leaps

Taking 10 leaps for humanity

How conquering ten huge challenges will have profound impact on humanity

Happiness Research Institute

Colo—phon

Taking 10 Leaps

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Con–tents

Fore— word

How do we make the 'Bio Revolution' a 'Wellbeing Revolution'?

Transformative biotechnologies and accelerating digital advancement have the potential to profoundly improve our health and agriculture, enhance our ability to effectively respond to global crises, and, ultimately, improve wellbeing for billions of people across the world. Yet, this 'Bio Revolution' – which we define it as the confluence of chemistry, biology, and data science – carries significant risks of failure as the probability of success of biotech innovations are often low, and countless solutions that work elegantly in the lab often fail in the real world. Moreover, the potential positive impact of such innovations on people's lives are sometimes considered but rarely quantified. It is our belief, that without a rigorous impact framework, investors will continuously run the risks of investing in biotech solutions that can't live up to promises of delivering meaningful impacts for people and the planet.

Encouragingly, private, and public sectors are today beginning to work together in unprecedented ways to ensure that businesses consider and demonstrate social impact in addition to profitability. This transformation is evidenced by the widespread adoption of initiatives including CSR (Corporate Social Responsibility), ESG (Environmental, Social, and Corporate Governance), and SDGs (Sustainable Development Goals). These programs help enable long-term value creation ensuring that aspects other than ROI, such as social and environmental impact, are prioritized in decision-making processes.

Yet, taking a closer look at the applied metrics, it becomes evident that they are over-reliant on objective indicators of impact rather than subjective measures of human wellbeing. As such, there is currently a lack of frameworks for measuring impact of investments on peoples' lives. Objective measures can tell us how many years of life a Parkinson's patient is expected to lose, how many CO_2 particles people in major cities are exposed to, and how climate change will drastically affect living conditions around the world. They can't, however, describe what it feels like to be terminally ill, to breathe polluted air, or to be forced to flee your home due to wildfires or rising sea levels.
Objective indicators remain essential, but the lack of guiding measures and data on wellbeing can ultimately result in sub-optimal resource allocation and in investors missing out on various opportunities to improve people's lives. On top of that, the term 'impact investment' can easily be used as an excuse for poor financial performance, and the fact that rigorous frameworks are lacking only compounds that. To fill these voids, Leaps by Bayer and The Happiness Research Institute created a new evidence-based impact metric to help better prioritize investment in breakthrough innovations. This impact metric is called 'Wellbeing Adjusted Life Years' (WALY)'.

The theoretical basis for WALY was developed with our initial report in 2019, with the following years spent validating the metric and broadening its analytical usefulness. This report, 'Taking 10 Leaps for Humanity, 2022,' is the result of this work process, and it demonstrates WALYs' ability to conduct novel market analyses and forecast unrealized investment potentials.

To us, WALY is critical for validating how great innovation can drive betterment for humanity on top of the financial return and for this reason, WALY is to be adopted at Leaps by Bayer for portfolio analysis and for ensuring more informed decision-making.

But we also hope to inspire broader adoption. Ultimately, we believe the time has come for the industry to adopt an empirical approach to address the immense promise for improved well-being that the biotech can provide. Or, to put it another way, the Bio Revolution must become a Wellbeing Revolution.

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Head of Leaps by Bayer

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Intro—duction

From Return on Investment to Return for humanity

Since 2018, we, at Leaps by Bayer and The Happiness Research Institute, have continuously designed and improved the WALY metric to ensure that it's a valid measure for capturing people's true experience of life, while also being technically applicable for impact assessments.

In 2019 we published our pioneering report on the WALY-metric which included an in-depth introduction to the methodology, compiling evidence of its validity as well as a set of analyses using WALY to assess the potential wellbeing impacts of investing in various conditions and challenges including Parkinson's disease, depression, and air pollution. Link to 2019-report: https://www.hap-pinessresearchin- stitute.com/waly

This report takes a step further.

In this report we seek to quantify the potential wellbeing impact of overcoming ten major health- and agricultural-related challenges for humanity: the ten Leaps.

The ten Leaps are all addressing major challenges that, if resolved, could drive very significant positive change for human wellbeing. But very often these wellbeing impacts are highly complex. Take, for example, Leap 03, 'Reduce the environmental impact of agriculture.' If we were able to enhance modern agriculture and dramatically reduce its associated carbon emissions, it will, at first, have a direct impact on human wellbeing for the current as well as for the future generations through a reduction in air pollution, but it will also drive more indirect impacts. It is, for instance, known that carbon emissions cause weather variability and natural disasters, which are linked to more aggressive human behavior and poor livability, respectively. Such issues are extremely detrimental to human well-being and should not be overlooked in any impact analysis.

As a result, we're attempting to reinvent the concept of 'impact' by considering a broader range of consequences while continuing to rely on empirically sound and valid data. To achieve this, we have leveraged large-scale datasets as well as existing outputs and results from experimental and evaluative studies to provide empirically solid WALY-estimates of all the benefits that would follow if we could achieve the ten Leaps.

This report contains 10 chapters, one for each leap. In every chapter, we measure and address the WALY potentials for the leap, focusing on three different impact domains: Health, Community, and Stability.

When it comes to the influence on people's lives, traditional measuring of return on investment has left a significant blind spot. The WALY metric fills this gap, providing an evidence-based framework for assessing the potential to deliver meaningful impacts on health, environment, and wellbeing.

As a result, The WALY metric enables Leaps by Bayer to make investment decisions not only based on financial returns but also on the immense potential for the bio revolution to improve peoples' lives.

WALY or WELLBY?
Wellbeing Adjusted Life Years is emerging as a common currency for impact evaluation around the world, with the Treasury in the UK being one of the most prominent adopters. However, because various organizations and institutions contributed to the development and applicability of this metric, it has gone by various acronyms. While we chose to shorten Wellbeing Adjusted Life Years to 'WALY' in our first report in 2019, others have chosen 'WELLBY'. It is critical to note that these various acronyms do not reflect important methodological differences. WALY and WELLBY are measuring the same entity.

Methodology and approach

WALY as an impact measure

WALYs are a measure of time, weighted by wellbeing. They are calculated on a 0 to 1 scale, where 1 WALY can be understood as one year lived in full wellbeing. Individual life satisfaction data – survey measurements of how pleased people are with their lives – serve as the foundation for the metric. When calculating WALYs we make use of the following formula:

WALYs lost = 1 - (actual life satisfaction / potential life satisfaction).

In this case "actual life satisfaction" refers to the average life satisfaction of the target group (e.g., cancer patients or the people exposed to the consequences of climate change) and "potential life satisfaction" refers to the level of wellbeing these people would experience in the absence of the respective condition (measured by the life satisfaction of a reference group). Thus, when we consider the impact in terms of WALYs, any impact is expressed as a decimal number ranging from 0 to 1. For example, if a patient loses 0.04 WALYs to a condition - such as asthma - she can be said to lose 4% of the wellbeing she could have otherwise experienced. This would be the case if the average life satisfaction of asthma patients were, for example, 8.64 (out of 10 points), and the average life satisfaction of the reference group were 9 (out of 10 points): 1 - (8.64/9) = 0.4 WALYs lost. Moreover, these individual losses can be aggregated to reflect 'societal values' by multiplying the individual WALY impact value by prevalence and then by adding mortality rates.

As an example, asthma affects around 12,000,000 Europeans aged 50+, and the condition claims the lives of 5,481 people each year. Furthermore, people who have asthma lose 0.04 WALYs every year on average. Therefore, asthma is estimated to cost Europeans (50+) 487,145 WALYs per year. This value reflects the burden that any technology related to combating Asthma can potentially address and alleviate – either completely (if one invented a cure) or partially (if one invented a treatment).

In this report we are applying WALY to conduct novel market analyses to demonstrate both its methodological capabilities and its potential to uncover and assess investment possibilities. The analysis covers ten huge challenges for humanity that Leaps by Bayer is addressing and ultimately trying to resolve. These challenges are referred to as the ten 'Leaps'.

The 10 Leaps' impact on one's well-being manifest themselves in many ways and at various levels. Curing cancer, for example, will have a direct impact on patients, as well as a secondary impact on family members and caregivers. Furthermore, such advances benefit society as a whole, as they result in fewer hospitalizations and free up resources in hospitals. We assess and address the WALY potentials in three different impact domains for each Leap: Health, Community, and Stability:

Health

This domain compiles the health-related impacts. This covers direct impacts from cures or treatments targeted specific diseases, but also indirect health effects from agricultural leaps such as reduced air pollution.

Community

This domain refers to broader impacts that cannot simply be inferred by aggregating individual impacts. This for instance applies to indirect impacts on family members and caretakers for health-related leaps and social risks (e.g., risk of violence) due to climate change when addressing agricultural leaps.

Stability

This domain composes the indirect financial and security impacts of any leap. For instance, improving people's lives often generates saved financial costs over time, which, in turn, means that resources could be freed to invest in other means.

The 10 leaps

At Leaps by Bayer, transformative biotechnologies and digital solutions are leveraged to conquer ten huge challenges that could have enormous impact on humanity. These are referred to as 'the ten leaps.' While bearing a high risk of technological failure, achieving any of the leaps could fundamentally change the world for the better.

01 // Cure genetic diseases

Stopping genetic diseases before they develop, or progress could prevent chronic suffering and give many of us the chance to live a full and healthy life.

02 // Provide sustainable organ and tissue replacement

Cell and gene therapies hold tremendous promise to restore health, reverse the course of degenerative diseases and prevent organ failure.

03 // Reduce environmental impact of agriculture

From carbon sequestration to reducing land and water usage, innovation has the power to transform modern agriculture.

04 // Prevent and cure cancer

Biotechnology that leverages the immune system and other emerging platforms could make huge strides in the fight against cancer.

05 // Protect brain & mind

Neurodevelopmental and neurodegenerative disease along with mental health disorders represent a massive and growing unmet need with no simple solutions available.

06 // Reverse autoimmune diseases and chronic inflammation

Systematically addressing autoimmune diseases and chronic inflammation could enable lives free of pain, disease management, and life-threatening conditions.

07 // Provide next generation healthy crops

The Green Revolution lifted millions out of starvation, yet new approaches are needed to provide comprehensive nutrition at a global scale.

08 // Develop sustainable protein supply

Nourishing a global population will require new approaches to sustain both a healthy planet and healthy people.

09 // Prevent crop and food loss

A pandemic, climate volatility, and an increasingly long and complex supply chain expose the fragility of our global food system and the need for resilience.

10 // transform health with data

From wearable devices to artificial intelligence to protein modeling, digital technology is sparking a revolution in medicine.

Summary of insights

According to our estimates, achieving any of the Leaps could fundamentally change the world for the better.

We could save more than 2.5 million WALYs per year in Europe alone if we could end the organ shortage. This equals the potential WALYs saved if we could give a job to every unemployed US American. We will also be able to save around 5 million WALYs by 2050 if we could eliminate food insecurity in Sub-Saharan Africa, and we will be looking into a potential wellbeing benefit worth almost 5 million WALYs by 2050 if we could cut world agricultural emissions.

These are just a glimpse of the estimated impacts conducted for this report. In the table below we have mapped all the impact of the ten Leaps covered in this report.

The scores are based on the WALY assessments made in the respective chapters; however, because these assessments are not always comparable across domains and chapters, the scores listed below should only be considered indicative.

All impacts are rated on a scale from 1-5 (5 being the greatest impact) based on the insights presented in the table cells.

A ‘starting point’ for assessing the impact of biotechnology on human well-being

The findings presented in Table 0.1 and throughout this report should generally be regarded as an attempt to provide a serious starting point for assessing the impact of biotechnology on human wellbeing.

For this starting point, we have for each Leap chosen a set of cases to represent the problem being addressed. For instance, for Leap 1 (Cure Genetic Diseases) we are not conducting individual analyses on the more than 6,000 genetic diseases that are known today. Rather, we are primarily analyzing four genetically linked health problems: Sickle Cell Anemia, Alzheimer’s, Stroke and Parkinson’s.

Moreover, while some of the Leaps are fit for in-depth analysis as the effects and target groups are well-defined and the necessary data is readily available, others are highly complex as the effects are diverse and the data is limited. The complexity and data limitations are, in particular, a challenge for the agricultural Leaps, where the potential wellbeing consequences are frequently characterized by a variety of knock-on effects and uncertainties. In these cases, we have again not been able to analyze all associated knock-on impacts, but it has also, at times, been necessary to use proxy variables and methods that deviate from the conventional WALY-approach.

In summary, this report offers a starting point for assessing the impact of biotechnology on human well-being, by presenting wellbeing impact analyses of various large-scale challenges. As the challenges we are addressing are broad, complex, and at times hampered by a lack of data, the offered insights will be case-driven and subject to uncertainties. We encourage the readers to be mindful of this when reading the report.

