BMI 30+	0.836	-0.033	-1 980

Remarks on Table 3: Regression coefficients in column 3: association of health condition with QALY control for sex, age group, ethnicity, educational attainment and socioeconomic position. All coefficients statistically significant at 0.1% level.

The relative ranking of these conditions based on QALYs aligns reasonably well with the estimates from wellbeing valuation. Heart-related conditions all appear more severe (as indicated by lower regression coefficients) than obesity, and stroke has a higher negative effect than heart problems, all as per the WV results.

The wellbeing values estimated in Table 2 are consistently higher than the implicit values estimated through the QALY for these health conditions. One reason for this is that the WV approach picks up more of the impact of the health condition. The QALY estimates are, for one, restricted by the narrowness of the EQ-5D health descriptive system, where impacts such as self-image, confidence and energy may not be taken into account. Also, the effect of the burden of the disease on family members is picked up in WV (to the extent that the individual cares about the impact on family members and incorporates this into their own wellbeing) but is not in the QALY score. Some of the values based on the QALY threshold are also questionable in an intuitive sense. For example, the cost of a heart attack (£3 600) seems implausibly low. One would expect people to be willing to pay more to avoid such a serious health incident that has high risk of death. The wellbeing cost at £22 779 feels more plausible in this respect as it represents a significant proportion of one's annual salary in this sample.

4.3. Estimating the agriculture and wider food system-related costs of health

4.3.1. Aggregating costs of health conditions (C.1 – C.3)

In this final section, steps C.1 to C.3 are implemented in order to estimate the total level of agriculture and wider food system-related costs of health. In order to estimate the number of people in a country, or any other geographic area of interest who have the health conditions, there are two approaches:

- National public health authorities tend to publish the numbers of people that have health conditions on a yearly basis. For instance, the number of people that had a heart attack in the UK in 2010 was 146 000[82].

[82] http://www.cardiacmatters.co.uk/facts-figures-heart-disease-uk.html

- This data can also be collected from the surveys that one could self-administer, providing that they are adapted to be representative of the wider population. Here the population-weighted percentage of people who have the condition would be estimated form the survey and applied to the overall total population of interest (see Annex 5).

As an example, the calculation is set-out for heart attacks. Based on the current evidence available, Chapter 2 suggests a preliminary estimate that the food system may be responsible for around 80% for heart attack cases. Using this information, as well as the other information derived in this report, the yearly cost to individuals in the UK of having a heart attack due to agriculture and the wider food system is as follows:

$$0.80 \times 146\,000 \times (-\$28\,474) = -\$3.33 \text{ billion}$$

Table 4 sets-out the annual food system-related costs for the UK for all 12 health conditions valued in this case study. Alzheimer's disease is not included because no significant impact was found on subjective wellbeing.

Table 4. Annual agriculture and wider food system-related costs of health for the UK

Health condition	Probability of causation by the food system[83]	Wellbeing valuation of health cost per person per year (USD)	Number of people affected by the health condition in UK annually	Total annual agriculture and wider food system-related costs of health per person per year (Billion USD)
Coronary heart disease	80%	-24 943	2 300 000	-45.89
Heart attack	80%	-28 474	146 000	-3.33
Stroke	50%	-31 174	152 000	-2.37
Emphysema	15%	-41 588	2 449 141	-15.28
Chronic bronchitis	15%	-33 339	4 192 867	-20.97
Liver Dysfunction	40%	-29 154	2 000 000	-23.32
Kidney Dysfunction	30%	-7 536	3 000 000	-6.78
Stomach Dysfunction	70%	-11 315	137 504	-1.09
Colorectal Cancer	63%	-60 272	41 265	-1.55
Obesity - BMI 30-40	100%	-4 913	10 362 387	-50.91
Severe Obesity - BMI 40+	100%	-13 587	2 854 943	-38.79
Male reproductive disorders	55%	-4 914	2 354 544	-6.31

[83] Rough estimates accounting for diet, food, agri-environment and occupational risk factors; these estimates require improvement, once a robust attribution methodology for causation is established.

An interesting point to note in
Table **4** is that the total annual costs depend on three key factors:

- the non-financial cost of the health condition at the individual level;
- the level of the health condition that can be attributed to agriculture and wider the food system; and
- the number of people suffering from the health condition. Whilst obesity has the lowest level of cost to individuals (USD4 913), it has the highest total cost in the UK, since there is a high link with the food system and since many people in the UK are obese.

4.3.2. Examples of financial costs associated with health conditions

This approach to estimating the agriculture and wider food system-related costs of health focused on non-financial cost of decreased wellbeing to the individuals. These estimates, aggregated across the UK population, are reported in Table 4. For a complete picture of the costs to the economy as a whole, however, financial costs associated with health conditions should also be considered, as explained in detail in section 3.1, including:

- any financial costs to the individual in terms of lost income and healthcare expenses;
- the cost to the government of preventing, treating and managing the health conditions;
- the cost to businesses in terms of lost productivity.

Several estimates of the above cost categories are available from the literature. For instance, the National Health Service (NHS) expenditure on treating cardiovascular disease was estimated at USD18 billion in 2006[84]. In another example, the NHS estimated that the cost to the UK economy in 2007 of individuals being overweight or obese was £15.8 billion[85], and this included £4.2 billion of NHS costs. In yet another study, the overall cost to the UK economy associated with stroke in 2005 was estimated at £8.9 billion a year[86], with direct care costs accounting for approximately 49% of this figure, informal care costs 27% and indirect costs (which included the cost of lost income and the cost of benefit payments) 24%.

The stroke example provides the most comprehensive estimate of the other costs category, according to the breakdown provided above. To aggregate this estimate with the non-financial cost of stroke to individual wellbeing reported in Table 4, the following steps are required:

- adjust the estimate to common year prices (here, 2016)[87];
- adjust the estimate to common currency (here, US dollars)[88];
- scale the estimate to reflect the probability of causation by the food system (based on Table 4, the probability that stroke has been caused by the food system is estimated to 50%).

[84] Luengo-Fernandez R, Leal J, Gray A et al., 2006. Cost of Cardiovascular Diseases in the United Kingdom. Heart 92: 1384–9

[85] Public Health England (2017). Obesity and Health. Retrieved 18th April 2017 from https://www.noo.org.uk/NOO_about_obesity/obesity_and_health

[86] Saka ö, McGuire A, Wolfe C, 2009, Cost of Stroke in the United Kingdom, Age and Ageing 2009; 38: 27–32

[87] CPI index ratio between 2005 and 2016 = 1.29. Source: UK Office for National Statistics

[88] £1=USD1.25, market exchange rate at 13:20 GMT 24.03.2017.

Using all this information, the other annual costs to the UK society associated with stroke due to agriculture and the wider food system can be calculated as follows (with references to steps i-iii):

$$(-£8.9 \text{ billion}) \times 1.29\ (i) \times 1.25\ (ii) \times 0.50(iii) = -\$7.18 \text{ billion}$$

Finally, Table 5 adds the wellbeing and financial costs together to provide an example of aggregated financial and non-financial costs for a specific condition.

Table 5. Aggregated wellbeing and financial costs for stroke attributed to the food system

Wellbeing cost attributed to food system (billion USD/cap/year)	-2.37
Other costs (healthcare and loss of income) attributed to the food system (billion USD/year)	-7.18
Aggregated wellbeing and other costs attributed to food system (billion USD/year)	-9.55

Note: to these costs borne by individuals, one may add costs to government and business.

4.4. Examples of ways to apply MARCH

In this section, two possible applications of MARCH are described, using the results calculated in the UK Case Study in hypothetical examples[89]. The first example shows how governments can use MARCH to evaluate policies which influence the food system.