Data used

In this report we have made use data from a range of source, but several og our analyses are based on ‘Survey of Health, Aging, and Retirement in Europe’ (SHARE). SHARE is an international survey of older populations in 29 European countries and Israel that has been conducted every two years since 2005. It contains detailed information on life satisfaction, health, socioeconomic status, and social networks of more than 150,000 individuals aged 45 or older. More information is available at www.share-project.org

Table 0.1 Impact overview

Leap	Health impacts (per 100.000 individuals)	Community impacts (per 100.000 individuals)	Stability impact (per 100.000 individuals)
1 Cure genetic diseases	Cure for sickle cell anemia (Global): **7.75 WALYs** Cure for Alzheimer's, stroke, and Parkinson's disease (Global): **123.3 WALYs** Impact rating / 3	Prevent heart attacks (Partner burden European union): **126.41 WALYs** Impact rating / 3	Cure genetic diseases among babies and paediatric patients (US): **13,6 WALYs** Impact rating / 2
2 Provide sustainable organ and tissue replacement	Cure Chronic Kidney Disease (CKD) (Germany): **947.89 WALYs** End organ shortage for CKD patients (European Union): **561.77 WALYs** Cure Parkinson's disease (European Union): **43.86 WALYs** Impact rating / 4	Cure CKD (Partner burden: European Union): **172.92 WALYs** End organ shortage (Partner benefit European Union): **418.05 WALYs** Cure Parkinson's disease (Partner burden European Union): **5.08 - 6.1 WALYs** Impact rating / 4	Lift economic burden of CKD transplants (Nordic countries): **24.94 WALYs** Lift economic burden of Parkinson's disease (UK): **6,38 WALYs** Impact rating / 2
3 Reduce environmental impact of agriculture	End agricultural contributions to air pollution (Europe): **145 WALYs** Impact rating / 3	Avoid rising crime rates brought on by climate change (US): **931.15 WALYs by 2100** Impact rating / 5	Avoid natural disasters from climate change, brought on by agricultural production (Globally): **62.22 WALYs from 2021 – 2050** Impact rating / 3
4 Prevent and cure cancer	Cure cancer (Globally): **361.02 WALYs per year** Impact rating / 4	Cure cancer (Partner burden: Globally): **Males: 15.65 WALYs** **Females: 21.91 WALYs** Impact rating / 3	Lift economic burden of cancer (UK & Spain): **UK: 131.95 WALYs** **Spain: 363.67 WALYs** Impact rating / 4
5 Protect brain & mind	Cure depression (Germany): **402.86 WALYs** Impact rating / 4	Cure depression (Partner burden: Germany): **Males: 138.75 WALYs** **Females: 201.82 WALYs** Impact rating / 4	Lift economic burden of depression (US): **1201.51 WALYs** Impact rating / 4
6 Reverse autoimmune diseases and chronic inflammation	Cure all autoimmune diseases (Europe): **533.27 WALYs** Impact rating / 5	Cure autoimmune diseases (Partner burden: European Union): **Type -1 diabetes: 7.71 WALYs** **Rheumatoid arthritis: 5.31 WALYs** **Multiple sclerosis: 16.33 WALYs** Impact rating / 4	Lift economic burden of autoimmune diseases (Europe): **Between 39.94 and 128.64 WALYs** Impact rating / 3
7 Provide next generation healthy crops	End obesity (UK): **1516 WALYs** Impact rating / 5	End obesity (Partner burden: UK): **BMI of 30-34.9: 352.94 WALYs** **BMI of 35-39.9: 208.55 WALYs** **BMI of 40+: 181.82 WALYs** Impact rating / 3	Lift economic burden of obesity (Germany): **Between 47.68 - 128.6 WALYs** Impact rating / 3
8 Develop sustainable protein supply	Vegetarianism: **Adults with low consumption of meat: +15% more satisfied with their health, but men and women who eat meat are slightly more satisfied with their lives than non-meat-eating counterparts** Impact rating / 1	End Deforestation: **Deforestation accounts for 20 % of all climate-related WALY losses documented in this report** Impact rating / 5	Transitioning away from unsustainable agriculture: **The economic impact of transitioning away from unsustainable agriculture is complex and consist of several long term positive cascade effects. However, it's important to be mindful of the immediate short-term potential inequality issues regarding distribution of economic benefits. All things being equal, our analysis suggest that Europeans are anticipated to profit from unsustainable agriculture, while individuals in other regions, particularly Africa, are expected to experience a loss of WALYs.** Impact rating / 2
9 Prevent crop and food loss	End food loss (Nigeria): **1,807 WALYs** Impact rating / 5	Avoid food insecurities caused by deteriorating climate change (India and Sub-Saharan Africa): **195.18 WALYs** Impact rating / 4	
10 transform health with data	Lift economic burden of conventional healthcare using telehealth (US): **9.6 WALYs** Increase life expectancy in Sub-Saharan Africa (to reach 60.4 years) using telehealth: **17,543 WALYs** Detect and care for 10% more of people suffering from depression using predictive medicine (US): **34.1 WALYs** Prevent 5% heart attacks and strokes using AI (Europe): **10 WALYs** Impact rating / 4		

Calculations for Table 0.1

1 Cure for sickle cell anemia (Global total): WALY-coefficient (0.10 WALYs) x Prevalence (5.7 million) + deaths (41,900) = 610,000 WALYs.

Cure for sickle cell anemia (Global per 100,000): WALYs total (610,000) / Global population (7.8 billion) * 100,000 = 7.75 WALYs.

2 Cure for Alzheimer's, stroke and Parkinsons: (EU total): Weighted average of WALY-coefficients (0.089) x Prevalence (17,394,761.38) + deaths (902,168) x percent attributable to genetic influence (22.4%) = 549,311 WALYs.

Cure for Alzheimer's, stroke and Parkinsons (EU per 100,000): WALYs total (549,311) / population EU (445,307,650) * 100,000 = 123.36 WALYs.

3 Partner burden of heart attacks (per 100.000): Prevalence (599,945,560.17) x share of population with partners (66.6%) x WALYs lost per partner (0.03) / population European union (445,307,650) x theoretical potential avoided heart attacks (47%) x 100,000 = 126.41 WALYs

4 Cure genetic diseases (US per 100,000): WALYs saved in the US total (45,200) / US population (332,915,074) x 100,000 = 13.6 WALYs.

Calculation for economic cost converted to the total yearly WALYs saved in the US (45,200) is shown in chapter 1.

5 Cure for CKD (Germany total): WALY-coefficient (0,88) x Prevalence (8,660,366) + Mortality (35,047.18) = 795,285.27 WALYs

Cure for CKD (Germany per 100.000): WALY total (795,285.27) / German population (83.900.471) x 100.000 = 947.89 WALYs

6 End organ shortage for CKD patients (European Union total): WALY-coefficient (0,88) x Prevalence (41,749,294.74) x share of patient's stage 3-5 (65%) + Mortality (119,425.99) = 2,501.613,42 WALYs

End organ shortage for CKD patients (European Union per 100,000): WALYs total (2,501.613,42) / EU population (445,307,650) x 100.000 = 561.77 WALYs

7 Cure for Parkinsons (EU total): WALY-coefficient (0.095 WALYs) x Prevalence (1,338,453) + deaths (63,423) = 195,301 WALYs.

Cure for Parkinsons (EU per 100,000): WALYs total (195,301) / population EU (445,307,650) * 100,000 = 43.86 WALYs.

8 Partner burden of CKD (European Union per 100.000): Prevalence (41,749,298.74) x share of population with partners (63.6%) x WALYs lost per partner (0.029) / population European union (445,307,650) x 100,000 = 172.92 WALYs

9 Partner benefit from ending organ shortage (European Union per 100,000): Prevalence stage 3-5 CKD (27,137,041.58) x share of population with partners (70%) x WALYs lost per partner (0.098) / population European union (445,307,650) x 100,000 = 418.05 WALYs

10 Partner burden of Parkinson's disease (Europe per 100,000): Prevalence (1,388,453.93) x share of population with partners (65.2%) x WALYs lost per partner (0.025 to 0,03) / population European union (445,307,650) x 100,000 = 5.08 - 6.10 WALYs

11 Economic burden of CKD transplants (Nordic countries per 100,000): WALYs saved in the Nordic countries total (6,730) / Nordic population (26,987,451) x 100,000 = 24.94 WALYs

Calculation for economic cost converted to total WALYs saved (6,730) is shown in chapter 2.

12 Economic burden of Parkinson's disease (UK per 100,000): Total WALYs saved in UK (4,350) / population (68,207,114) x 100,000 = 6.38 WALYs

Calculation for economic cost converted to total WALYs saved (4,350) is shown in chapter 2.

13 End agricultural contributions to air pollution (Europe total): WALY-coefficient (0.039) x contributions from pollution (5%) x population (748,962,983) = 1,085,996.33 WALYs

End agricultural contributions to air pollution (Europe per 100.000): WALYs total (1,085,996.33) / population (748,962,983) x 100,000 = 145 WALYs

14 Rising crime rates brought on by climate change (US per 100.000): Total WALYs (3,040,000) / population (332,915,074) x 100,000 = 931.15 WALYs

Calculations for total WALYs (3,040,000) is shown in chapter 3.

15 Economic burden of natural disasters from climate change by agriculture production (Global per 100,000): Total WALYs saved (4,900,000) / population (7,874,965,730) x 100,000 = 62.22 WALYs

Calculation for economic cost converted to total WALYs saved (4,900,000) is shown in chapter 3.

16 Cure for cancer (Global total): WALY-coefficient (0.04 WALYs) x Prevalence (472,397,254) + deaths (9,534,619) = 28.403,509.16 WALYs.

Cure for cancer (Global per 100,000): WALYs total (28.403,509.16) / Global population (7.8 billion) * 100,000 = 361.02 WALYs.

17 Partner burden of Cancer (Global per 100,000): Prevalence (85,831,226.83) x share of population with partners (71,8%) x WALYs lost per partner (0.02 (male) to 0.028 (female)) / population global (7,874,965,730) x 100,000 = 15.65 to 21.91 WALYs

18 Economic burden of cancer (UK per 100,000): Total WALYs saved (90,000) / population (68,207,114) x 100,000 = 131.95 WALYs

Calculation for economic cost converted to total WALYs saved (90,000) is shown in chapter 4.

19 Economic burden of cancer (Spain per 100,000): Total WALYs saved (170,000) / population (44,745,211) x 100,000 = 363.67 WALYs

Calculation for economic cost converted to total WALYs saved (170,000) is shown in chapter 4.

20 Cure for depression (Germany total): WALY-coefficient (0.18 WALYs) x Prevalence (1,844,714) + deaths (0) = 337,687.87 WALYs.

Cure for depression (Germany per 100,000): WALYs total (337,687.87) / population Germany (83,900,471) * 100,000 = 402.49 WALYs.

21 Partner burden of depression (Germany per 100,000): Prevalence (3,492,813.78) x share of population with partners (60.6%) x WALYs lost per partner (0.055 (male) to 0.08 (female)) / German population (83,900,471) x 100,000 = 138.75 to 201.82 WALYs

22 Economic burden of depression (US per 100,000): Total WALYs saved (4,000,000) / population (332,915,074) x 100,000 = 1201.51 WALYs

Calculations of economic cost converted to total WALYs saved (4,000,000) is shown in chapter 5.

23 Cure for all autoimmune diseases (Europe total): WALY-coefficient (0.132) x prevalence (29,958,519) + death (39,462) = 3,993,987 WALYs

Cure for all autoimmune diseases (Europe per 100.000): WALYs total (3,993,987) / population (748,962,983) x 100,000 = 533.27 WALYs

24 Partner burden type –1 diabetes (EU per 100,000): Prevalence (3,601,235.38) x share of population with partners (68.2%) x WALYs lost per partner (0.013) / population European union (445,307,650) x 100,000 = 7.17 WALYs

25 Partner burden of Rheumatoid arthritis (EU per 100.000): Prevalence (2.074.521.43) x share of population with partners (63.3%) x WALYs lost per partner (0.018) / population European union (445,307,650) x 100,000 = 5.31 WALYs

26 Partner burden of multiple sclerosis (EU per 100.000): Prevalence (549,691.84) x share of population with partners (70%) x WALYs lost per partner (0.189) / population European union (445,307,650) x 100,000 = 16.33 WALYs

27 Economic burden of autoimmune diseases (Europe per 100,000): Total WALYs saved (299,138 (lower range) to 107,900 (upper range) / population (748,961,983) x 100,000 = 39.94 to 128.64 WALYs

Calculation for economic cost converted to total WALYs saved (299,138 and 107,900) is shown in chapter 6.

28 End obesity (UK total): WALY-coefficient ((0.5) BMI [30 - 39,9], (0,1) BMI 40+) x prevalence ((15,687,636) BMI [30 - 39,9], (2,046,213) BMI 40+) + death (45,390) = 1,034,393 WALYs

End obesity (UK per 100.000): WALYs total (1,034,393) / population (68,207,114) x 100,000 = 1,516.55 WALYs

29 Partner burden of obesity BMI 30-34.9 (UK per 100.000): Prevalence (11,254,173.81) x share of population with partners (71.13%) x WALYs lost per partner (0.03) / population European UK (68,207,114) x 100,000 = 352.09 WALYs

30 Partner burden of obesity BMI 35-39.9 (UK per 100.000): Prevalence (4,433,462.41) x share of population with partners (71.13%) x WALYs lost per partner (0.045) / population European UK (68,207,114) x 100,000 = 208.06 WALYs

31 Partner burden of obesity BMI 40+ (UK per 100.000): Prevalence (2,046,213.42) x share of population with partners (71.13%) x WALYs lost per partner (0.09) / population European UK (68,207,114) x 100,000 = 181.38 WALYs

32 Economic burden of obesity (Germany per 100,000): Total WALYs saved (40,000) / population (83,900,471) x 100,000 = 47.68 WALYs

Calculation for total WALYs saved (40,000) is shown in chapter 7.

33 Economic burden of obesity including lost GDP due to obesity (Germany per 100,000): Total WALYs saved (107,900) / population (83,900,471) x 100,000 = 128.6 WALYs

Calculation for economic cost converted to total WALYs saved (107,900) is shown in chapter 7.

34 End food loss (Nigeria total): WALY-coefficient (0.329 WALYs) x Prevalence (11,596,700 million) + deaths (0) = 3,820,987 WALYs.

End food loss (Nigeria per 100,000): WALYs total (3,820,987) / Nigerian population (211,400,704) x 100,000 = 1,806.99 WALYs

35 Avoid food insecurity (per 100.000): Total WALYs (5 million) / population Sub Saharan Africa and India (2,561,781,463) x 100,000 = 126.41 WALYs

36 Lift economic burden of conventional healthcare using telehealth (US per 100.000): Total WALYs (32,000) / population US (332,915,074) x 100.000 = 9.61 WALYs

37 Increase life expectancy to reach 60.4 years using telehealth (Sub-Saharan Africa per 100,00): Total WALYs (227,854,240) / Population Sub-Saharan Africa (1,107 billion) x 100.000 = 17,543 WALYs

38 Detect and care for 1% more of people suffering from depression using predictive medicine (US per 100,000): Total WALYs (113,435) / Population US (332,915,074) x 100,000 = 34.1 WALYs

39 Prevent 5% heart attacks and strokes using AI (Europe per 100,000): Heart attacks: Total WALYs (37,229 WALYs) / Population Europe (748,962,983) x 100,000 = 4.97 WALYs. Stokes: Total WALYs (37,593WALYs) / Population Europe (748,962,983) x 100,000 = 5.02 WALYs.

Leap 01

Cure genetic diseases

The problem

There are trillions of cells inside the human body, each containing about two meters of DNA. Together, our cells contain enough DNA to stretch across the length of the solar system.[1] Within each cell, this DNA is tightly packed into structures called chromosomes. The function of most of our DNA – about 98% – is still unknown.[2] However, some important sections act as instruction manuals for our cells to create proteins and amino acids, which influence and determine our physical characteristics. These are our genes.

Genes are essential in determining whether we have straight or curly hair, blue or brown eyes, free or attached earlobes, and thousands of other traits. We each have 20,000 to 25,000 genes in total, almost all of which we share with everyone else. All the observable genetic differences between people arises from variations in less than 0.1% of our genes.[3] Some of these differences can have more serious consequences than others. Abnormalities in certain gene sequences can be the source and basis of genetic diseases.

More than 6,000 genetic diseases have been identified by researchers, and the list is growing every day.[4] They fall into three categories: single gene, multifactorial, and chromosomal (Table 1.1).[5]

Table 1.1 Types of genetic disorders

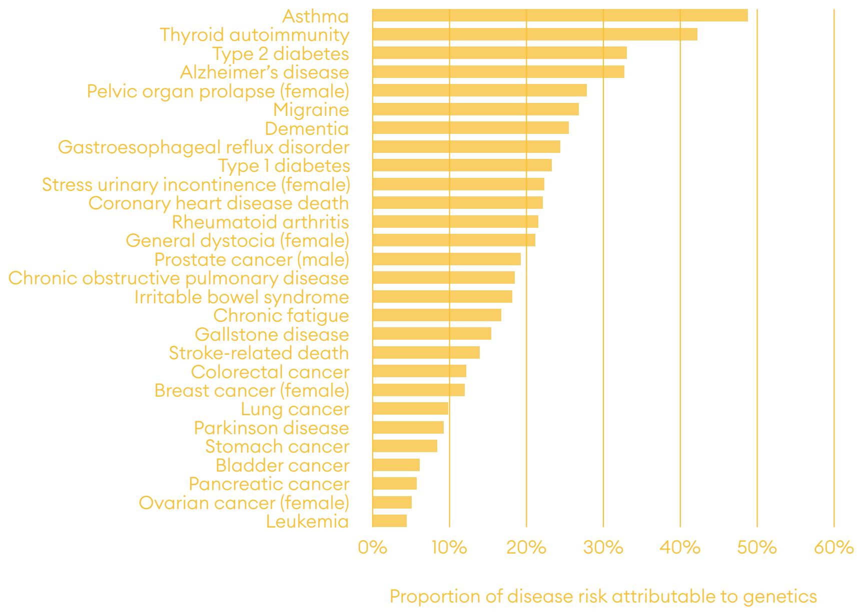
	Single gene disorders	Multifactorial disorders	Chromosomal
Description	A single abnormality causes one gene to stop functioning properly. These diseases can be dominant, recessive, or X-linked.	A variety of mutations in different genes, often in conjunction with environmental or behavioral factors, combine to produce a given disease.	An entire chromosome, or large segments of it are missing, copied, or otherwise affected.
Rate	≈ 7% of genetic diseases	≈ 88% of genetic diseases	≈ 3% of genetic diseases
Examples	Sickle cell anemia Cystic fibrosis Muscular dystrophies Tay-Sachs	Epilepsy Diabetes Cleft palate Alzheimer's	Down syndrome

Source World Health Organization (2020), Vermi & Puri (2015)

While sickle cell anemia, cystic fibrosis, and Down syndrome are some of the most widely known and well-understood genetic diseases, the class of single-gene disorders they belong to makes up less than 10% of all genetically influenced diseases and disabilities. The vast majority are "multifactorial" or "complex" genetic diseases. These arise from contributions of multiple genes interacting with each other and the surrounding environment. At least some type of genetic influence is assumed to play a role in almost all health conditions and diseases. Diabetes, asthma, congenital heart disease, obesity, Alzheimer's disease, and cancer have all been identified to be at least partly genetically influenced, though there are thousands more examples.

One of the most common approaches to estimating the genetic influence of diseases is to consider cases of identical twins. Controlling for environmental factors, diseases that affect twin pairs are more likely to be genetically influenced. One study conducted along these lines in Western Europe found that rates of genetic predispositions for 28 chronic diseases ranged from 3.4% for leukemia to 48.6% for asthma (Figure 1.1).[6] Another recent study on the largest twin dataset ever assembled in the United States found that genetic influence accounted for 40% of the more than 500 diseases under consideration.[7]

Figure 1.1 Genetic influence of major diseases



Source Rappaport (2016)

What if?

What if babies born with cystic fibrosis or sickle cell anemia could be treated with successful gene therapies in the first months of life, preventing these diseases from ever taking hold? What if CRISPR gene editing could be used to prevent Alzheimer's, Parkinson's, and other degenerative conditions? In what follows, we will discuss several genetic diseases to illustrate the types of wellbeing effects they can have on patients, caregivers, and society. In doing so, we will also bring to light some of the wellbeing burdens that could be reduced by improved genetic screening and therapies targeted to alleviate them.

Health impact

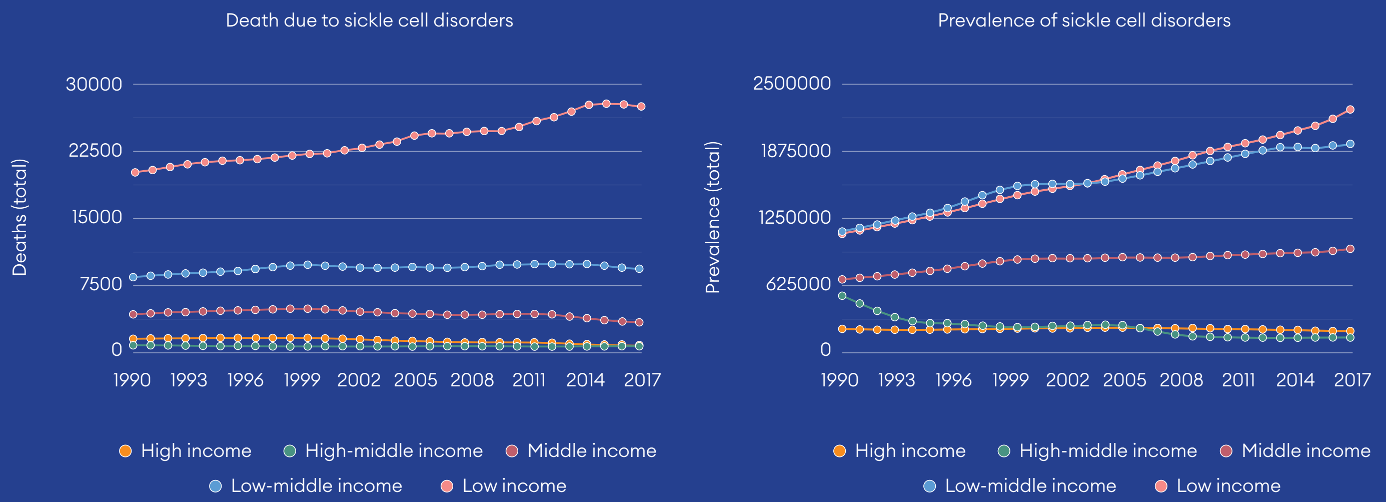
Wellbeing burdens of sickle cell disease

To illustrate how the health effects of genetic disease can impact wellbeing, this section will provide a case study of sickle cell anemia. We will first focus on wellbeing burdens experienced by patients themselves, before analyzing community and societal burdens in later sections.

Sickle cell anemia is the most inherited blood disorder in humans. Patients suffering from the disease produce red blood cells that take on a curved sickle shape, causing them to break down faster than typical healthy blood cells and resulting in a chronic shortage of red blood cells. Patients can develop any number of health conditions including swelling, infections, stroke, and perhaps most often, pain. The life expectancy of sickle cell patients ranges from 40 to 60 years, relative to the global average life expectancy of 70 to 75 years.[8]

The recessive sickle cell gene is believed to have evolved as a natural resistance to malaria and is primarily found in people of African descent. An estimated 80% of disease cases are concentrated in Sub-Saharan Africa.[9] In some parts of Uganda, population prevalence rates can climb to 45%.[10] The disorder is also common in India and parts of the Arabian peninsula.[11] In the United States, more than 100,000 people are estimated to have sick cell anemia, primarily African-Americans.[12] The overall prevalence of sickle cell disorders has increased by 40% since 1990[13] and each year 300,000 babies are born with the disorder, with many of them dying within the first five years of life.[14] Today, more than 3 million people around the world live with the disease, and more than 460 million people carry the sickle cell gene.[15]

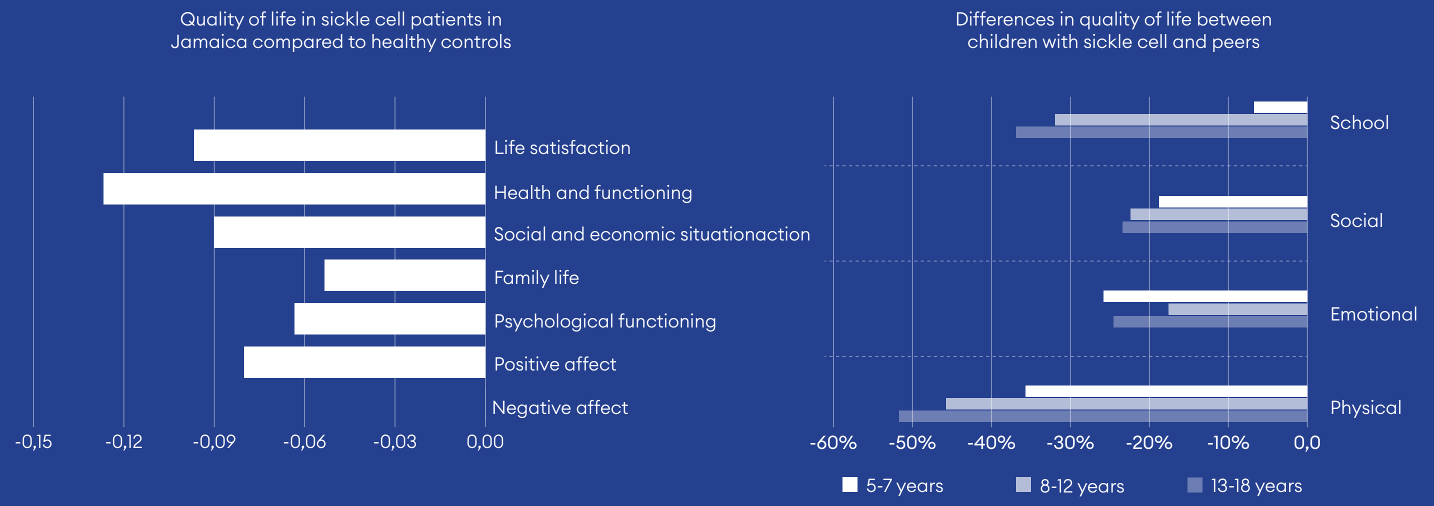
Figure 1.2 Sickle cell disorders by global economic region



Source Global Burden of Disease Collaborative Network (2020)

Realities such as depicted in the figure above can translate into significant wellbeing burdens. The disease subjects patients to continuous physical changes, making it exceedingly difficult to adapt to. Sickle cell patients are more likely to report negative evaluations of their social, psychological, and economic functioning, as well as lower levels of lower positive affect.[16] African-Americans with sickle cell anemia are more likely to suffer from depression, as well as mood and alcohol related disorders than healthy counterparts.[17] One study conducted in Brazil found that children under the age of 18 with sickle cell anemia scored lower than their peers in physical, emotional, social, and educational wellbeing domains (Figure 1.3).[18] In another analysis, Jamaican patients with sickle cell anemia were found to be 10% less satisfied with their lives than healthy controls (Figure 1.3).[19] This is roughly akin to the difference in average life satisfaction between Sweden and El Salvador.[20]

Figure 1.3 Quality of life among sickle cell patients



Note Positive and negative refer to the frequency and intensity of experienced positive or negative emotional states – e.g. sadness, joy, anxiety, etc. – or simply, mood.
Source Thomas & Lipps (2011), Menezes et al. (2012)

While no cure for sickle cell disease currently exists, advances in genetic screening and gene therapy could have staggering implications for the wellbeing of current patients, and future generations. In 2019, there were roughly 5.7 million people living with sickle cell disorders around the world in total, of which 41,900 patients lost their lives due to the disease.[21] **In terms of Wellbeing Adjusted Life Years (WALYs), even conservative estimate therefore suggests that curing the disease among living patients could have saved more than 610,000 WALYs in that year alone, more than five times the potential wellbeing gain from eradicating skin cancer around the world.[22]**

Looking forward, the estimated number of babies born with sickle cell anemia each year is also expected to rise from approximately 300,000 today to more than 400,000 in 30 years.[23] Most of this increase will occur on the African continent. Developing a cure for the disorder therefore has the potential to extend the lives of more than 10,000,000 children born with the disease by 2050.[24]

Genetic determinants of other major diseases

In the last section we considered the patient wellbeing burdens associated with sickle cell anemia. However, as noted in the introduction of this chapter, most genetic diseases are not single gene disorders, but instead involve the interaction of multiple genes and environmental factors. Examples of these sorts of diseases include Alzheimer's, stroke, and Parkinson's disease. While genetics play a role in vastly more common diseases and disabilities, given the high rates of mortality and disability associated with these three major diseases, they can provide a uniquely useful case study to examine the potential benefit of genetic interventions. In this section, we will therefore consider the prevalence, mortality, genetic influence, and individual wellbeing burdens of each of these major diseases. In doing so, we can then estimate the overall potential benefit in developing successful genetic therapies to treat them. Our population of interest in this case will be European adults.

In a previous report, we estimated individual wellbeing burdens for each disease among European adults using the nationally representative Survey of Health, Aging, and Retirement in Europe (SHARE).[25] The most burdensome disease in question proved to be Parkinson's disease, which reduced patient wellbeing by an average of 9.3%. The corresponding figures for Alzheimer's disease and stroke are 9.1% and 6.9%, respectively.

To estimate the overall potential benefit of genetic testing and screening for each disease, we also need to account for the total number of patients in Europe. This information was gathered from the Global Burden of Disease dataset.[26] Out of the three diseases in question, strokes were by the most common, affecting around 7.4 million European adults per year. **To estimate the wellbeing burden of each disease among living patients, we can then multiply WALYs lost per patient by the total number of patients in Europe. This exercise produces a total wellbeing loss of 2.45 million WALYs among European adults.[27] However, in this case, as we are only considering the genetic influence of major diseases, we then need to rescale this overall burden by the percent attributable to genetic influence. This reduces the overall wellbeing burden among living patients to 549,000 WALYs lost.[28]**

Finally, when thinking about the burden of disease on a population level, we need to account not only for wellbeing burdens among living patients, but also wellbeing lost due to deaths attributable to each disease. Overall, of all the deaths in Europe in 1999, one study estimated 16.8% to be attributable to genetics. Another more recent analysis in 2019 on the largest twin dataset ever assembled in the United States found that genetic influence accounted for 40% of the more than 500 diseases under consideration.[29] Even conservatively adopting the lower estimate of the first study would imply that, of the 1.28 million deaths reported in Western Europe in 2000, 16.8% could have been attributed to genetics.[30] Carried forward to today, this would suggest that more than 856,800 lives were lost to genetically influenced diseases in Western Europe in 2016 alone.[31] Overall, these figures imply that roughly 9.5 million lives could be saved every year by developing cures and effective treatments to eradicate genetic disease.

When we limit our view to the burden of the three diseases in question – Alzheimer's, Parkinson's, and stroke – we find in our sample population of European adults that, of the more than 1.1 million annual deaths due to all diseases in total, roughly 22.4 percent (or 205,000) can be attributed to genetic influence. The majority of these occurred in Germany, Italy, and France, given the sizeable populations of older adults in each country.[32] The highest rates of death due to genetically influenced disease were observed in Bulgaria, Romania, and Latvia.[33]

Finally, to estimate the total potential return for humanity by curing the genetic influence, we combine both figures – WALYs lost among living patients and WALYs lost due to death. These figures are represented graphically in Figure 1.4.[34] Given the high prevalence of each disease among older populations in Europe, coupled with the trend in demographic aging in almost every European country, it would be quite difficult to overstate the potential benefit of alleviating these wellbeing burdens to individuals, caregivers, parents, and society writ larger with further improvements in genetic testing, screening, and eventual cures.