Box 3. How governments can use the wellbeing valuations in cost-benefit analysis

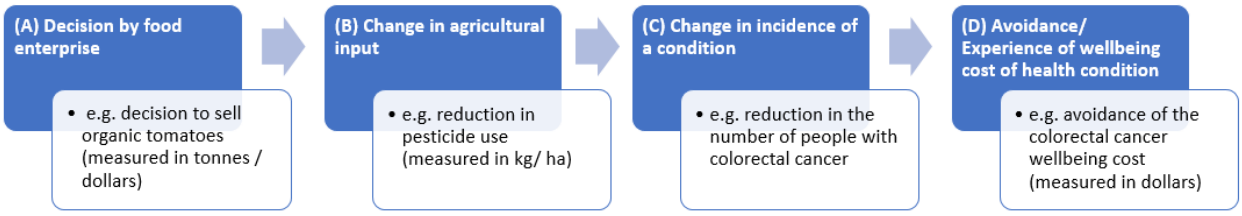
In the face of growing concerns about the health risks of pesticide use, the UK government is considering regulations which restrict the allowed use of synthetic fertilizers. (Future) Research finds that reducing fertilizer use by an x amount would reduce the number of people who have colorectal cancer in the UK by 6 514 per year, if the policy took effect in 2017. This number of avoided colorectal cancer patients/cases can be multiplied by the wellbeing costs of –USD 60272 to estimate an overall wellbeing value of the annual benefits of the policy of USD 0.39 billion. Further benefits to individuals in terms of avoided lost income or healthcare expenses, benefits to businesses through avoided lost productivity, and benefits to governments through reduced healthcare expenditure could also be added to this estimate. Finally, this can be compared to the costs of the policy in terms of lost agricultural production in order to conduct a cost-benefit analysis of the proposed policy.

Second, the estimates of the agricultural and food system-related costs of health can be used by food enterprises to demonstrate the true unit costs or benefits of their activities. This requires the additional step of estimating the link between the enterprises' activity and agricultural or food system inputs.

[89] Note that more research is required to determine the full list of possible applications of MARCH.

In Figure 4, the light blue arrows show the links required to apply MARCH to calculate the unit cost of a food enterprises' activity, the blue boxes show the stages in the causal chain through which a food enterprise impacts on the incidence of health conditions, and the white boxes relate these stages in the causal chain to the example in Box 4 of a UK food enterprise's decision to only sell organic tomatoes.

Figure 4. Linking food enterprise activity to MARCH



Box 4. How food enterprises can use the wellbeing valuations to estimate the cost or benefit of their activities to health

A UK-based agricultural enterprise (Supermarket A) sells 5 000 tonnes of tomatoes per year, which constitutes about 0.07% of the total amount of agricultural crops produced in the UK. By influencing its suppliers to produce organic tomatoes, this reduces the amount of fertilizers and pesticides used at the supplier farms. (Future) Research finds that reducing input use, especially around drinking water sources, throughout the UK would reduce the number of people who have colorectal cancer in the UK by 7 200 per year. Using Supermarket A's share of UK's total value of agricultural crops, one can estimate the number of colorectal cancer patients/cases avoided because of Supermarket A's supplier's reduced pesticide use as $(0.07\%) \times 7\,200 = 5$. This can be further multiplied by the wellbeing costs of –USD 60 272 to estimate an overall wellbeing value of the annual benefits of Supermarket A selling organic tomatoes; USD 301360, or USD60.27 per tonne of tomatoes sold by Supermarket A per year. Ideally, several health conditions influenced by agricultural inputs could be accounted for, should robust causation ratios be established for a full-cost accounting of food systems impact on health.

4.5. Interpretation of health costs results

The values estimated in Table 2 and Table 4 require careful interpretation. As discussed, these values represent non-financial costs of these health conditions for individuals. It is important to make clear that the costs are not related to any financial outlay or loss of income related to the health conditions. They are the non-financial costs to the individual's quality of life. In this respect, they are similar measures to the QALY. Financial impacts on individuals, such as loss of income due to worklessness as a result of the health condition, and impacts on businesses and government would be additional to the non-financial costs estimated here and would have to be estimated separately. An example of such calculation is provided in section 4.3.1 above.

The values represent averages across a number of dimensions. They are the costs of the health condition for people in the UK at the average level of severity and duration of the condition. People who respond to the health questions will be living with differing levels of severity of the condition and also the condition will have started at different points: for some the onset of the condition will have been very recent, whilst for others they may have been living with the condition for a long time. The duration issue is an important one as people are generally able to adapt to most types of health conditions, such that the negative impact on their wellbeing falls over time. Since data is taken from all of the people in the sample that suffer from the condition, the costs will be associated with an overall average level of severity and duration.

This is the case for any type of valuation methodology and outcome, unless further data on severity and duration is collected within the survey. Indeed, in the WV approach, if data on severity and duration were collected, it would be possible to estimate costs that differ by severity and how long the individual has lived with the health condition. It is also possible to estimate costs of health conditions differentiated by the characteristics of the person suffering from the condition (e.g. by different age groups or socio-economic class), as long as background data on these characteristics is also collected.

Care must also be taken when using these costs in cost-benefit analysis and other forms of policy evaluation, so as not to double-count costs where health conditions are related chronologically (i.e. when one health condition increases the risk or likelihood of another condition). For example, the costs for obesity should not be added to the costs of heart disease. This is because it would be reasonable to assume that the impact of obesity on wellbeing would include the individual's understanding that obesity increases risk of heart related problems and so the increased risk of heart problems is internalised to some extent in the impact and cost of obesity. There are questions regarding the extent to which individuals with obesity (and any health condition) fully understand all of the implications and future health risks.

If knowledge were poor then there would be reason to add the costs of the health conditions together. However, it is assumed that people are generally well informed about the implications of their health condition and therefore, assume that the costs of health conditions incorporate costs of future related health issues. Hence, it is not recommended that the costs in Table 2 and Table 4 be added together, with a view to avoid double-counting. In these cases, it is necessary to consider whether it is more suitable to measure the cost of the impact of the food system on the risk factor (e.g. being obese) or the condition (e.g. heart disease). This in part depends on the specific policy intervention which is considered.

Care must also be given to the conditions that are likely to occur simultaneously. For instance, the value attributed to "chronic bronchitis" may also partially include the impact of "emphysema" and any other condition to the extent that they occur simultaneously. Therefore, clinical guidance combined with future analysis of appropriately collected data can control for the other health conditions which may occur at the same time as the condition that MARCH is applied to. Controlling for them in step C.1 of MARCH, would adjust for the impact of the other conditions on wellbeing, while estimating the impact of the specific condition is of interest for policy-makers. For instance, to estimate the full wellbeing cost of chronic bronchitis, one would also control the

impact of “emphysema” and any other correlated condition. In this example, this would then better account for the health cost of “chronic bronchitis”.

4.6. Caveats

One of the key issues in WV is the correct estimation of the statistical models that underlie the value calculation. The values should be estimated based on robust and unbiased estimates of the impact of health conditions and income on wellbeing. In order to robustly estimate the impact of income, an IV model with lottery wins from Fujiwara and Dolan (2016) is used in this study.

The health models are estimated using multivariate regression analysis, which relies on the analyst including (controlling for) confounding factors, that is, factors that influence both the likelihood of suffering a health condition and SWB). In this study models, the main determinants of SWB are controlled, as is standard in the wellbeing literature, but some of these factors will be unobserved or unobservable in the data; for example, it is hard to measure and control for hereditary characteristics.

Whilst the statistical approach and models used are in line with best-practice academic research in this area, it should be recognized that there is always a potential for bias in studies of this nature which use observational (i.e. non-randomised) data. Where this is the case, estimates of the costs of health conditions may also be biased to some extent. This is a caveat that needs to be born in mind as the results of these types of studies are being used and interpreted, though these issues are pertinent and inherent to most forms of policy evaluation, because very few studies are able to use random assignment.

5. Conclusions and recommendations

5.1. Validity of the Subjective Wellbeing Valuation method

This study has developed a methodology for estimating the agriculture and the wider food system-related costs of health (MARCH), which was applied to the UK to estimate costs of health for individuals for twelve health conditions that are related to food system issues, including: coronary heart disease, heart attack or myocardial infarction, stroke, emphysema, chronic bronchitis, liver dysfunction, kidney dysfunction, stomach dysfunction, colorectal cancer, obesity (BMI 30-40), severe obesity (BMI 40+) and male reproductive disorders.

The costs of these health conditions were estimated to the individual’s quality of life, measured as the cost per annum per individual. This is similar to the evaluation undertaken in the QALY approach. Then, these costs were multiplied by the estimated probability of causation by the food system, and an estimate of the number of people in the UK that have the conditions. This results in an estimate of the annual agriculture and wider food system-related costs of health for the UK for these 12 health conditions.

Internal and external validity checks of the results demonstrated that the WV results were plausible in the context of other valuation studies, lending support to the WV method.

The WV method is a relatively new method for valuing non-market outcomes, such as health. It has numerous advantages over traditional health valuation methods and is also able to derive monetary values of health outcomes:

- First, it overcomes the focussing illusion by utilizing survey responses of people who experience health problems, without ever asking people to value them.
- Second, WV can derive monetary values of health conditions, which other valuation methods cannot do.
- Third, WV allows for the health condition to impact on SWB through any channel, unlike preference methods which have to define health as a pre-defined set of outcomes.
- Fourth, WV can capture the impacts of feeling like a burden on others as a result of having a health condition.

The evidence here suggests that the WV approach is a viable method for valuing food system-related health costs if good quality data on SWB and health conditions are available.

5.2 The way forward

There are multiple avenues for future research and application of the WV method in the health and food systems field. Some main areas for future research are suggested below, to complete MARCH in order to offer a meaningful full-cost accounting metric for health.

i. Complete and strengthen the food system and health data sets. Develop a wider and bigger set of food system-related health costs using current data sets from the UK, beyond the 12 health conditions considered in this study. More importantly, establish a **methodology for attributing causation ratios** of the agricultural or wider food system to health, based on available epidemiological, toxicological and clinical evidence. The examples used in this study are based on a desk study of scientific literature (though not always consistent), and there is need to develop a methodology for aggregating the causation ratios from diets, food, agro-environmental and occupational quality.

ii. Extend the current MARCH methodology to allow for the **aggregation of the health costs** of different conditions, in order to be able to find the overall effect of a given food-system risk factor on health (by adding the effects of a single risk factor across different health conditions), and possibly also the total effect of the entire food system (by adding the effects across different risk factors). To do this, the causation probabilities linking health conditions to the food system would have to account for the interdependencies between the conditions. Moreover, the wellbeing value of all correlated health conditions would have to be estimated jointly (in one regression, so that each coefficient captures the effect of a single health condition while holding everything else constant).

iii. As an alternative to the above approach, establish a causation ratio between the agricultural or wider food system and a **single (subjective) general health metric**. This would avoid the need for aggregating health costs of different conditions described in (ii), and therefore simplify the wellbeing valuation step outlined in this report. However, more research is required to consider the relative effectiveness of linking the agricultural and wider food

system to a single subjectively measured general health question, or to multiple objectively measured health conditions (as conducted in this paper).

iv. Further develop MARCH **Survey Instrument** to collect primary data on health conditions and Subjective Wellbeing, through very specific surveys in terms of the health conditions and the severity and duration in these surveys. If administered to large samples, this will allow the development of many new health cost-estimates in this area. The survey instrument in Annex 3 only represents an example survey; more work is required to determine a full list of medical conditions that are to be included in the survey.

v. Build on this study to demonstrate how MARCH can be used by policy-makers and enterprises in **cost- benefit analysis**, to fully account for the impacts of agriculture and the wider food system on individuals (wellbeing, income and private healthcare costs), businesses (productivity costs) and government (public healthcare costs and lost tax receipts). Section 4.3.1 illustrates how impacts can be aggregated across these stakeholders in the case of obesity. For full-cost accounting purposes, unit costs health impacts need to be established for specific diets or agricultural practices (e.g. organic agriculture).

Whilst points ii to v are all "doable", establishing a methodology for attributing disease causation to the food and agricultural system is a priority requirement. This will necessitate a comprehensive review of epidemiological, toxicological and clinical evidence and convening expert panels (using for instance the Delphi method) to make decisions on the strength of the data. The IPCC[90] and the Endocrine Society study[91] on EDCs have managed uncertainties by applying the weight-of-evidence characterization for probability of causation. A similar approach could be developed for informed decision-making on food systems and health.

5.3 End notes

The landmark study of John Snow in 1854 gathered evidence in support of waterborne transmission of a suspected living organism contaminating drinking water by proximity to sewage. After 30 years, Robert Kotch isolated *Vibrio cholerae* and formulated the approach that worked well within the specificity of unique germ-disease link. A hundred years later, the mechanism of action of the cholera toxin was established. The original observation of Snow sufficed to take appropriate action (closing the pump) without waiting until a mechanism of action has been demonstrated, thereby sacrificing the lives of thousands of people. Correlation and sketchy evidence in the health sector are enough to arouse the amygdala, triggering a precautionary approach. While this precautionary principle is embedded in human beings' construct (i.e.

[90] Intergovernmental Panel on Climate Change, 2015. Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties.
[91] Trasande et al., 2015. Estimating Burden and Disease Costs of Exposure to Endocrine-Disrupting Chemicals in the European Union. J. Clin. Endocrinol. Metab. 2015, April; 100(4).

individual health), it does not apply to group behavior towards a common good (i.e. public health), and is often confounded by vested interests and misleading information.

In fact, experience has shown that it takes at least half a century for evidence to sufficiently build-up and trigger mitigating action to address food system-related health impacts, from which long-lasting effects continue today. A few examples illustrate this trend:

- banning highly hazardous pesticides, such as DDT: concerns about DDT started in the manufacturing place in the 30s (due to affected workers' health) but DDT was banned for agricultural use only in 2001;
- moderated use of food additives, such as sugar: health effects of sugar were denunciated in the 60s, and while the debate on <10% energy intake continues today, the WHO is urging countries to consider introducing sugary drink tax to curb soaring global obesity rate;
- climate change anxiety is dominated by scientific probabilities (or reticence) and much-less-certain science of human response in the face of yield declines and droughts.

Our uncertainty about uncertainty (and complexity) should not stop us from acting now by adopting a public health prevention approach at every step of the food system.

"All scientific work is incomplete – whether it be observational or experimental. All scientific work is liable to be upset or modified by advancing knowledge. That does not confer upon us a freedom to ignore the knowledge we already have, or to postpone the action that it appears to demand at a given time." (Sir Austin Bradford Hill).

Annex 1 - Risk factor, exposure variable and disease outcomes linked to the food and agriculture system

The table below aggregates health risks, including both mortality and burden of disease, according to exposure routes that are to some extent related to food and agriculture, by adapting the WHO Global Health Risks (2009) that includes the following categories: (i) childhood and maternal under-nutrition; (ii) other nutrition-related risk factors and physical activity; (iii) sexual and reproductive health; (iv) addictive substances; (v) environmental risks; (vi) occupational risks; and (vii) other selected risks (e.g. unsafe health care). It expands on categories (i), (ii), (v) and (vi), where WHO declares having explicitly avoided covering broad risk factors such as diets.

Risk factor, exposure variable and disease outcomes linked to the food system

Risk factor	Exposure variable	Disease outcome	Food system exposure
Childhood and maternal under-nutrition			
Underweight	Children below -1SD weight-for-age and maternal body mass index below 20 kg/m2	Mortality and acute morbidity from diarrhoeal diseases, malaria, measles, pneumonia for children under 5 and perinatal conditions from maternal underweight	Malnutrition due to food access issues
Iron deficiency	Haemoglobin concentration	Anaemia and cognitive impairment, maternal mortality	Applies also to nourished individuals consuming industrially-grown crops with reduced Fe and Ca and phenolic compounds
Vitamin A deficiency	Low serum retinol (less 0.7umol) among children aged 0-4 years	Mortality due to diarrhoeal diseases, measles, prematurity and low birth weight, neonatal infections and morbidity	Applies also to nourished individuals consuming: - Irradiated crops that destroy Vitamins A and K and reduce Vitamins C B1 and E - N-fertilized crops - refined cereals (i.e. white flour)
Other nutrition-related risk factors			
High blood pressure	Systolic blood pressure mean of 115 mmHg and SD of 6 mmHg	Stroke, hypertensive disease and other cardio-vascular diseases	Unhealthy diets
High cholesterol	Mean blood cholesterol of 3.8 mmol/l and standard deviation of 0.6 mmol/l	Ischaemic heart disease (IHD) and ischaemic stroke	Grain-fed livestock products (less Omega-3 and more Omega-6)
Overweight and obesity	Mean BMI of 21 kg/m2 and standard deviation of 1 kg/m2	IHD, ischaemic stroke, hypertensive disease, diabetes, osteoarthritis, colon and uterine cancers, post-menopausal breast cancer	Unhealthy diets
High blood glucose	Fasting plasma glucose mean of 4.9 mmol/l and standard deviation of 0.3 mmol/l (people over 30 years)	- Diabetes mellitus, IHD, cerebrovascular disease - Attention deficiency and hyper-activity in children	Industrially-processed foods, especially refined cereals and sugar (including soft drinks and other sweetened beverages)