Figure 1.4 Potential WALYs saved by alleviating genetic influence of disease in Europe (per 100,000)

Note Authors' calculations using SHARE and GBD data.

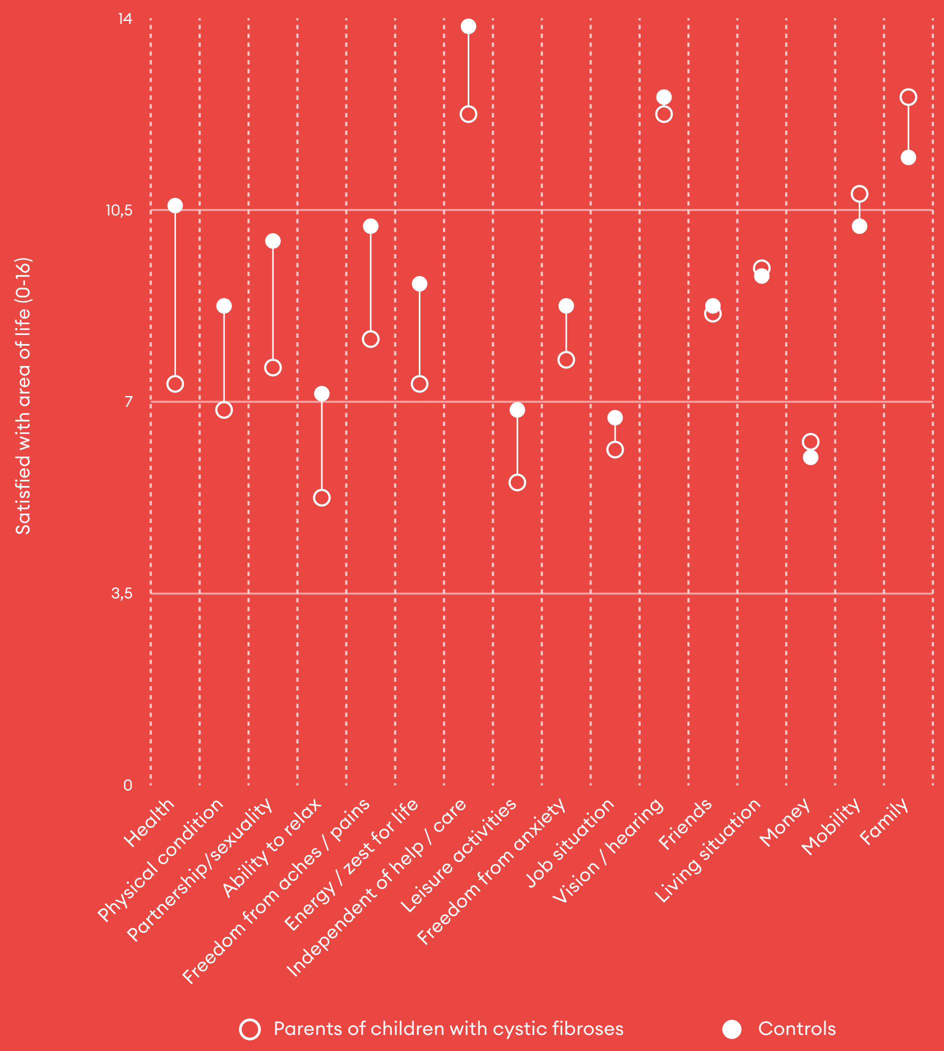
Community impact

Community burdens of cystic fibrosis and heart attacks

In the last two sections, we considered the direct health consequences of genetic diseases on patients themselves, and the potential benefits of developing successful therapies to treat them. In turn, the benefits of curing disease would then extend to parents, caregivers, families, and communities. To illustrate these dynamics, this section will provide a case study of cystic fibrosis and heart attacks – both of which have been found to be at least partly genetically influenced – to highlight potential benefits of successful cures or treatments for both diseases that could be delivered to parents and partners of patients. In this case, our focus will be on Europe and the United States.

Let's begin with cystic fibrosis. In one analysis of 650 parents of children with cystic fibrosis in Germany, parents scored lower on several wellbeing dimensions relative to parents with healthy children (Figure 1.5).[35] They were significantly more likely to experience symptoms of depression and anxiety, and rated their own satisfaction with their health, ability to relax, partnerships, and energy up to 30 percent lower than counterparts. Overall, parents of children with cystic fibrosis were 4.2 percent less satisfied than the control group.[36] If this is taken to be representative, it would translate into significant community burdens. **In the United States alone, 31,199 people were diagnosed with cystic fibrosis in 2019, 46 percent of whom were under the age of 18.[37] This would imply an annual wellbeing burden of 1,148 WALYs lost among American parents of children with cystic fibrosis.[38]**

Figure 1.5 Quality of life for parents of patients with cystic fibrosis



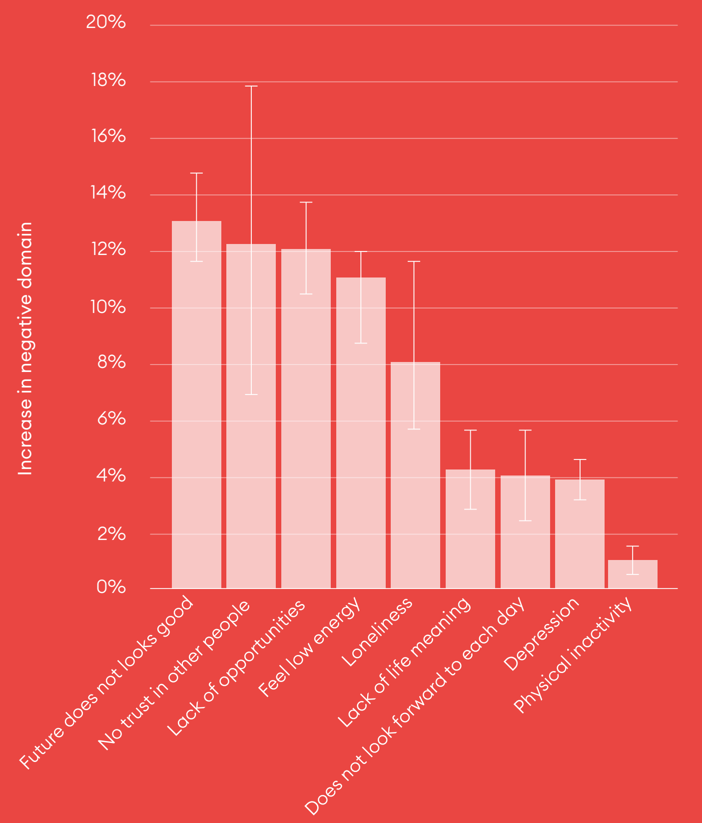
Source Beiser et al. (2011)

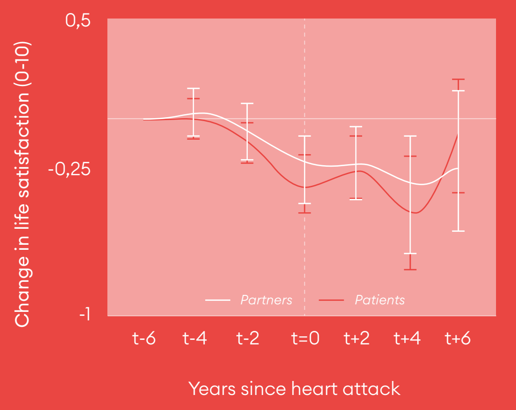
These community burdens do not only affect parents of children living with a genetic disease. Even among adults, wellbeing burdens can also extend to partners. In this case, it is worth considering the case of cardiovascular disease. Heart disease is the number one leading cause of death around the world, accounting for roughly one out of every three total deaths each year. Of these, 85 percent are due to heart attacks and strokes. Both genetic and behavioral factors have been identified as key drivers of heart disease, and there is often complex interactions between them.[39] Behavioral and social risk factors include gender (heart disease is more prevalent among males), weight, diet, exercise, smoking, poverty, and stress.[40] Genetic influence has also been identified in family history and twin studies.[41] One of the most widely cited longitudinal studies of 20,966 twins in Sweden estimated the heritability of heart disease to be 57 percent for males and 38 percent for females.[42]

Improved genetic screening therefore has the potential to alleviate enormous wellbeing burdens not only among patients themselves, but also the associated burdens that accrue to partners and family members. To further investigate these potential impacts, we turn to an analysis of SHARE data on the health and happiness European adults.

Even for those who survive, we find that wellbeing loses associated with heart attacks for partners of patients can be dramatic. Using linear regressions controlling for age, gender, education, employment, income, wealth, residential area, number of children, year, and country, we find that partners of those who suffer a heart attack are significantly more likely to experience lower quality of life than controls with healthy partners (Figure 1.6). The former is more than 10% less likely to be optimistic, trust others, feel that life is full of opportunities, and have energy. They are also 4% more likely to be depressed and 8% lonelier than those with healthy partners.43 This picture is only reinforced when we consider partner wellbeing associated with heart attacks over time. The wellbeing trajectory of both partners and patients in the wake of a heart attack proceed almost exactly in tandem with one another. Even four years after the fact, the life satisfaction of both groups is roughly 0.3 points lower on scale from 0 to 10 than it was ten years before (Figure 1.6).

Figure 1.6 Wellbeing among partners of patients with a heart attack





Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

Yet, by only looking at partners of patients who survive heart attack, even these figures dramatically underestimate the true wellbeing cost of heart disease. Once the high mortality rate of heart attacks is accounted for, these burdens grow substantially. As we discuss in more detail later in this report, experiencing the death of a partner has profound impacts on subjective wellbeing, resulting in 0.13 WALYs lost in the first twelve months.[44] In 2019, heart disease accounted for the deaths of 1.97 million adults in Europe, approximately 59 percent of whom were married.[45] **This suggests that 1.16 million WALYs were lost just by partners of patients who died of heart attacks that year, almost half of this which (47%) could have been theoretically saved with successful genetic screening and treatments.[46]**

Stability impact

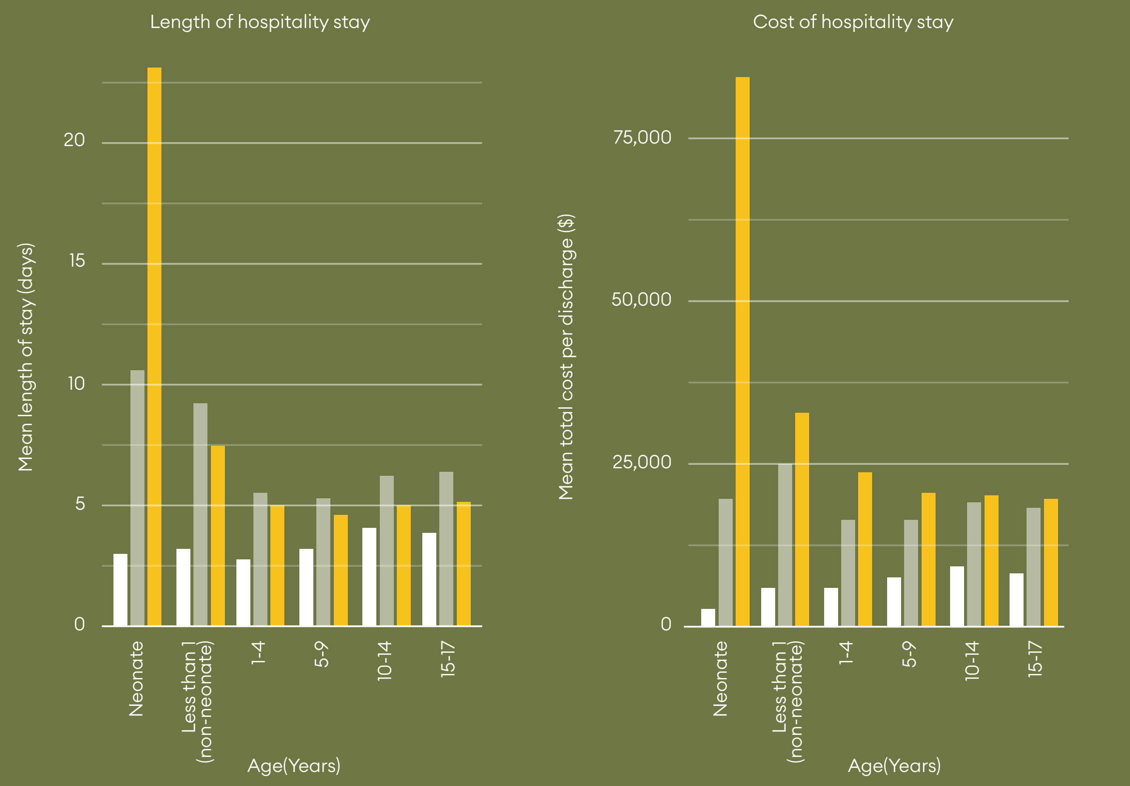
Economic burdens of pediatric genetic disease

Throughout this chapter, we have considered the direct and indirect impacts of genetic diseases on patients, parents, and partners through health and community channels. While these are substantial, they alone do not capture the true societal burden of genetic disease. In addition to the direct consequences for those affected, the price tag for treating and caring for patients with genetic disease can also become substantial. In many countries around the world, this burden is paid for with out-of-pocket expenses by patients, family members, and communities. In many developed countries, national healthcare and insurance schemes pick up the tab. Nevertheless, this economic burden represents yet another hidden cost of genetic disease. What if these resources could be directed elsewhere in society? What is the true wellbeing burden of the economic costs associated with treating genetic disease? To help answer these questions, we will turn our attention to a case study of genetic disease among children in the United States.