Low fruit and vegetable consumption	<600 g intake per day for adults	IHD, stroke and cancers of: colon, rectum, gastric, lung, oesophageal	Unhealthy diets
Food-borne infections	31 foodborne diseases agents, including: 11 diarrhoeal agents, 7 invasive infectious agents, 10 helminthes and 3 chemicals (according to WHO Foodborne Disease Burden Epidemiology Reference Group)	32 diseases (e.g. non-typhoidal Salmonella enetrica, enteropathogenic Escherichia coli)	Unsafe livestock and food management
Antibiotic resistance	Meat, dairy or eggs with: - Methicillin-resistant strains of Staphylococcus aurus - 3rd generation cephalosporin-resistant E. coli - 3rd generation cephalosporin-resistant K. pneumonia - Non-typhoidal Salmonella enterica serotype Typhimumium	Respiratory, blood stream, skin, bone and urinary tract infections, diarrhoea, gastroenteritis	Preventive use of antimicrobials and growth promoters in livestock and aquaculture production; genetically-modified crops
Pesticides	Maximum residue limits in food and dissipation half-lives for harvested crops include 875 pesticides that have human health impacts	- 17 cancer types examined by American Institute for Cancer Research - Non-cancer toxicity effects	- Long-term low level exposure to food crops treated with pesticides: glyphosate and phenoxy herbicides and carbamate, organophosphorus, lindane and organochlorine insecticides - Endosulphans used in salmon farming
Environmental risks			
Unsafe drinking water		Diarrhoeal diseases	Fertilizers-related nitrates and pesticide leaching: - Cancer (ovarian/colon/bowel) - Blue baby Syndrome - Diabetes in children
Air pollution	Mean PM2.5 of 7.5 ug/m3 and PM10 of 15 ug/m3	Respiratory infections, lung cancer and selected cardio-pulmonary diseases	Pesticides drifts from aircraft spraying and intensive factory farms: - Particulate Matter (PM)-related respiratory diseases - Human variants of animal illnesses
Endocrine-Disrupting	800 chemicals suspected by WHO/UNEP. 194 out	- IQ loss and associated intellectual disability,	Hundreds agricultural pesticides and chemical

Chemicals (EDCs): multiple exposure	of 432 candidate substances listed by the EU with evidence of endocrine-disrupting properties	autism, attention deficiency and hyperactivity - Childhood and adult obesity - Adult diabetes - Cryptorchidism, male infertility and mortality associated with reduced testosterone	agents found in water, air, food and kitchenware: - Atrazine in water - Organophosphates in animal fat (fish) - Pyrethroids, dithiocarbamate fungicides, etc. - Artificial food colorants
Global climate change		Flood injury, malaria, under-nutrition and associated disease	Agriculture emits 24% of global greenhouse gases, with higher incidence of: - food-related infections - water-borne infections Ozone loss due to nitrous oxides causes - Skin cancer - cataract
Occupational risks			
Occupational injuries	Exposure to injury risk factors	Unintentional injuries	Workplace safety
Occupational carcinogens	Low and high exposure to chemical and physical agents that cause cancer	Leukaemia, lung cancer, mesothelioma	- Agricultural pesticides: organophosphates tightly linked to cancer risk (especially hematopoietic) of pesticide applicators - Strong evidence of risk of Leukaemia among pesticide manufacturing workers - Tumour viruses (avian sarcoma) in poultry slaughterhouses associated with non-Hodgkin lymphoma among workers
Occupational diseases	Low and high exposure to poisoning chemicals	Alzheimer's disease, Parkinson's and lower cognitive performance	Agricultural pesticide applicators
Occupational airborne particulates	Low and high exposure	Chronic Obstructive Pulmonary Disease (COPD) and asthma, pneumoconiosis, silicosis and asbestosis	Intensive livestock systems
Occupational ergonomic stressors	Physical workload	Lower back pain	Contractual practices for workers, especially in processing units

Based on WHO, 2009: the text in black font shows the original source; the blue font shows new information added in this study.

Annex 2 - Wellbeing Valuation Applied to Health: Full Methodology

Section 3 underlines the interest to estimate the CS or ES of health conditions. With no loss of generality, this study focuses on CS here: CS is also the main measure of welfare change used in CBA. CS can be estimated as follows using the direct utility function:

$$u(M, H^0) = u(M + CS, H^1) \qquad (4)$$

Where H^0 is health status before the onset of the condition and $H^1$is health status after the onset of the condition. Here CS represents the compensation amount which keeps utility (welfare) constant. To estimate (1) empirically we develop in equation (5) an empirical version of equation (2) (we substitute health status in (2) instead of Q_i):

$$SWB_i = f(M_i, Q_i, X_i) \qquad (2)$$

$$SWB_i = \alpha + \beta_M M_i + \beta_H H_i + \beta_X X_i + \varepsilon_i \qquad (5)$$

Equation (4) then becomes

$$(\alpha + \beta_M M_i + \beta_H H_i^0 + \beta_X X_i + \varepsilon_i) = (\alpha + \beta_M M_i + \beta_H H_i^1 + \beta_X X_i + \varepsilon_i) \qquad (6)$$

Re-arranging this, CS can be estimated as follows:

$$CS = {\beta_H (H_i^1 - H_i^0)}\Big/{\beta_M} \qquad (7)$$

In order to derive robust estimates of CS β_H and β_M must be unbiased estimates. In order to estimate the impact of health conditions on SWB (β_H) we employ the following type of multivariate regression analysis for one condition at a time [92].

$$LS_i = \alpha_i + \beta_H H_i + \beta_X X_i + \epsilon_i \qquad (8)$$

Where LS_i is the life satisfaction score of individual i and since H_i is a binary variable which equals 0 without the condition and 1 with the condition, $H_i = (H_i^1 - H_i^0)$. Depending on the data set used equation (8) may be run on panel data over time which would mean that there is an additional time (t) subscript which is not included here.

In order to reduce bias in β_H we control for a comprehensive set of confounding variables in X_i. We use a set of variables that are included as standard in most wellbeing research and as we set out in Green Book guidance on wellbeing valuation. [93] In U Soc these are:

[92] Exogenous changes or valid instruments were not available for the health condition variables and hence we used multivariate regression as the next-best option. Regression analysis will provide results that are useful and robust enough for use in policy

[93] Note that we did not include personality traits (which is sometimes used in wellbeing analysis) in the models as there were no data on these variables. In U Soc and HSNI. We did not include measures of social relations or crime

- Income
- Age
- Gender
- Marital status
- Educational status
- Employment status
- Number of children and other dependents (including caring duties)
- Geographic region
- Ethnicity
- Housing status and satisfaction with housing
- Religious Status
- Wave of survey

In HSNI these are:

- Age
- Socioeconomic Status (as income was not available in all waves)
- Educational Status
- Employment Status
- Number of Children
- Marital Status
- Housing Status
- Smoker and Drinker status (due to the condition being valued)
- Wave of survey

In HSE, there is no measure of life satisfaction so we employ a two-step procedure as set out in FAO, 2014[94] whereby we first estimate the impact of H_i on general health measured on a 1-5 likert scale (1 = 'Very good' to 5 = 'Very bad') and then estimate the impact of general health (GH) on life satisfaction in the U Soc data [95]:

$$LS_i = \alpha_i + \beta_{GH} GH_i + \beta_X X_i + \epsilon_i \qquad (9)$$

The product term of the impact of H_i on general health multiplied by β_{GH} from (9) provides an estimate of β_H in order to estimate CS in equation (7).

Whilst we control for all of the key drivers of life satisfaction it is important to caveat this approach as there may still be omitted confounding variables included in ϵ_i in equations (8) and (9) which would bias our estimates of β_H and β_{GH}. However, this approach represents one of the best methods for estimating impacts using observational data (i.e. data where the outcome has not been randomly assigned) and is the main method used in social science research on wellbeing.

in the local area as it would involve excluding out large parts of the sample as they were not available together in every wave. Social relations or level of crime in the local area were not available in the HSE.

[94] http://www.fao.org/3/a-i3991e.pdf

[95] Although it is measured on the same five-point scale, the general health question is slightly different worded in HSE and U Soc.

Whilst we could also estimate the impact of income on life satisfaction in equation (8) it is possible to derive a more robust causal estimate of income using an instrumental variable (IV) approach. An IV is a variable that creates exogenous or random change in the variable of interest (income) and we use lottery wins as an IV here. Since lottery wins analysis can only be conducted with lottery players and winners we estimate the lottery wins model separately to avoid reducing sample sizes in the main health model analysis. We use the estimate of the impact of income using the lottery wins IV from Fujiwara (2013) and Fujiwara and Dolan (2016). This comes from the following model:

The causal effect of income on life satisfaction using a lottery wins IV

First stage regression. Dependent variable: Ln(household income)		
Independent variables	Coefficient	S.E.
lottery win	0.102***	(-0.015)
previous lottery wins	6.82e-06***	(0.000)
Constant	9.999***	(0.007)
Observations	10,461	
Second stage regression (estimated using the Control Function approach) Dependent variable: life satisfaction		
Independent variables	Coefficient	S.E.
Ln (household income)	1.103***	(0.252)
previous lottery wins	-0.00001***	(0.000)
$\hat{\vartheta}_2$	-1.108***	(0.260)
$\hat{\vartheta}_2 \cdot \ln(M)$	0.011*	(0.006)
Constant	-5.777**	(2.530)
Observations	10,328	

Notes: * = significance at 10%, ** = significance at 5%, *** = significance at 1%. Heteroscedasticity-robust standard errors used. Source: Fujiwara (2013).

Note that in order to account for diminishing marginal utility of income it is customary to use a non-linear logarithmic format (Ln) for income as we have done in Table 3. Using the log of income means that we need to adjust the CS equation in (7) as follows:

$$CS = e^{\left[\frac{-\beta_H}{\beta_M} + \ln(M^0)\right]} - M^0 \qquad (10)$$

Where M^0 is the sample average level of household income and as set out in Table 3, β_M = 1.103. β_H comes from equation (8) (or for the case of the HSE survey from the product term of the impact of H_i on general health multiplied by β_{GH} from (9)).

Annex 3 – MARCH Survey Instrument

Q1. Are you male or female?
1 = Male
2 = Female

Q2. What is your date of birth?
____/____/_____ *(day/month/year)*

Q3. Life satisfaction
We would like to ask you a question about your feelings about your life overall. There are no right or wrong answers. For this question, we'd like you to circle your answer on a scale of 0 to 10, where 0 is 'not at all' and 10 is 'completely'.
Overall, how satisfied are you with your life nowadays?
0 = Not at all satisfied
1
2
3
4
5
6
7
8
9
10 = Completely satisfied

Personal Information

Q4. Marital status
(a) What is your legal marital status?
1 = Married / in civil partnership
2 = Separated
3 = Divorced
4 = Widowed
5 = Single (never married or in civil partnership)

If your answer above is not Married / in civil partnership, please also answer part (b).
(b) Are you living as a couple with another person?
1 = Yes
2 = No

Q5. Dependents
(a) How many dependent children are there in your household?
____ *(please enter number)*
(b) How many dependents other than children are there in your household?

____ *(please enter number)*

Q6. Social Relations
How many close friends do you have?
0
1
2
3
4
5 or more

Q7. What is the highest level of education you have completed?
1 = Primary
2 = Secondary
3 = Tertiary (Higher education)
4 = None

Q8. What is your employment status?
1 = Self-employed
2 = Full-time employed
3 = Part-time employed
4 = Unemployed
5 = Retired
6 = Student
7 = Other (for example: looking after family or home, long-term sick or disabled, etc.)

Q9. Household income
What was your household's gross income in the last 12 months? *Please include all types of income (employment, inheritance, lottery wins, government transfers).*
_____ *(local currency units)*

Q10. Lottery
(a) How many times have you played a lottery over the past 12 months? *Please include all types of lotteries here (e.g. national lottery/lotto, scratch cards, etc.).*
____ *(please enter number)*
If you did play a lottery at least once over the past 12 months, please also answer part (b):
(b) What was the total amount that you have won by playing lotteries in the last 12 months?
_____ *(local currency units)*

Q11. Which of the following ethnic groups you consider you belong to?
1 = Asian
2 = Black
3 = White
4 = Mixed
5 = Other

Q12. What is your religion?
0 = None
1 = Buddhist
2 = Christian
3 = Hindu
4 = Jewish
5 = Muslim/Islam
6 = Sikh
7 = Other

Housing and Local Environment

Q13. What type of accommodation do you live in?
1 = Detached house
2 = Semi-detached house
3 = End terraced house
4 = Terraced house
5 = Flat/ Apartment
6 = Retired/sheltered accommodation
7 = Institutional
8 = Other

Q14. Does your household own this accommodation outright, is it being bought with a mortgage, is it rented or does it come rent-free?
1 = Owned outright
2 = Owned/being bought on mortgage
3 = Shared ownership (part-owned part-rented)
4 = Rented
5 = Rent free
6 = Other

Q15. How safe do you feel in your neighbourhood?
1 = Completely safe
2
3 = Neither safe nor unsafe
4
5 = Completely unsafe

Q16. Do you ever worry about the level of pollution in your neighbourhood?
1 = Not at all
2 = Sometimes
3 = Most of the time
4 = All of the time
5 = Don't know

Q17. Which type of area do you live in?
1 = Rural – (less than 10,000 people live in your local area)
2 = Urban – (at least 10,000 people live in your local area)

Personality

For each of the following statements, please select a number which best describes how you see yourself.

Q18. I see myself as someone who:

(a) Does a thorough job.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

(b) Is talkative.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

(c) Worries a lot.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

(d) Tends to be lazy.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

(e) Is outgoing, sociable.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

(f) Gets nervous easily.

1	2	3	4	5	6	7
Does not apply to me at all						Applies to me perfectly

Health section

Q19. How would you rate your health in general?
1 = Excellent
2 = Very good
3 = Good
4 = Fair
5 = Poor

Q20. Your Health State Today – EQ5D
For each section below, please indicate which statement best describes your health state today:
(a) Mobility
1 = I have no problems in walking about
2 = I have some problems in walking about
3 = I am confined to bed
(b) Self-Care
1 = I have no problems with self-care
2 = I have some problems with washing or dressing myself
3 = I am unable to wash or dress myself
(c) Usual Activities (e.g. work, study, housework, family or leisure activities)
1 = I have no problems with performing my usual activities
2 = I have some problems with performing my usual activities
3 = I am unable to perform my usual activities
(d) Pain / Discomfort
1 = I have no pain or discomfort
2 = I have moderate pain or discomfort
3 = I have extreme pain or discomfort
(e) Anxiety / Depression
1 = I am not anxious or depressed
2 = I am moderately anxious or depressed
3 = I am extremely anxious or depressed

Note - The following questions ask about the 13 health conditions in the UK case study. Future research, would tailor this list to ask the questions for the specific health conditions of interest.

Q21. Chronic Bronchitis
(a) Have you been told by a doctor that you have Chronic Bronchitis?
1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No
If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).
(b) How long have you had Chronic Bronchitis?
1 = Less than a week
2 = At least a week, but less than a month

3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Chronic Bronchitis is on the following scale:

0 = No Chronic Bronchitis at all
1
2
3
4
5
6
7
8
9
10 = Most severe Chronic Bronchitis possible

Q22. Coronary Heart Disease

(a) Have you been told by a doctor that you have Coronary Heart Disease?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No

If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).

(b) How long have you had Coronary Heart Disease?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Coronary Heart Disease is on the following scale:

0 = No Coronary Heart Disease at all
1
2
3
4
5
6
7
8
9
10 = Most severe Coronary Heart Disease possible

Q23. Emphysema

(a) Have you been told by a doctor that you have Emphysema?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No

If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).

(b) How long have you had Emphysema?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Emphysema is on the following scale:

0 = No Emphysema at all
1
2
3
4
5
6
7
8
9
10 = Most severe Emphysema possible

Q24. Liver Dysfunction

(a) Have you been told by a doctor that you have Liver Dysfunction?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No

If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).