In recent years, several careful studies have attempted to account for the added economic burden of childhood genetic disease on the American healthcare system. In one analysis of a children's hospital in Cleveland, Ohio, researchers analyzed 98% of patients admitted to the hospital over the course of one year. Of all children admitted, more than 70% had an underlying disorder with a significant genetic component. Overall, out of total cost of all hospital admissions in that year, 80% ($50 million) was spent on children with conditions that were entirely or at least partly genetically determined. In other words, four out of every five dollars spent at the hospital in that year were spent on genetic disease. In large part, this could be attributed to longer stays for children with genetic disorders. The average length of stay for children with genetic disorders was reported to be 40% longer than for children without.[47]

This tells the story of just one hospital, though it is suggestive of broader national trends. In another study, a team of researchers analyzed a nationally representative database of pediatric hospital admissions in the United States. Of the 5.85 million total admissions considered, roughly 14% of patients reported some type of underlying genetic disorder. Relative to children without any genetic disorder at all, the cost of hospital visits for patients with genetic conditions was $12,000 to $17,000 higher. Once again, this gap in treatment burdens was primarily attributed to differences in the length of hospital stays (Figure 1.7). These differences were even larger for babies with and without genetic disease. Average costs of hospital stays for babies with any underlying genetic conditions were on average $77,000 more than babies without any genetic disease. Overall, when these costs are aggregated across the total population, hospital costs associated with genetic disease in children total to $57 billion, or 46% of the total national bill for pediatric patients in the year of the study.[48]

Figure 1.7 Increased length of hospital stays and associated costs for children with genetic disorders



Patients without genetic desease
Patients without genetic desease as the primary diagnosis
Patients with any genetic desease

Note "Patients with genetic disease as the primary diagnosis" refers to patients who are in the hospital for reasons directly related to their genetic disease. "Patients with any genetic disease" refers to patients who are in the hospital for reasons not directly related to their genetic disease.
Source Beiser et al. (2011)

We can now take one final step back and convert these economic burdens of genetic disease in the United States to Wellbeing Adjusted Life Years. To this end, we can rely on a modified form of "wellbeing valuation."[49] Simplified, by considering the relationship between subjective wellbeing and income, we can ask how much wellbeing could be saved if the financial burdens of genetic disease were eliminated and converted into income. While this is obviously a theoretical exercise, it can help to contextualize the broader societal burden of genetic disease. Converted into Wellbeing Adjusted Life Years, this exercise would therefore suggest that **alleviating the economic burden of genetic disease among babies and pediatric patients in the United States would save approximately 45,200 WALYs each year.[50] To put this figure into context, it would be roughly equivalent to the expected wellbeing benefit of doubling the incomes of more than 1.5 million middle class Americans.** As large as these benefits may be, even they may be underestimated. Children who visit the hospital due to genetic diseases and disorders often miss days of school, which can have even more long-lasting effects on their development.[51] Throughout this chapter, we have attempted to provide several illuminating case studies and insights into the potential wellbeing benefits of developing successful treatments and cures for genetic disease. However, these analyses are not intended to be comprehensive. Given the variety of possible benefits and dynamics we have not considered that lay beyond the scope of this analysis, it is more than likely that even these substantial returns for humanity are underestimated. Nevertheless, it is unquestionable that curing genetic disease could help to alleviate substantial wellbeing burdens for patients, partners, parents, communities, and societies around the world.

Impact summary

In this chapter, we have presented how effective solutions targeted patients with genetic diseases holds the potential to alleviate critical wellbeing burdens in society.

Health impact

When considering single gene disorders, we find that if health technology become capable of curing sickle cell anemia, it's possible to save more that 610,000 WALYs in the year of intervention and extend the lives of 10,000,000 children born with the disease by 2050.

However, as noted in the introduction of this chapter, most genetic diseases are not single gene disorders, but instead involve the interaction of multiple genes and environmental factors. Examples of these sorts of diseases include Alzheimer's, stroke, and Parkinson's disease.

When predicting the potential impact by curing the genetic influence for these three diseases, we identify an existing wellbeing burden in European countries ranging from 29,173 WALYs lost per 100,000 people to 56,471 WALYs lost per 100,000 people.

Community impact

The social cascade effects of genetic diseases are also noticeable for parents and among partners.

Alone in the United States, 31,199 people were diagnosed with cystic fibrosis in 2019, 46 percent of whom were under the age of 18. We find this to imply that American parents of children with cystic fibrosis are subject to an annual wellbeing loss of 1,148 WALYs.

Moreover, in 2019, heart disease accounted for the deaths of 1.97 million adults in Europe, approximately 59 percent of whom were married. As experiencing the death of a partner results in 0.13 WALYs lost in the first twelve months, we can infer that 1.16 million WALYs were lost in 2019 just by partners of patients who died of heart attacks. Almost half of these cases (47%) could have been theoretically saved with successful genetic screening and treatments.

Stability impact

By considering the relationship between subjective wellbeing and income, we tested how much wellbeing could be saved if the financial burdens of genetic disease were eliminated and converted into income. This exercise suggests that alleviating the economic burden of genetic disease among babies and pediatric patients in the United States could save approximately 45,200 WALYs each year.

Endnotes

1 About 2 meters of DNA per cell. 16 billion kilometers. For reference, the diameter of Neptune's orbit is 9 billion kilometers. (Bryson, 2019; Meeus, 1998).
2 Palazzo & Gregory (2015).
3 National Institutes of Health (2007).
4 This is not because new diseases are arising, but rather because scientists are getting better at detecting them. For more information, see: www.omim.org/statistics/entry
5 A fourth category – mitochondrial disorders – can occur by mutations in non-chromosomal DNA located within the mitochondria. However, these are quite rare. For more information, see: WHO (2020); Verma & Puri (2015).
6 Rappaport (2016).
7 Lakhani et al. (2019).
8 World Health Organization (2006).
9 Rees et al. (2010).
10 Ndeezi et al. (2016).
11 World Health Organization (2006).
12 Centers for Disease Control (2020).
13 Piel et al. (2013)
14 Piel et al. (2013)
15 Global Burden of Disease Collaborative Network (2020).
16 Thomas & Lipps (2011, p. 184). However, the authors did not observe any significant differences in negative affect.
17 Bruton et al. (2015).
18 de O et al. (2013).
19 Thomas & Lipps (2011, p. 184).
20 Helliwell et al. (2020).
21 Global Burden of Disease Collaborative Network (2020).
22 See chapter 4.
23 Piel et al. (2013).
24 Piel et al. (2013).
25 Happiness Research Institute and Leaps By Bayer (2020).
26 Global Burden of Disease Collaborative Network (2020).
27 Based on authors own calculations. Contact for more information.
28 Based on authors own calculations. Contact for more information.
29 Lakhani et al. (2019).
30 Rappaport (2016).
31 Eurostat (2019).
32 Germany: 161,600; Italy: 140,000; France: 116,600.
33 Bulgaria: 36,791 (per 100,000); Romania: 36,266; and Latvia: 31,917.
34 Based on authors own calculations. Contact for more information.
35 The sample includes parents of children ages 0 to 17 (Beiser et al. 2011)
36 Life satisfaction: 63.36 (M=69.09 control group) (scale -96 to 160). Converted to a 0-10 scale: 63.36 (-96-160) - 10*(63.36+96)/(160+96)= 6.21 (0-10) / 69.09 (-96-160) - 6.48 (0-10). WALYs lost = (6.48-6.21)/6.48 = 0.04
37 Cystic Fibrosis Foundation (2020).
38 ((31199*.46)*2)*.04 = 1148. But this is likely to grow as more patients are being born each year with the disease.
39 Khera et al. (2016).
40 ½World Health Organization (2017).
41 McPherson & Tybjaerg-Hansen (2016).
42 Zdravkovic et al. (2002).
43 Based on authors own calculations. Contact for more information.
44 Life satisfaction data and coefficients drawn from Oswald & Powdthavee (2008).
45 Representative of European Union. Mortality data drawn from the Global Burden of Disease Collaborative Network (2020). Marriage rates from authors calculations of Eurostat data. For more information about Eurostat data, visit: www.appsso.eurostat.ec.europa.eu/nui/show.do
46 (21,833.32+861,372.75)*.59*.57 = 297022.2 WALYs lost due to genetically influenced male deaths. (6,696.59 + 1,081,267.65)*.59*.38 = 243921.6 WALYs lost due to genetically influenced female deaths. Total = 540944
47 McCandless et al. (2004).
48 This is the cost associated for patients with any diagnosed genetic disease. Primary diseases the estimate is lower, but still substantial at $14 billion (11%). For more information, see Gonzaludo et al. (2019).
49 Fujiwara (2013); Trotter et al. (2014).
50 If we divide the total cost of this treatment by the total US population, each American would receive $172.98 ($57 billion/329.5million US citizens). This extra money would increase the wellbeing of each citizen by 0.3*log(54,569/(54,569-172.98)) = 0.0009525 points (where 54,569 represents the median income per capita in the US. The formula comes from Fujiwara (2013)). Considering that the average life satisfaction in the US is ~6.95 (Gallup 2018), WALYs saved would be 0.0009525 / 6.95 = 0.000137 WALYs saved per citizen. It is a small value for each person, but aggregating this value across the entire population we arrive at 329.5 million US citizens X 0.000137 WALYs saved per citizen = 45,158 WALYs saved in total.
51 For a recent analysis of this sort related to lost schooling as a result of COVID-19, see Hanushek & Woessmann (2020).

Leap 02

Provide sustainable organ & tissue replacement

The problem

It is common in science fiction to imagine a future where humans can cure their injuries as easily as lizards regenerate their tails. Unfortunately, while the science of human tissue regeneration has advanced in recent decades, we can't quite regenerate our limbs just yet, nor have we been successful in curing some of the most severe diseases related to organ damage. Diseases such as Parkinson's or heart failure still have no cure, and much of the elusive solution will likely involve tissue regeneration.

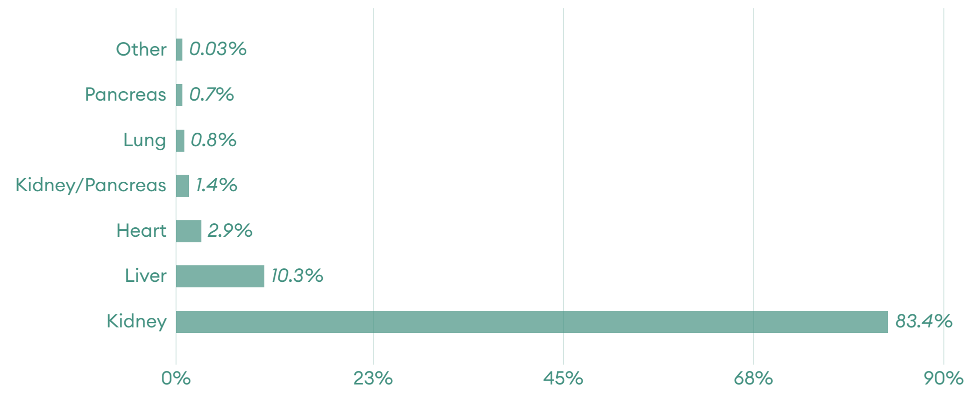
Heart attacks and cardiovascular diseases are the leading cause of death worldwide, and they are on the rise.[1] The reason why tissue replacement treatments are important in the specific case of heart attacks is that about one billion heart cells die from every heart failure.[2] Some experiments have already shown that stem cells can be reprogrammed into cardiomyocyte-like cells that are able to contract spontaneously, so they can be used to replace dead heart cells.[3] Some teams have been able to generate complete organ structures successfully in rats, but not yet in humans.[4]

Tissue replacements have the potential to cure diseases and save lives. For instance, In the United States, it is estimated that one million people are affected by Parkinson's disease, a number that could double in 20 years because of demographic aging.[5] One potential cure for this disease could involve the development of stem cells that can replace the damaged neuroanatomy and the dopaminergic neurons in Parkinson's patients. However, this objective remains unattainable.

While 'repairing' organs and neurons holds great potential for impacting human wellbeing and saving lives, it is also paramount that we find more sustainable solutions for the people in need of completely new organs.

It is estimated that between 1.5 and 2 million people are on organ transplant waitlists globally.[6] In the United States (US) alone, the waiting list includes more than 119,000 patients - the majority of whom require a kidney transplantation (Figure 2.1).[7]

Figure 2.1 US transplant waiting list by organ (as of December 3rd, 2020)



Source Organ Procurement and Transplantation Network

However, these numbers represent only a fraction of the true need for organ replacement. In the US, only 50,000 people are added to the transplant waitlist each year, yet over 700,000 deaths per year are attributable to end-stage organ disease. Globally, the unmet needs are far greater, as deaths from organ impairment number rise above 15 million per year.[8]

Figure 2.2 America's organ shortage

Source Organ Procurement and Transplantation Network

Moreover, end-stage organ disease also takes enormous wellbeing tolls on patients. A systematic review and meta-analysis including 216 studies of 55,982 patients examined the prevalence of depression in people with chronic kidney disease – both for non-dialysis patients and dialysis patients.[9] When evaluated by screening questionnaires, the summary prevalence of depression among patients not receiving dialysis was 25.5%, and 39.3% for patients receiving dialysis. Alone for non-dialysis patients, that rate of depression is up to 3 times higher than of those in the general population.

Unfortunately, adding more donors may not provide the most sustainable solution. Only 3 in 1000 people die in a way that their organs can be donated, further limiting supply.[10] Organ compatibility also complicates matters, as there are multiple genetic factors that make it difficult to match an organ donor with a patient.[11]

What if?

What if we could stop the progression of Parkinson's disease, or even cure it through replacement of damaged cells to restore tissue function? Or what if a diagnosis of kidney failure meant scheduling a prompt transplant operation, without having to wait for years for an organ donor? What if this operation had very low risks of organ rejection, and meant skipping dialysis entirely?

As we'll see in this chapter, providing considerably better options for healing our bodies through tissue replacement and more long-lasting organ transplants has the potential to enhance and save lives across the world. This chapter focuses on chronic kidney disease and Parkinson's disease, respectively, to address the topic of organ transplantation and tissue replacement.

Health impact

The wellbeing benefit of chronic kidney Disease and organ transplant

In this section, we will provide a case study on the wellbeing impact of chronic kidney disease on individual patients. This case study will help us identify the potential wellbeing gains for patients that could be brought about by ending kidney organ shortage.