(b) How long have you had Liver Dysfunction?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Liver Dysfunction is on the following scale:

0 = No Liver Dysfunction at all
1
2
3
4
5
6
7
8
9
10 = Most severe Liver Dysfunction possible

Q25. Kidney Dysfunction

(a) Have you been told by a doctor that you have Kidney Dysfunction?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No

If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).

(b) How long have you had Kidney Dysfunction?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months

5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Kidney Dysfunction is on the following scale:

0 = No Kidney Dysfunction at all
1
2
3
4
5
6
7
8
9
10 = Most severe Kidney Dysfunction possible

Q26. Stomach Dysfunction

(a) Have you been told by a doctor that you have Stomach Dysfunction?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No

If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).

(b) How long have you had Stomach Dysfunction?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your Stomach Dysfunction is on the following scale:

0 = No Stomach Dysfunction at all
1

2
3
4
5
6
7
8
9
10 = Most severe Stomach Dysfunction possible

Q27. Colorectal Cancer
(a) Have you been told by a doctor that you have Colorectal Cancer?
1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No
If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).
(b) How long have you had Colorectal Cancer?
1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more
(c) Please indicate how severe your Colorectal Cancer is on the following scale:
0 = No Colorectal Cancer at all
1
2
3
4
5
6
7
8
9
10 = Most severe Colorectal Cancer possible

Q28. Reproductive Disorders
(a) Have you been told by a doctor that you have a Reproductive Disorder?

1 = Yes, and I still have the condition
2 = Yes, but I no longer have the condition
3 = No
If your answer to (a) is 1 or 2, please also answer part (b).
If your answer to (a) is 1, please also answer parts (b) and (c).
(b) How long have you had the Reproductive Disorder?
1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more
(c) Please indicate how severe your Reproductive Disorder is on the following scale:
0 = No Reproductive Disorder at all
1
2
3
4
5
6
7
8
9
10 = Most severe Reproductive Disorder possible

Q29. Obesity
(a) What is your BMI?
_____ *(please enter number)*
If your answer to (a) is greater than or above 30, please also answer part (c).
(c) How long have you had Obesity?
1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years

9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

Q30. Heart Attack
(a) Have you ever been told by a doctor that you have/had a Heart Attack?
1 = Yes, once
2 = Yes, more than one time
3 = No
If your answer to (a) is 1 or 2, please also answer part (b and c).
(b) How long ago did you have your most recent Heart Attack?
1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more
(c) Please indicate how severe your most recent Heart Attack was on the following scale:
0 = No Heart Attack at all
1
2
3
4
5
6
7
8
9
10 = Most severe Heart Attack possible
If your answer to (a) is 2, please also answer part (d, e and f)
(d) How long ago did you have your first Heart Attack?
1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years

8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(e) Please indicate how severe your <u>first</u> Heart Attack was on the following scale:

0 = No Stroke at all
1
2
3
4
5
6
7
8
9
10 = Most severe Stroke possible

(f) Please indicate how many times you have had a Heart Attack:

1
2
3
4
5
6
7
8
9
10

Q31. Stroke

(a) Have you ever been told by a doctor that you have/had a Stroke?

1 = Yes, once
2 = Yes, more than one time
3 = No

If your answer to (a) is <u>1 or 2</u>, please also answer part (b and c)

(b) How long ago did you have your <u>most recent</u> Stroke?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years

9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(c) Please indicate how severe your <u>most recent</u> Stroke was on the following scale:

0 = No Stroke at all
1
2
3
4
5
6
7
8
9
10 = Most severe Stroke possible

If your answer to (a) is <u>2</u>, please also answer part (d, e and f)

(d) How long ago did you have your <u>first</u> Stroke?

1 = Less than a week
2 = At least a week, but less than a month
3 = At least a month, but less than 2 months
4 = At least 2 months, but less than 3 months
5 = At least 3 months, but less than 6 months
6 = At least 6 months, but less than a year
7 = At least a year, but less than 2 years
8 = At least 2 years, but less than 3 years
9 = At least 3 years, but less than 4 years
9 = At least 4 years, but less than 5 years
10 = At least 5 years, but less than 10 years
11 = At least 10 years, but less than 15 years
12 = 15 years or more

(e) Please indicate how severe your <u>first</u> Stroke was on the following scale:

0 = No Stroke at all
1
2
3
4
5
6
7
8
9
10 = Most severe Stroke possible

(f) Please indicate how many times you have had a Stroke:

1
2

3
4
5
6
7
8
9
10

Thank you for taking the time to complete this survey.

Annex 4 – Health Regression Results

The column numbers of **Ошибка! Источник ссылки не найден.**8 below indicate the regressions used to obtain the association between life satisfaction and the following health conditions:

1 = Coronary Heart Disease
2 = Heart Attack or Myocardial regression
3 = Stroke
4 = Emphysema
5 = Chronic Bronchitis
6 = Any Kind of Liver Condition
7 = Obese
8 = Currently taking gastrointestinal medicine
9 = General Health

Regression of life satisfaction on health conditions (Understanding Society)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No condition	0.00								
Currently has it	-0.47***								
Has another long term condition	-0.39***								
Log equivalised household income	0.09***	0.09***	0.09***	0.09***	0.09***	0.09***	0.10***	0.11***	0.07***
Age	-0.03***	-0.03***	-0.03***	-0.03***	-0.03***	-0.03***	-0.04***	-0.04***	-0.03***
Age squared	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
Male	-0.02**	-0.02***	-0.02***	-0.02***	-0.02***	-0.02***	-0.03	-0.03	-0.02***
Married or civil partner or living as a couple	0.26***	0.26***	0.26***	0.26***	0.26***	0.26***	0.34***	0.35***	0.26***
Divorced or former civil partner	-0.05***	-0.05***	-0.05***	-0.05***	-0.05***	-0.05***	0.02	0.02	-0.03**

Widowed or surviving civil partner	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.06	0.02
Separated from husband / wife / civil partner	-0.16***	-0.16***	-0.16***	-0.17***	-0.16***	-0.16***	-0.18*	-0.13	-0.16***
Single	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No qualifications	0.00	0.01	0.01	0.01	0.01	0.00	0.06	0.07	0.06***
A level or GCSE qualification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other qualification	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	0.01
Degree or Higher Degree	0.12***	0.12***	0.12***	0.12***	0.12***	0.12***	0.08***	0.10***	0.06***
Self employed	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.08*	-0.08*	-0.03***
In paid employment (full or part-time)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployed	-0.45***	-0.45***	-0.45***	-0.45***	-0.45***	-0.45***	-0.37***	-0.37***	-0.39***
Retired	0.21***	0.21***	0.21***	0.21***	0.21***	0.21***	0.24***	0.24***	0.24***
On maternity leave	0.24***	0.24***	0.24***	0.24***	0.24***	0.24***	0.40***	0.39***	0.23***
Looking after family or home	-0.07***	-0.07***	-0.07***	-0.07***	-0.07***	-0.07***	0.00	0.00	-0.02
Full-time student	0.25***	0.25***	0.25***	0.25***	0.25***	0.25***	0.28***	0.29***	0.21***
Long-term sick or disabled	-1.09***	-1.10***	-1.09***	-1.09***	-1.08***	-1.09***	-1.48***	-1.42***	-0.75***
On a government training scheme	-0.30**	-0.30**	-0.30**	-0.30**	-0.30**	-0.29**	-1.46***	-1.43***	-0.21*
Unpaid worker in family business	-0.15	-0.15	-0.15	-0.14	-0.15	-0.15	-0.31	-0.27	-0.16
Doing something else	-0.15***	-0.15***	-0.15***	-0.15***	-0.15***	-0.15***	0.11	0.15	-0.14***
Number of children	0.02***	0.02***	0.02***	0.01***	0.01***	0.02***	-0.02	-0.02	0.01**
Religious	0.04***	0.04***	0.04***	0.04***	0.04***	0.04***	0.06**	0.06**	0.03***
Carer	-0.24***	-0.24***	-0.24***	-0.24***	-0.24***	-0.24***	-0.28***	-0.28***	-0.20***
North East	-0.00	-0.00	-0.00	0.00	-0.00	-0.00	0.00	-0.00	0.03
North West	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.00
Yorkshire and Humber	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.04	0.04	0.01
East Midlands	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	-0.03	0.01
West Midlands	-0.06***	-0.06***	-0.06***	-0.06***	-0.06***	-0.06***	-0.01	-0.01	-0.03**
East of England	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.02*

London	-0.06***	-0.05***	-0.06***	-0.06***	-0.06***	-0.06***	-0.02	-0.03	-0.05***
South East	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South West	0.03**	0.03**	0.03**	0.03**	0.03**	0.03**	0.04	0.04	0.03**
Wales	-0.04**	-0.04**	-0.04**	-0.04**	-0.04**	-0.04**	0.02	0.01	-0.01
Scotland	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.10**	0.12**	-0.01
Northern Ireland	0.07***	0.07***	0.07***	0.07***	0.07***	0.07***			0.09***
House owned outright	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
House owned/being bought on mortgage	-0.15***	-0.15***	-0.15***	-0.15***	-0.15***	-0.15***	-0.18***	-0.19***	-0.12***
House - shared ownership (part-owned part-rented)	-0.25***	-0.25***	-0.25***	-0.25***	-0.25***	-0.25***	-0.35**	-0.42**	-0.18***
House rented	-0.26***	-0.26***	-0.26***	-0.25***	-0.25***	-0.26***	-0.37***	-0.37***	-0.18***
House Rent free	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***	-0.08	-0.09	-0.09***
Other	-0.04	-0.03	-0.03	-0.03	-0.03	-0.04	-0.10	-0.06	-0.03
Would like to move house	0.31***	0.31***	0.31***	0.31***	0.31***	0.31***	0.34***	0.36***	0.28***
White: British/English/Scottish/Welsh/Northern Irish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White: Irish	-0.05**	-0.05**	-0.06**	-0.05**	-0.06**	-0.06**	-0.29**	-0.29**	-0.07***
White: Gypsy Or Irish Traveller	-0.03	-0.03	-0.02	-0.03	-0.04	0.02	-0.13	-0.17	-0.08
White: any other White background	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***	-0.12***	-0.03	-0.02	-0.10***
Mixed: White And Black Caribbean	-0.19***	-0.19***	-0.19***	-0.19***	-0.19***	-0.19***	-0.11	-0.15	-0.14***
Mixed: White And Black African	-0.25***	-0.25***	-0.25***	-0.25***	-0.25***	-0.26***	-0.23	-0.24	-0.23***
Mixed: White And Asian	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.07	-0.07	-0.01
Mixed: Any Other Mixed Background	-0.13**	-0.13**	-0.13**	-0.13**	-0.13**	-0.12**	-0.05	0.06	-0.09*
Asian/Asian British: Indian	-0.24***	-0.24***	-0.24***	-0.24***	-0.24***	-0.24***	-0.41***	-0.42***	-0.16***
Asian/Asian British: Pakistani	-0.34***	-0.34***	-0.34***	-0.34***	-0.34***	-0.34***	-0.21	-0.19	-0.24***

Asian/Asian British: Bangladeshi	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.26***	-0.54*	-0.49*	-0.18***
Asian/Asian British: Chinese	-0.25***	-0.25***	-0.25***	-0.25***	-0.25***	-0.24***	0.15	0.15	-0.14***
Asian/Asian British: Any Other Asian Background	-0.14***	-0.14***	-0.14***	-0.15***	-0.15***	-0.15***	-0.53***	-0.51***	-0.09***
Black/African/Caribbean/Black British: Caribbean	-0.21***	-0.21***	-0.20***	-0.21***	-0.21***	-0.21***	-0.53***	-0.53***	-0.13***
Black/African/Caribbean/Black British: African	-0.14***	-0.14***	-0.14***	-0.14***	-0.14***	-0.14***	-0.13	-0.15	-0.16***
Black/African/Caribbean/Black British: Any Other Black Backg	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.61	-0.61	0.04
Other Ethnic Group: Arab	-0.27***	-0.27***	-0.27***	-0.27***	-0.27***	-0.26***	0.21	0.13	-0.22***
Other ethnic group: any other ethnic group	-0.16***	-0.16***	-0.16***	-0.16***	-0.17***	-0.17***	-0.14	-0.13	-0.11**
Wave=1	0.00	0.00	0.00	0.00	0.00	0.00			0.00
Wave=2	-0.09***	-0.09***	-0.09***	-0.09***	-0.09***	-0.09***	0.00	0.00	-0.07***
Wave=3	-0.19***	-0.19***	-0.19***	-0.19***	-0.19***	-0.19***	-0.26***	-0.26***	-0.18***
Wave=4	-0.28***	-0.28***	-0.28***	-0.28***	-0.28***	-0.28***			-0.25***
Wave=5	-0.30***	-0.30***	-0.30***	-0.30***	-0.30***	-0.30***			-0.28***
Wave=6	-0.13***	-0.13***	-0.13***	-0.12***	-0.12***	-0.13***			-0.11***
No condition		0.00							
Currently has it		-0.45***							
Has another long term condition		-0.39***							
No condition			0.00						
Currently has it			-0.53***						
Has another long term condition			-0.39***						
No condition				0.00					
Currently has it				-0.73***					
Has another long term condition				-0.39***					

No condition					0.00				
Currently has it					-0.64***				
Has another long term condition					-0.38***				
No condition						0.00			
Currently has it						-0.54***			
Has another long term condition						-0.38***			
No condition									
Currently has it									
Has another long term condition									
Obese							-.1354174***		
Severely obese							-.3401176***		
Has not taken gastrointestinal medicine								0	
Has taken gastrointestinal medicine								-.2900651***	
General health									-0.35***
Constant	5.28***	5.28***	5.28***	5.27***	5.27***	5.27***	5.24***	5.16***	6.04***
Observations	207015	206899	206895	206966	207047	206986	14753	15318	210320
R-squared	0.12	0.12	0.12	0.12	0.12	0.12	0.14	0.14	0.16
Adjusted R-squared	0.12	0.12	0.12	0.12	0.12	0.12	0.14	0.14	0.16
F	367.21	366.21	366.53	368.72	368.79	367.25	31.65	34.59	540.92

Robust standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.

Regression of life satisfaction on health conditions (Health Survey Northern Ireland)

	Colorectal Cancer
	b
No Cancer	0.00
Prostate	0.09
Colorectal	-0.75**
Skin (melanoma)	-0.48
Mouth / Neck / Throat	0.80***
Lymphoma	-0.79*
Lung	-1.59***
Bone	0.08
Other cancers	0.11
Multiple cancers	-2.10***
16-24 years	0.00
25-34 years	-0.14***
35-44 years	-0.16***
45-54 years	-0.33***
55-64 years	-0.25***
65-74 years	-0.01
Professional	0.00
Employer, manager	-0.02
Intermediate non-manual	-0.02
Junior non-manual	-0.10
Skilled manual	-0.11*
Semi-skilled manual	-0.08
Unskilled manual	-0.14*
No socio-economic group	0.04
Drink	0.07**

Current smoker	0.00
Not a current smoker	0.15***
Left school before age of 18	-0.07**
Practice religion	0.00
Don't practice religion	-0.16***
Number of children – calculated	-0.01
Single, that is never married	0.00
Married and living with husband\wife	0.16***
a civil partner in a legally-recognised Civil Partnership	-0.19
Married and separated from husband\wife	-0.18**
Divorced	-0.02
Widowed	0.14
Spontaneous only - In a legally-recognised Civil Partnership	-0.19***
Worked last week	0.00
Away from work last week	-0.18*
Waiting to take up job	-0.27
Looking for work	-0.26***
Not looking – sick	-0.95***
Economically inactive	-0.34***
Don't Know	-0.43
Detached house	0.00
Semi-detached house	-0.01
Terraced/end of terrace house	-0.08**
wave=1	0.00
wave=2	-0.07*
wave=3	-0.07**
wave=4	0.05
Constant	4.47***
Observations	3650
R-squared	0.16

Adjusted R-squared	0.15
F	.
Robust standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.	