Kidney failure is the end-stage of chronic kidney disease (CKD) and occurs when the kidneys become unable to remove metabolic waste products from the body.[12] While early stages of CKD often show no symptoms and can go undetected, the later stages show obvious symptoms, and at the final stages, the patients will experience kidney failure, which requires either dialysis or transplant for survival.
Dialysis is a treatment that takes over your kidney function after kidney failure. The most common type of dialysis is hemodialysis

Table 2.1 Stages of Chronic Kidney Disease and prevalence

	Kidney function	Description	Global prevalence	
Stage 1	› 90%	Normal or high function	3.5 %	≈277 million people
Stage 2	60-89%	Mild decreased function	3.9 %	≈308 million people
Stage 3	20-59%	Mild to moderately decreased function	7.6 %	≈600 million people
Stage 4	15-19%	Severely decreased function	0.4 %	≈316 million people
Stage 5	‹ 15%	Kidney failure	0.1 %	≈79 million people

Source https://www.kidney.org/es/node/25721 & Hill, N. R. et al. (2016).

which is a treatment that uses a machine to filter and purify the blood. Patients normally undergo dialysis treatment at hospitals or clinics for 3 to 4 hours at a time, three times a week.[13] The treatment is highly time-consuming and requires radical lifestyle changes, which ultimately can have negative impacts on social, psychological, and physical wellbeing.[14]

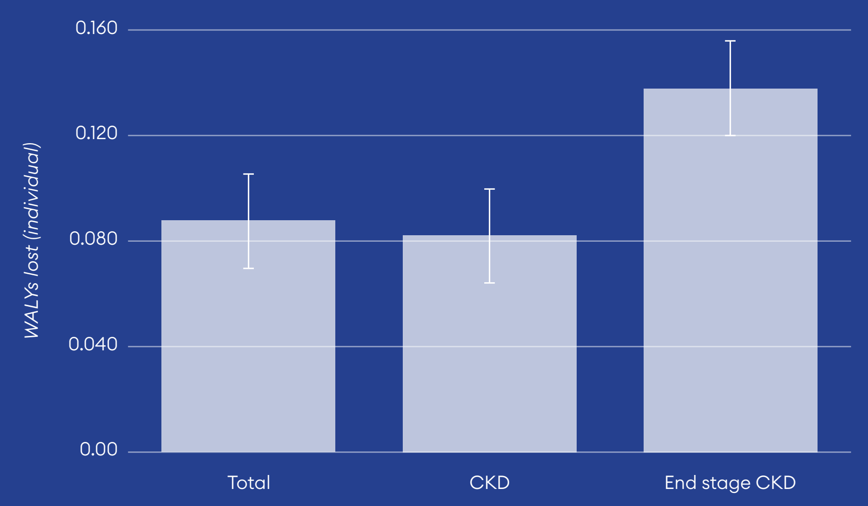
To assess the burden of chronic kidney disease, we rely on life satisfaction data from the Survey of Health, Aging, and Retirement in Europe (SHARE), which contains a representative sample of European adults over the age of 50.

Unfortunately, this data does not allow us to distinguish between the different stages of CKD, however, it does allow us to identify patients with a high rate of hospital visits (spending more than 20 days at the hospital a year), which likely is indicative of dialysis treatment. Overall, about 0.2% of the SHARE sample fall into this category.

Moreover, as the early stages of CKD often go unnoticed, it is probable that they are not reported in SHARE. Thus, it is most likely that the remaining CKD patients in the sample possibly only cover mid to late-stage CKD.

Using these two categories to assess wellbeing burdens, it can be estimated that **people living in Europe experiencing end-stage CKD annually lose 13.8% of their potential wellbeing, while people living with mid to late-stage CKD lose 8.2% (Figure 2.3).[15]** Other studies have identified even larger wellbeing burdens for people in dialysis than what we present in Figure 2.3. In an Aus-

Figure 2.3 Individual wellbeing burdens of chronic kidney disease



Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, marital status, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

tralian study, the authors measured the wellbeing of people with kidney failure on dialysis and compared their subjective well-being with a general population cohort. The scale used to assess wellbeing rated satisfaction with life in seven domains: standard of living, health, achievements in life, relationships, safety, community, and future security. The global score got ranked on a 0-100 scale – the general population scored 77.44, while the kidney failure patients scored 63.55. These results suggest that patients in dialysis could even lose up to 17.9% of their potential wellbeing each year.[16]

Regardless of whether we consider the wellbeing loss of 17.9% or the slightly more conservative estimate of 13.8%, it seems almost unquestionable that ending organ shortage holds the potential to lift people suffering from kidney failure (and perhaps also late-stage CKD) out of miserable circumstances.

The wellbeing benefits of organ transplant

In the last section, we concluded that CKD poses a great threat to the individuals who suffer from the disease – especially as the disease progresses. In this section, we will explore how these individual burdens translate into patient population burdens by considering the societal prevalence and mortality rates of the disease.

Globally, CKD has an estimated prevalence of 11–13%, and 1.9 million patients are undergoing dialysis therapy.[17] In Europe, the prevalence of CKD is significantly higher, with an estimated prevalence of 18.39% for stage 1-5 and 11.86% for stage 3-5.[18] Additionally, CKD is a disease that is growing in prevalence in part due to trends in obesity and diabetes and in part due to an aging population in many countries.[19] According to the Global Burden of Disease, the increasing prevalence and death rate seem to be particularly high in high-income countries, while mortality in low-income countries does seem to be decreasing.[20]

Moreover, those with CKD are more likely to die from cardiovascular disease than to progress to kidney failure, and patients who survive to progress to dialysis experience are subject to a mortality rate of 21% in their first year of dialysis.[21]

By multiplying the individual wellbeing burden with the prevalence of the disease and adding the associated mortality (Individual WALYs x Prevalence + Death), CKD emerges as one the most burdensome diseases in Europe. **Alone in Germany, 795,285 WALYs are lost every year to CKD (Figure 2.4). To put this in context, if this burden of CKD in Germany could be completely alleviated, it would – in terms of WALYs saved – equal the benefit of making everyone feel safe in their neighborhoods in all of Germany.[22]**
It is important to note, that it's of course unlikely that all CKD patients would immediately benefit from an ending to organ shortage – as early-stage CKD cases may not be considered eligible for transplants. Yet, even if we only considered people with late-stage and end-stage chronic kidney disease, the years of full wellbeing that the populations could experience are still substantial.

Figure 2.4 WALYs lost due to kidney disease among European adults

Source Authors' calculations using SHARE and GBD data.

Assuming stage 3-5 CKD make up 65% of all reported CKD-cases, then ending organ shortage could be projected to save up to 2.5 million WALYs in Europe.[23]

Due to the widespread and increasing prevalence and mortality rates for CKD, as well as these highlighted wellbeing burdens, ending the organ shortage must be considered a top priority for public health and wellbeing.

Wellbeing burdens of Parkinson's disease

In an extensive literature review conducted by Janasson et al. (2020), five major sources of distress were found among Parkinson's patients.[24] The first is the effect of Parkinson's on patient's social identity. Many patients struggle to deal with all the stereotypes associated with the disease. The second source of distress relates to the psychosocial challenges associated with the disease. These can include reduced social confidence, lower self-esteem, feelings of incompetence, inability to fulfill desired social roles, and ultimately the development of social anxiety. The third source of unhappiness among Parkinson's patients is perhaps the most obvious: symptom severity. These can be quite difficult to adapt to, as Parkinson's symptoms often fluctuate with "on-off" periods that are related to the medication. Periods of severe symptoms can also place additional caregiving burdens on loved ones and family members.

The fourth source of distress is related to the specific physical and cognitive strategies carried out by each patient to deal with their disease. Many patients are focused on daily challenges as opposed to planning for the future. This can make it difficult to stay active, goal oriented, and maintain a social identity beyond Parkinson's. Many patients' strategies for dealing with the disease are not only cognitive, but also structural, which may involve adapting their homes for greater independence.

Finally, the fifth source of distress (or relief) for Parkinson's patients concern their networks of social support. In times of illness, maintaining close and strong relationships with family, friends, and communities can become even more important.

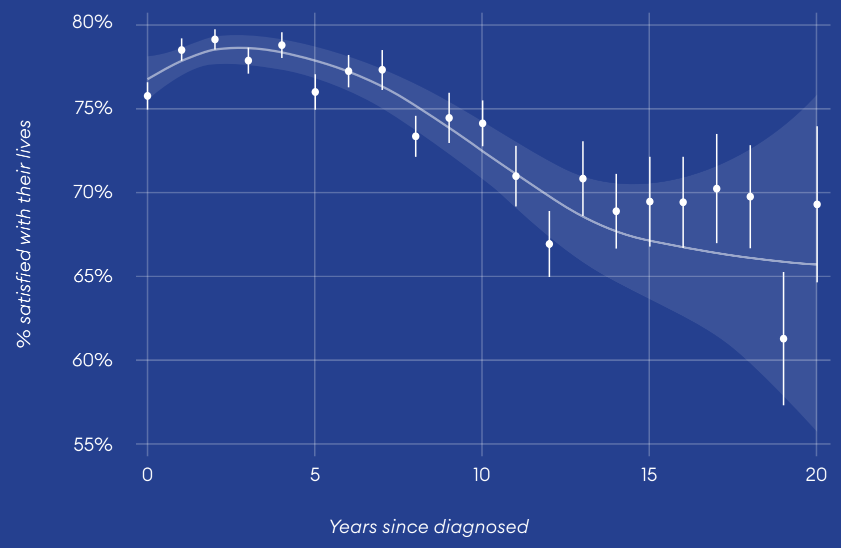
Together, all these physical, social, and cognitive symptoms can have an overall effect on wellbeing that differ greatly from patient to patient. Nevertheless, even though each patient's conditions differ, we can draw general conclusions about patient wellbeing by asking large samples of patients how satisfied they are with their lives.

In a sample of 1,432 patients with Parkinson's in Sweden, Gustafsson et al. (2015a) found that only 62.4% patients were satisfied with their lives, while that percentage increased to 91.5% in the group of their healthy counterparts – a 30% gap.[25] Given the degenerative nature of Parkinson's disease, longitudinal studies are especially important in this case. Following patients over three years, Johansson et al. (2020) found that, while 63.2% of patients diagnosed with Parkinson's were satisfied with their lives at the beginning of the study, this percentage was reduced to 49.7% by the end of the study.[26] Using linear fixed effects models, Buzcak-Stec et al. (2018) from the University Medical Center in Hamburg also found that life satisfaction of Parkinson patients decreased by 13% over the course of six years.[27]

In our previous report, we also conducted a detailed analysis on the development of life satisfaction over time in Parkinson's patients using Fox Insights data from the Michael J. Fox Foundation, a longitudinal study analyzing the wellbeing of thousands of Parkinson's patients since 2015. The analysis considered the life satisfaction of patients with Parkinson's as the disease developed, as well as the death rate associated to this disease. **According to our analysis, a Parkinson's patient may lose about 29% of the wellbeing they could have enjoyed if they never had the disease – or what is equivalent to 0.29 WALYs lost (Figure 2.5).**

Given the prevalence of Parkinson's disease, we estimate that **the total number of WALYs gained would amount to 195,300 in the 28 European countries analyzed if this disease was cured, a value which is greater than the wellbeing gained by the eradication of much more widespread diseases such as rheumatoid arthritis.[28]**

Figure 2.5 Life satisfaction of Parkinson's patients in the years since diagnosis



Source Happiness Research Institute & Leaps by Bayer (2020)

Community impact

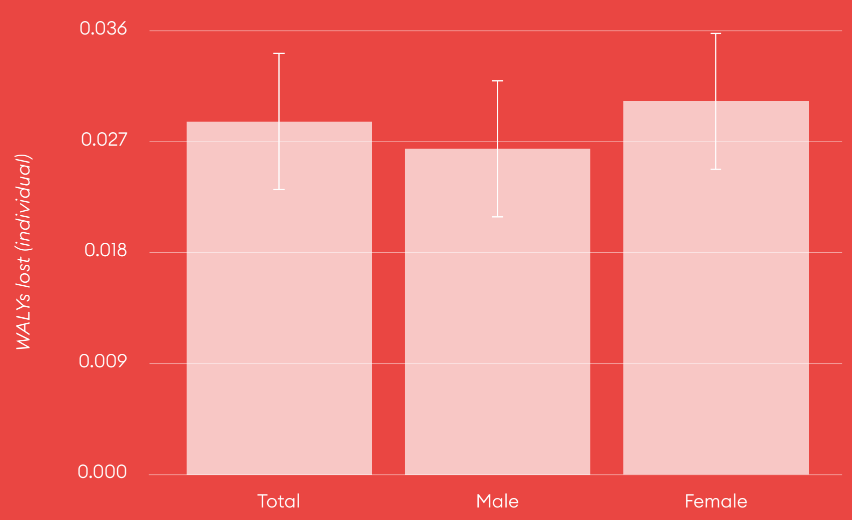
The wellbeing benefits for family caregivers

Ending organ shortage will not only realize potent wellbeing gains for the patients – but will also have knock-on benefits in their immediate social surroundings. In this section, we turn our attention to the wellbeing burdens of partners to patients suffering from CKD.

When a CKD patient progresses into Stage 5, a family caregiver often must assist with daily activities, including transportation to the dialysis clinic, symptom management, mobility, dressing, preparing an appropriate renal diet, and psychosocial support.[29] This caregiving burden often adversely affects multiple aspects of the caregiver's own life, including his or her stress level, family relationships, and social lives in general.[30]

Using SHARE data on European adults, we also find significant wellbeing burdens among partners of patients with diagnoses. **Compared to counterparts with healthy partners, partners of patients with chronic kidney disease lose approximately 2.9% of the wellbeing they could have otherwise experienced (Figure 2.6).** There is no evidence of any significant gender differences in this partner burden.

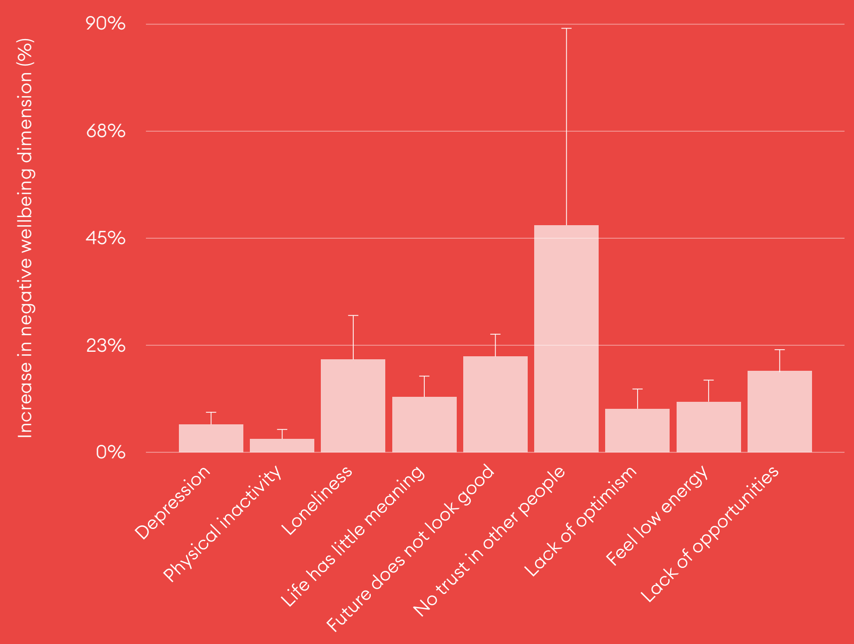
Figure 2.6 Partner wellbeing burdens of kidney disease



Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, marital status, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

Using the same data to investigate what could lie behind this loss of wellbeing, we find that the partners of CKD patients are 19% more likely to experience loneliness, 20% more likely to have grim thoughts about the future and 48% more likely to distrust other people - compared to counterparts with healthy partners (Figure 2.7).