Regression of life satisfaction on health conditions (Health Survey for England)

	Dementia	Kidney Dysfunction	Male Reproductive Disorders
	b	b	b
Dementia	0.63		
Female	-0.00	-0.00	
16-24 years	0.00	0.00	0.00
25-34 years	-0.06	0.09*	0.12***
35-44 years	0.37***	0.18***	0.26***
45-54 years	0.46***	0.27***	
55-64 years	0.54***	0.31***	
65-74 years	0.36***	0.26***	
75+ years	0.31**	0.36***	
Higher managerial and professional occupations	-0.49***	-0.49***	-0.51***
Lower managerial and professional occupations	-0.39***	-0.44***	-0.48***
Intermediate occupations	-0.28**	-0.32***	-0.43***
Small employers and own account workers	-0.20	-0.37***	-0.43***
Lower supervisory and technical occupations	-0.36***	-0.29***	-0.37***
Semi-routine occupations	-0.24**	-0.22***	-0.29***
Routine occupations	-0.28**	-0.13**	-0.22**
Never worked and long term unemployed	0.00	0.00	0.00
Other	-0.24	0.00	-0.15
NVQ4/NVQ5/Degree or equiv	-0.37***	-0.38***	-0.36***
Higher ed below degree	-0.27***	-0.27***	-0.24***
NVQ3/GCE A Level equiv	-0.21**	-0.31***	-0.25***

NVQ2/GCE O Level equiv	-0.25***	-0.21***	-0.17***
NVQ1/CSE other grade equiv	-0.04	-0.12***	-0.15**
Foreign/other	-0.27***	-0.18***	-0.51***
No qualification	0.00	0.00	0.00
FT Student	-0.09	-0.29***	-0.29***
Never smoked cigarettes at all	0.00	0.00	0.00
Used to smoke cigarettes occasionally	0.13	-0.00	0.06
Used to smoke cigarettes regularly	0.18***	0.11***	0.04
Current cigarette smoker	0.21***	0.39***	0.36***
Urban	0.00	0.00	0.00
Town & fringe	-0.19***	-0.06**	-0.10***
Village, hamlet and isolated dwellings	-0.31***	-0.10***	-0.12***
Kidney Dysfunction		0.58***	
White – English/Welsh/Scottish/Northern Irish/British		0.00	
White – Irish		0.09	
White – Gypsy or Irish Traveller		0.04	
Any other white background		0.11	
White and Black Caribbean		0.01	
White and Black African		0.08	
White and Asian		0.19	
Any other mixed/multiple ethnic background		0.35***	
Indian		0.42***	
Pakistani		0.39***	
Bangladeshi		0.36***	
Chinese		0.15*	
Any other Asian background		0.17*	
African		-0.05	
Caribbean		0.25*	
Any other Black/African/Caribbean background		0.22	
Arab		0.64**	
Any other ethnic group		-0.01	

(D) Valid BMI measurements using estimated weight if >130kg		0.02***	0.01***
Male reproductive disorder			0.39
Constant	3.13***	2.01***	2.26***
Observations	2669	13361	4639
R-squared	0.07	0.14	0.12
Adjusted R-squared	0.06	0.14	0.12
F	6.76	47.92	26.61
Robust standard errors. *, **, *** indicates significance at the 90%, 95%, and 99% level, respectively.			

Annex 5 – Data on Number of People with Health Conditions in the UK

Disease	Number of People Affected in the UK Annually	Source
Coronary heart disease	2 300 000	NHS, 2014 (http://www.nhs.uk/Conditions/Coronary-heart-disease/Pages/Introduction.aspx)
Heart attack or myocardial infarction	146 000	Cardiac Matters, 2010 (http://www.cardiacmatters.co.uk/facts-figures-heart-disease-uk.html); Heart Research Institute UK (87360) in 2014 (1 has a heart attack every 6 minutes - https://www.hriuk.org/about-heart-disease/facts-about-heart-disease)
Stroke	152 000	The Stroke Association, 2016 (https://www.stroke.org.uk/sites/default/files/stroke_statistics_2015.pdf)
Emphysema	2 449 141	600,0000 are affected by Chronic Obstructive Pulmonary Disease (which includes emphysema, bronchitis and chronic airflow limitation / obstruction). As quoted in https://www.nice.org.uk/guidance/cg101/resources/costing-report-134511805 (Healthcare Commission (2006) Clearing the air: a national study of chronic obstructive pulmonary disease. London: Healthcare Commission.) Wave 1 of Understanding Society gives the relative proportion of people who suffer from each.
Chronic bronchitis	4 192 867	600,0000 are affected by Chronic Obstructive Pulmonary Disease (which includes emphysema, bronchitis and chronic airflow limitation / obstruction). As quoted in https://www.nice.org.uk/guidance/cg101/resources/costing-report-134511805 (Healthcare Commission (2006) Clearing the air: a national study of chronic obstructive pulmonary disease. London: Healthcare Commission.) Wave 1 of Understanding Society gives the relative proportion of people who suffer from each.
Liver Dysfunction	2 000 000	Liver disease (NHS, 2014 - http://www.nhs.uk/conditions/liver-disease/Pages/Introduction.aspx)
Kidney Dysfunction	3 000 000	Kidney Disease affects 3 million people in the UK (World Kidney Day - http://www.worldkidneyday.co.uk/kidney-facts/ ; accessed April 2017, no 'last edited' date). As expected with 1.8m in England alone (2014-5 - Health & Social Care Information Centre, Recorded disease prevalence, achievements and exceptions. Quality and Outcomes Framework (QOF) for April 2014-March 2015, England.)
Stomach Dysfunction	137 504	Stomach dysfunction is taken to mean gastroparesis, Crohn's Disease and stomach cancer. We exclude gastritis and diarrhoea because of their lower severity. There are very few statistics on gastroparesis. An American study found a prevalence of 24.2 per 100,000 (Rochester Epidemiology Project as quoted in https://synapse.koreamed.org/Synapse/Data/PDFData/0081JNM/jnm-18-34.pdf). Crohn's Disease - 115,000 people in the UK (https://www.crohnsandcolitis.org.uk/about-inflammatory-bowel-disease/crohns-disease, last updated 2013). Stomach Cancer - 6682 new cases of stomach cancer in 2014 in UK

		(http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/stomach-cancer).
Colorectal Cancer	41 265	New cases in 2014 in UK (Cancer Research UK - http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/bowel-cancer)
Obesity BMI 30-40	10362387	This is for all obesity (BMI of 30+) minus the figures for those severely obese. This is calculated as 25% of the adult population (15+) from 2015 NHS estimations (http://content.digital.nhs.uk/catalogue/PUB20562/obes-phys-acti-diet-eng-2016-rep.pdf) and 2015 ONS population estimations (Age distribution of the UK population, 1975 to 2045 (projected) accessed from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/mar2017). This is a little high at three times the figure (4185697) for all obesity (30+) only in England from (2014-5 - Health & Social Care Information Centre, Recorded disease prevalence, achievements and exceptions. Quality and Outcomes Framework (QOF) for April 2014-March 2015, England.)
Severe Obesity - BMI 40+	2 854 943	Health Survey for England found 3.6% of female adults (16+) and 1.8% of male adults (16+) were severely obese in England in 2014. The number affected in the UK is assumed to be the same proportion as in England, and is applied to 2015 ONS population estimations (Age distribution of the UK population, 1975 to 2045 (projected) accessed from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/overviewoftheukpopulation/mar2017).
Male reproductive disorders	2 354 544	No data for male reproductive disorders overall so the numbers are added on the basis of disorders outlined in: Toppari, J., Larsen, J.C., Christiansen, P., Giwercman, A., Grandjean, P., Guillette, L.J., Jr., Jegou, B., Jensen, T.K., Jouannet, P., Keiding, N., Leffers, H., McLachlan, J.A., Meyer, O., Muller, J., Rajpert-De Meyts, E., Scheike, T., Sharpe, R., Sumpter, J., Skakkebaek, N.E. (1996). Male reproductive health and environmental xenoestrogens. Environ Health Perspect 104 Suppl 4: 741-803. 2418 new cases of testicular cancer in 2014 (http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/testicular-cancer); incidence of cryptorchidism was 7% amongst infants in 2009 (http://adc.bmj.com/content/94/11/868). Hypospadias affects 1 in 300 boys (Great Ormond Street Hospital, 2013 - http://www.gosh.nhs.uk/medical-information-0/search-medical-conditions/hypospadias). Number of men in the UK taken from ONS

		Mid-Year 2015 Population Estimates (https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesanalysistool)
Alzheimer's Disease	850 000	Alzheimer's Society (https://www.alzheimers.org.uk/info/20027/news_and_media/541/facts_for_the_media), updated 2017.