Figure 2.7 Subjective wellbeing depending on partner status



Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, marital status, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

However, as worrisome as these burdens are, they are likely to be alleviated if the patient received successful treatment. A wellbeing study of spouse caregivers of kidney transplant patients in New England has documented a positive impact of the transplant procedure.[31] According to the study, spouse caregivers before kidney transplantation had significantly lower life satisfaction scores than did caregivers after kidney transplantation. **In WALY-terms this effect equals a gain of 9.8% wellbeing.[32]**

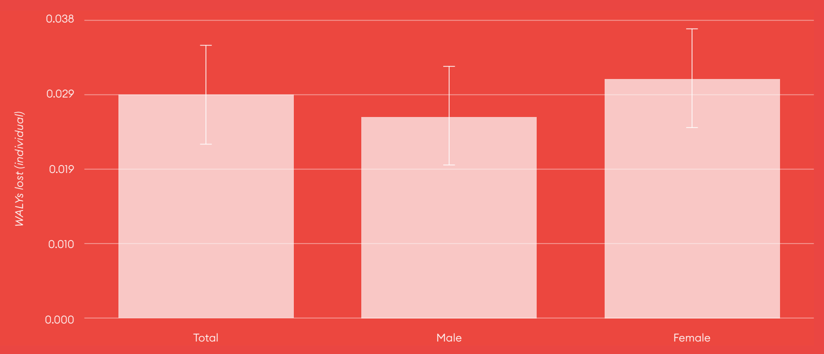
Wellbeing burdens of Parkinson’s on family caregivers

Family members of Parkinson’s (PD) patients suffer from seeing their families lose independence. Partners of Parkinson’s patients often report to experience reduced health, feelings of isolation, uncertainty about the future, and ultimately depressive symptoms. According to our own analysis using the SHARE data, 11% of partners to PD patient were treated medically for depression or anxiety – this is 4% more than partners to healthy people.[33]

While many studies have analyzed the wellbeing on partners to PD patients, relatively few compare these wellbeing states to control groups. Using SHARE data, we can estimate the life satisfaction of partners to patients with Parkinson’s relative to similar controls with healthy partners (Figure 2.8).

According to our estimates, partners to Parkinson’s patients lose about 2.5% - 3% of their potential wellbeing (life satisfaction they could have enjoyed if their partners had not been diagnosed).[34] As we can see, female partners also tend to be more negatively affected than male partners.

Figure 2.8 Partner wellbeing burdens of Parkinson’s



Note Authors’ calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

These numbers make it evident that the burden of Parkinson’s disease affects not only patients themselves but can also have significant and substantial knock-on effects on loved ones. Alleviating the burden of the disease would therefore have positive benefits on wellbeing that would carry over to patients’ social networks and communities.

Stability impact

The economic savings of ending organ shortage

The economic cost of organ shortage is immense, and diseases treatable by organ replacement disproportionately strain healthcare infrastructures. In this section, we will present a case study on how ending organ shortage can free enormous sums of money, which can then be invested in other areas – which, in turn, will save societies more WALYs.

In the US, treatment of CDK consumes 6.7% of the total Medicare budget to care for less than 1% of the covered population.[35] In England, CDK costs £1.4 billion a year, which is more than breast, lung, colon and skin cancer combined (even though these diseases account for more total deaths).[36] On a global level, the cost of end-stage organ disease is tremendous: more than $1 trillion USD expected to be spent in the next decade on treatments alone.[37]

These costs also do not include productivity loss[38], which is estimated to account for 2/3 of the total societal costs of kidney failure.[39] From a societal cost perspective, including both direct and indirect costs,[40] per patient result in annual non-dialysis costs of CKD stages 1–3 accounted for $11,920, whereas CKD stages 4–5 accounted for $20,142 in the Nordic countries (Table 2.2). Dialysis also proves to be much more costly ($88,943) than kidney transplants ($37,849).

Table 2.2 Economic burdens of kidney disease in Nordic countries, and per person WALY equivalents

Denmark	Per patient mean annual cost	Value in WALYs (per person)
CKD Stage 1-3	$10,431	-
CKD Stage 4–5	$18,600	-
Dialysis	$100,758	-
Transplant	$36,430	-
Per patient savings (Dialysis-transplant)	$64,328	0.05
Per patient savings (Dialysis-transplant) + CKD Stage 4+5	$82,928	0.06

Finland	Per patient mean annual cost	Value in WALYs (per person)
CKD Stage 1-3	$10,261	-
CKD Stage 4–5	$18,971	-
Dialysis	$87,106	-
Transplant	$33,515	-
Per patient savings (Dialysis-transplant)	$53,591	0.05
Per patient savings (Dialysis-transplant) + CKD Stage 4+5	$72,562	0.06

Norway	Per patient mean annual cost	Value in WALYs (per person)
CKD Stage 1-3	$15,001	-
CKD Stage 4–5	$28,428	-
Dialysis	$106,614	-
Transplant	$36,702	-
Per patient savings (Dialysis-transplant)	$69,912	0.05
Per patient savings (Dialysis-transplant) + CKD Stage 4+5	$98,340	0.07

Sweden	Per patient mean annual cost	Value in WALYs (per person)
CKD Stage 1-3	$10,274	-
CKD Stage 4–5	$19,556	-
Dialysis	$92,440	-
Transplant	$31,557	-
Per patient savings (Dialysis-transplant)	$60,883	0.05
Per patient savings (Dialysis-transplant) + CKD Stage 4+5	$80,439	0.06

In a future scenario where organ shortage ceased to be a problem, immense amounts of resources could be saved by reducing the need for dialysis treatments. In the Nordic countries, these costs vary between $87,106 in Finland to $106,614 in Norway every year, while a transplant procedure roughly costs one third of that and only generates marginal costs in the following years. **If saved costs from transplants were valued in terms of their potential impact on human wellbeing, we could expect wellbeing equivalent benefits of 0.05 WALYs per patient undergoing transplant.**

If we considered an even more optimistic scenario where late-stage CKD also were offered transplants, this valuation could increase to between 0.06-0.07 WALYs per patient undergoing transplant.

Assuming a prevalence of stage 4 and 5 CKD of 0.5% of the population (Table 2.1), this could add to as much as 6,730 WALYs saved in the Nordic countries in the year of transplant.[41] To put these numbers in perspective, this WALY gain is approximately equal to the projected well-being gain of a 10% pay raise for more than 1.8 million middle-class workers in Denmark.[42]

Economic savings of alleviating Parkinson's disease

The array of expenses associated with Parkinson's (PD) is long and complex. The economic burden of the disease depends on patients' motor and non-motor symptoms, doses, and treatments, as well as the need for nurses, caregivers, physiologists, etc. In addition, costs tend to increase with the progression and severity of the disease. In the United States, one study estimated the cost of Parkinson's to be approximately $35 billion per year.[43] However, slowing down the development of the disease could save up to $450,000 per patient, and even if the progression of the disease was only reduced by 20%, this benefit could be expected to reach up to $75,000 per patient.

Another study researching the economic burden of PD in the United States of America (USA) between 1999 and 2002 estimated it to be $10,349 in direct costs and $25,326 in indirect costs per patient.[44] The total cost in the USA would then aggregate to $23 billion per year. By far, the largest share of the cost is due to productivity loss (49.4% of the total costs). For example, in Sweden, about 20% of men and 10% of women with Parkinson's work full-time, but these percentages would likely reach 50% and 39%, respectively, if these people were freed from their disease.[45]

These differences are representative of the impact that Parkinson's can have on a country's workforce.

In the United Kingdom (UK), the financial loss associated with Parkinson's can also be divided into similar categories: [46]

- Direct healthcare costs (£2,229) including medications, mobility aids, and travel to health appointments including parking charges.
- Social care costs (£3,622) including changes to their homes, assistance with daily tasks, and equipment to help them stay independent.
- Loss of income due to early retirement or absenteeism (£10,731).

In total, Parkinson's therefore roughly costs £16,582 (€18,400) per patient per year in the UK. To better understand the underlying burden of these costs, we can estimate equivalents in Wellbeing Adjusted Life Years by theoretically converting the financial burden of the disease to income, and in doing so, consider its potential effect on life satisfaction. Considering only the treatment and social care costs (€6,500), each patient loses 0.22 life satisfaction points (0.03 WALYs) per patient per year.[47] **This is equivalent to 4,350 WALYs throughout the entire Parkinson's population in the UK.[48] Thus, the cost for each patient is enormous, however, at a social level it is very small given the low incidence of this disease. In other words, the impact of freeing Parkinson's patients from the costs of their treatment would be equal, in absolute terms, to the total wellbeing benefit of lifting 48,300 people out of unemployment in the UK alone.[49]**

Impact summary

In this chapter, we have investigated how better options for tissue replacement and more long-lasting organ transplants could generate wellbeing impact for people living with CKD and Parkinson's disease.

Health impact

According to our estimations, CKD emerges as one the most burdensome diseases in Europe. Assuming a prevalence for stage 3-5 CKD of 11.86% in Europe, and an annual wellbeing loss to patients equal to 8.8%, ending organ shortage could be projected to save up to 2.5 million WALYs in Europe.

For Parkinson's, we estimate that a patient may lose about 29% of the wellbeing they could have enjoyed if they never had the disease (0.29 WALYs lost). Given the prevalence of this disease in Europe, we find that the total number of WALYs saved amount to 195,300 in Europe if this disease was cured.

Community impact

CKD and Parkinson's are known to be particularly burdensome conditions for partners and family members of the patients, as they often require intensive care.

In our analysis, we find that both partners of patients with chronic kidney disease and Parkinson's lose approximately 2.5% - 3% of their potential wellbeing annually (0.025 – 0.03 WALYs).

Stability impact

The economic cost savings related to more effective organ and tissue replacement is immense.

According to our estimates for CKD, 6,730 WALYs could be saved in Nordic countries by freeing the economic costs associated with transplant. A similar analysis for Parkinson's patients in the UK, suggest that 4,350 WALYs could be saved throughout the entire Parkinson's population in the UK if the associated treatment costs could be freed.

Endnotes

1 Mendis et al. (2011).
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3 Smart et al. (2011); Laugwitz et al. (2005); Ieda et al. (2010).
4 Masumoto et al. (2014).
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6 Bayer (2019)
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14 Nabolsi, M. M. et al. (2015); Sousa, L. M. M. D. et al. (2017).
15 Based on authors own calculations. Contact for more information.
16 Life satisfaction: Patient group: M= 16.90; Control group: M=19.13 (On 7-35 scale). Converted to 0-10 scale: Patient group: M= 3.5; Control group: M=4.3.
17 Bikbov, B. et al. (2020).
18 Hill, N. R. et al (2016).
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22 Equivalent WALY burden: Feeling unsafe in neighborhood in Germany: 769,152 WALYs
23 Assuming a total prevalence of 27 million patient of stage 3-5 CKD in the European countries mapped in Figure 2.4. Also assuming that all deaths due to CKD are attributed to stage 3-5.
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28 Happiness Research & Leaps by Bayer (2020).
29 Gayomali, C. et al. (2008).
30 Avşar, U. et al. (2015).
31 Rodrigue, J. R. et al. (2010).
32 Life satisfaction: T1: M= 47.1; T2: M=51.6 (On 7-35 scale). Converted to 0-10 scale: T1: M= 6.1; T2: M=6.7.
33 116,591 respondents, 3.803 partners of PD patients. Control variables: gender, age, education level, job status, country, total household income.
34 114,044 respondents, 3,803 partners of PD patients. Control variables: gender, age, education level, job status, country, total household income.
35 World Kidney Day (2020).
36 NHS (2012).
37 Stenvinkel, P. (2010).
38 Productivity loss cover absenteeism (work absences) or presenteeism (reduced productivity among those with CKD in work)
39 Elshahat, S. et al. (2020).
40 Lost productivity, general healthcare costs and out of pocket costs, including informal care, paid domestic help and transportation
41 0.5% of the Nordic population (26,921,093 people) * 0.5%= 134,605 patients. Assuming each patient gain 0.05 WALYs from treatment savings, 134,605 patients * 0.05 WALYs gained per patient = 6,730 WALYs gained in total
42 Rising 10% the income of a median-class Danish citizen would increase their life satisfaction 0.028 (0.3*log(abs(1-20,086)/18,260, where 18,260 is median income per-capita in Denmark). WALYs gain would therefore be 0.028 / 7.62 = 0.0037. This means 6,730 / 0.0037 = 1,818,919 citizens.
43 Johnson et al. (2013).
44 Huse et al. (2005).
45 Gustafsson et al. (2015b).
46 Gumber et al. (2017).
47 Assuming median per-capita income of €12,400 from Phelps & Crabtree (2013). For the transformation between income and life satisfaction we use the coefficient and equation extracted in Davies (2018). Increase in life satisfaction - 0.3 * LN(Median Income / (Median Income – Treatment)).
48 145,000 Parkinson patients in the UK (Parkinson's UK, 2018).
49 Here we have only taken into account the cost of treatment and social care costs. The reason we have not accounted for the loss of income due to early retirement or absenteeism is because the total cost would far exceed the median income of the patients. However, we can assume that the costs of treatment, social costs and absenteeism are not paid by patients, but by the society as a whole. In that case, considering that there are about 145,000 patients in the UK, with total cost per patient of €18,400, the total cost to society is €2.6 billion. In other words, each citizen in the UK pay €40 each year for the treatment of Parkinson's patients. If we were to deduct this value from each citizen's taxes, the happiness earned per individual would be very low, but accumulated over the entire population would be equal to 9,200 WALYs gained, only through the savings that the eradication of Parkinson's would have on the state coffers.

Leap 03

Reduce environmental impact of agriculture

The problem

Today, there are almost 8 billion living people living on the planet, roughly double the amount 60 years ago. While the growth rate of the global population has begun to slow down, the United Nations still expects global population to rise to 11 billion by the end of the century.[1] Such staggering increases have already taken a substantial toll on food systems around the world, which is likely to be even larger in the future. In turn, these pressures are exacerbating climate change. Today, food production accounts for about one fourth of total global greenhouse gas emissions. Roughly half of all habitable land on earth is now used for agriculture.[2] If we continue with business-as-usual, the environmental impact of agriculture will only continue to increase in the years ahead. Addressing climate change requires rethinking our approach to food production.

Throughout this chapter, we will consider the real and potential wellbeing impacts of unsustainable processes of agricultural production and consider the potential wellbeing impact if they could become more sustainable. Given the immense amount of complexity and uncertainty inherent in any discussion of potential future scenarios regarding sustainability and climate change, this analysis is not intended to be exhaustive. There are sure to be dynamics and interactions between food systems and human wellbeing that remain unaddressed. Instead, as in previous chapters, we will select several case studies using the general framework we laid out in the introduction to illustrate how the dynamics of food production can impact human wellbeing. Here again, we will consider three main channels of impact: health, community, and stability (Table 3.1).

Table 3.1 Flowchart of impact channels

Environmental impact of agriculture				
Greenhouse gases	Freshwater use	Land use and deforestation	Eutrophication (water pollution)	Biodiversity loss
↓	↓	↓	↓	↓

Wellbeing impacts		
Health	Community	Stability
• Malnutrition/hunger • Unhealthy diets/obesity • Pesticides • Water stress • Pollution	• Social capital • Crime and violence • Weather variability	• Displacement • Conflict • Employment and income • Economic burden • Natural disasters

Food systems have both direct and indirect effects on human health and wellbeing. Perhaps the most notable direct impacts relate to food intake and nutrition. Worldwide, malnutrition in all its forms, is the leading cause of poor health. A 2019 report published in The Lancet medical journal documented a "syndemic" of obesity, malnutrition, and climate change.[3] Today, food scarcities and obesity affect roughly 2 billion people. In low- and middle-income countries, more than 150 million children are stunted due to insufficient nutritional intake.[4] In high income countries, overconsumption of meat has been linked to higher rates of heart disease, cancer, and obesity, especially in the United States.[5] Increased use of pesticides has also been directly associated with reproductive risks, cancer, neurodevelopment disorders, and immunodeficiencies.[6]

However, food production can also have more subtle indirect effects on health and wellbeing by stressing ecological systems and contributing to climate change. If we do not reverse the spread of air pollution, the prevalence of heart disease, lung cancer, and respiratory disorders will likely rise[1], and if global temperatures continue to rise, half of the world's population could be living in water-stressed areas by 2025, which could lead to increased reliance on contaminated water sources and accelerate disease spread.[7] In the next section, we will dive deeper into the direct and indirect health and wellbeing impacts of agriculture by considering another key health channel: the impacts of air pollution.

Agricultural food production can also take a toll on human wellbeing through indirect community channels of impact. A recent report from the American Psychological Association documented breakdowns of social trust and social cohesion as a result of displacement and changing land use, particularly among affected native and vulnerable populations.[8] It is also well-known that people tend to become more irritable and aggressive when they experience an uncomfortable climate, and a number of studies have linked rising temperatures to an increase in intrapersonal violence and crime, such as homicides and assaults - a trend that is sure to be exacerbated by continued global warming.[9] Even simple increases in variable weather patterns have been linked to lower subjective wellbeing.[10]

Taking an even further step back, increasing climate change can also threaten societal stability. Climate migration is expected to continue to rise in the coming decades as a result of natural disasters and inhabitable land caused by changing weather patterns and sea rise.[11] While migrants and refugees can have positive impacts on societal wellbeing in the long-term, waves of intense migration can destabilize political processes and strain geopolitical relationships.[12] Climate change has also already begun to deplete natural resources around the world, which can lead to water and food scarcity, threatening not only individual health, but also increasing the risk of civil and international conflict. Most of the global poor are employed in agriculture, who could become unemployed as the world transitions to sustainable food production. At the same time, billions of jobs around the world may also become threatened by climate change, while new green jobs may be created in the future. All these trends can interact to affect global economic wellbeing of individuals and societies in dynamic ways.

What if?

What if we could fill our grocery cart with carbon neutral produce, grown with dramatically reduced farming inputs at reasonable costs? What if we could grow corn that could extract nitrogen from the air like a soybean plant to reduce synthetic fertilizer runoff and limit carbon emissions? Addressing the environmental impact of agriculture is fundamental to address the growing threat of climate change in the years to come. While it is not the only threat to ecological sustainability, re-envisioning and improving the global food system could have cascading positive. In the sections that follow, we will consider some of the existing wellbeing burdens associated with the global food system and estimate the potential returns for humanity if we are successful in addressing its environmental costs.

Health impact

Wellbeing burdens of agricultural pollution

In this section, we will consider the health impacts of food production by looking at the case and consequences of the agricultural impact on the environment. We will focus on Europe using data provided by the European Environmental Agency (EEA) and the Eurobarometer survey.[13] This analysis proceeds in three steps. First, using EEA data we will consider the contribution of the agricultural sector to air pollution levels in European countries. Second, we will isolate differences in subjective wellbeing levels between selected European cities and examine the extent to which higher levels of pollution can explain them. Third, we can aggregate these burdens across the population of each city to arrive at an understanding of total WALYs lost due to agricultural production.

Air pollution is a hidden and pernicious threat to health and wellbeing around the world. In Europe, air pollution is the largest environmental health risk, accounting for roughly 400,000 premature deaths in European countries each year.[14] These mortality rates are generally attributed to elevated health risks including heart disease, stroke, lung disease, cancers, diabetes, and asthma. Children, pregnant women, and people of low socioeconomic status are particularly at risk.[15] In Europe, pollution levels – in this case measured in terms of ambient particular matter in the air – can be accounted for by five primary sources: agriculture, energy supply, manufacturing, transport, and waste (Figure 3.1). While overall levels of emissions have been declining in recent years, the contribution of the agricultural sector to air pollution levels has remained roughly constant at 5%.

In addition to elevated health and mortality risks, higher levels of air pollution have also been associated with lower levels of subjective wellbeing.[16] These types of analyses are generally conducted by considering the extent to which wellbeing differences between countries or cities can be explained by differences in pollution levels, after controlling other relevant background, personal characteristics, and societal conditions. One analysis carried out along these lines found that the gains in wellbeing brought on by reduced levels of air pollution in Europe between 1990 and 1997 were roughly equivalent to expected wellbeing gains of raising per capita incomes between $750 and $1400 per year.[17] In a previous report, we also found that the wellbeing burdens of current levels of air pollution in European cities remained equivalent to reductions in annual income of 5-15 percent.[18]

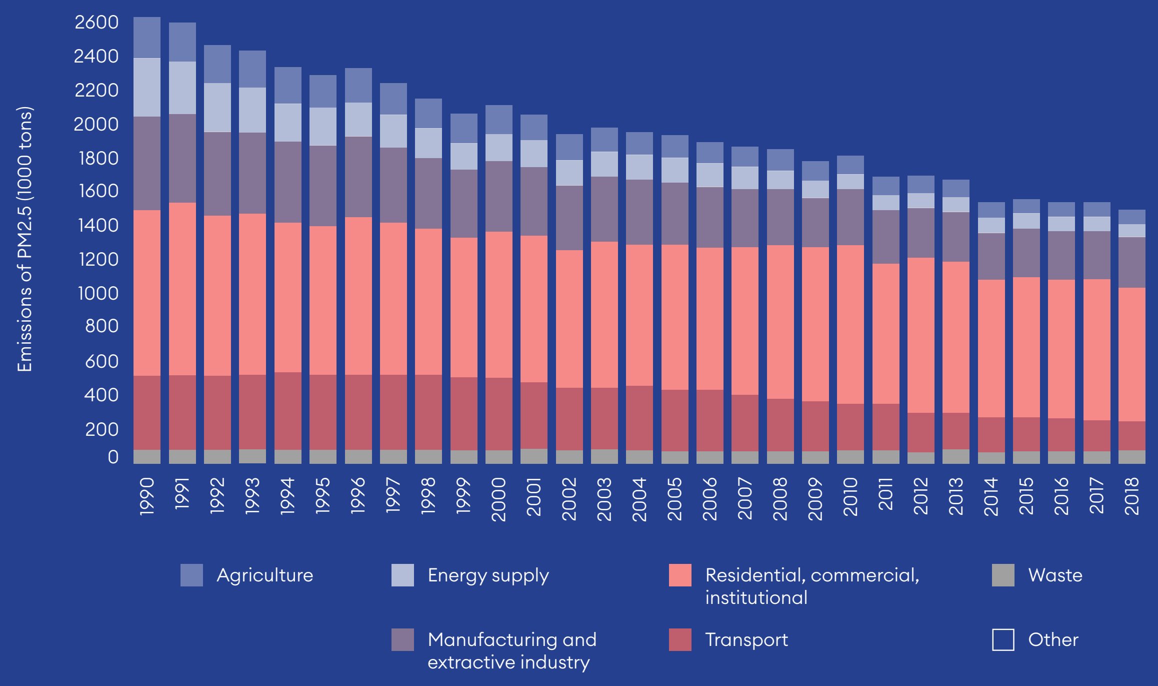
For the purposes of this chapter, we can consider the WALYs lost due to air pollution that can be attributed both to lower levels of subjective wellbeing among current residents of European cities, as well as the additional wellbeing losses associated with premature deaths linked to pollution. This analysis relies on wellbeing data provided by the European Eurobarometer survey and pollution data provided by the EEA.[19] In this case, we are also only interested in the percentage released by agricultural production, and not the overall wellbeing burden of pollution in each city attributable to all possible sources. The full output of this procedure is presented in Figure 3.2.[20] Out of all the cities under consideration, we find that the total wellbeing burden of air pollution attributable to agriculture is highest in Berlin, followed by several Italian cities, Hamburg, and Prague.

Overall, in Europe, this analysis suggests an average WALY loss of 0.039 WALYs per person due to air pollution, of which 5% can be attributed to agriculture. **This would imply that more than 1 million WALYs could be saved each year by eliminating agricultural contributions to air pollution in European cities. By doing so would also be expected to save 21,000 WALYs in lives saved.**

Disclaimer

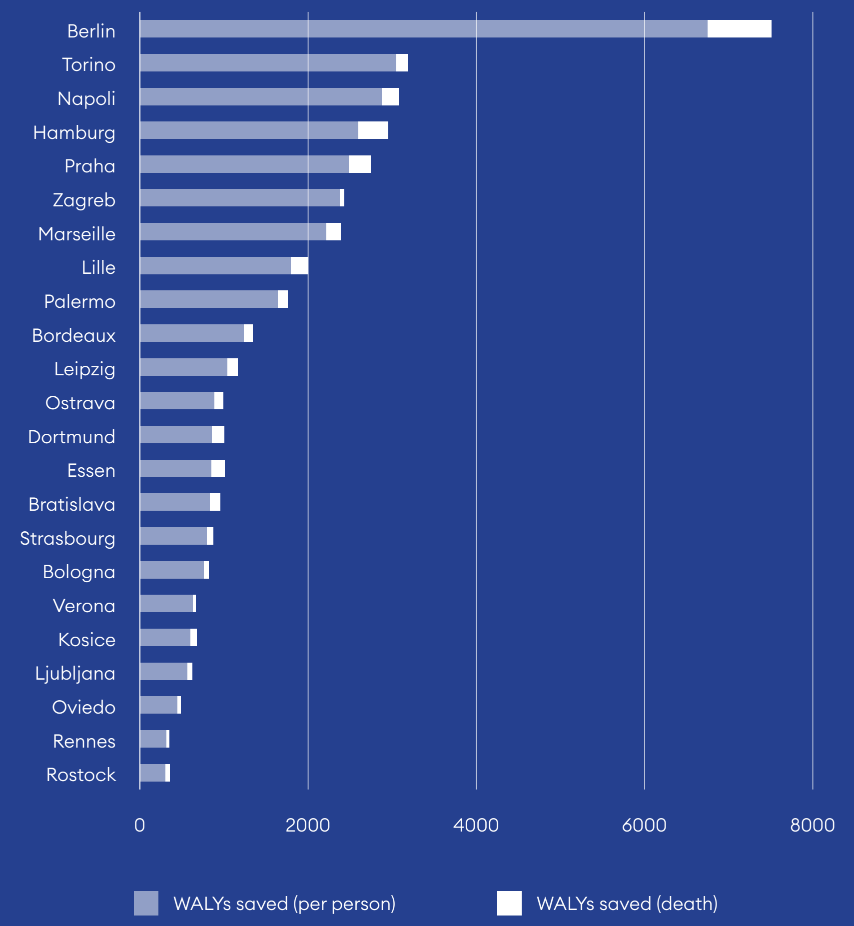
For this analysis and for the figures below, it is important to emphasize, that we are only considering air pollution in terms of particulate matter and not greenhouse gas emissions. For the latter, agriculture is a much greater contributor.

Figure 3.1 Contributors to air pollution in Europe



Source European Environmental Agency (2019).
Note: Authors' calculations using EEA and Eurobarometer data.

Figure 3.2 Potential WALYs saved by reducing agricultural air pollution to zero



Note Authors' calculations using EEA and Eurobarometer data.

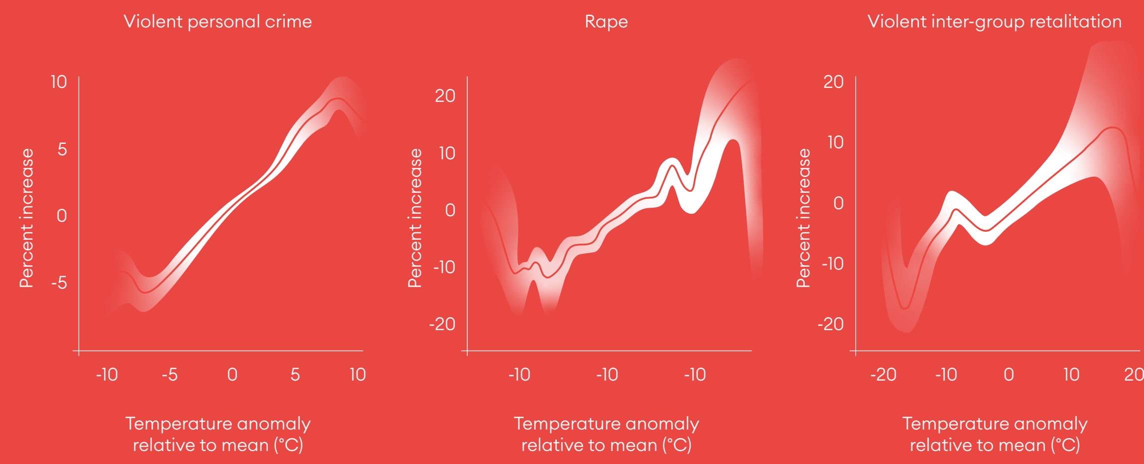
Community impact

Community risks of violence and weather variability

In the last section, we considered the direct health effects of air pollution caused by agricultural production in Europe. While these impacts are often invisible, they can nevertheless take a dramatic toll on individual health and wellbeing. However, unsustainable agricultural practices and climate change can have even broader impacts on the health and wellbeing of communities. In this section, we will consider the community wellbeing impacts of intrapersonal violence and weather variability. Both dynamics are likely to be exacerbated by worsening climate change, and as a result, both may be able to be at least partly alleviated by addressing the environmental impact of agriculture in the years to come.

One of the most obvious and notable effects of climate change, one that is already being recognized in many regions of the world, is temperature change. While global temperatures have been steadily increasing for the last two centuries, the rate of change has more than doubled over the last thirty years. The ten hottest years ever recorded have occurred after 1998, nine of them since 2005.[21] These developments are beginning to not only pose an array of ecological and environmental risks but can also result in meaningful changes to human social behavior and relationships. In one comprehensive analysis of relevant studies published in the journal *Science,* researchers noted a clear trend between rising levels of climate change and rising levels of crime and intrapersonal violence.[22] Increased temperature anomalies of five to ten degrees Celsius predicted a rise in violent crimes, rapes, and intergroup conflict of 5 to 10 percent (Figure 3.3).

Figure 3.3 Increased risk of violence and crime with higher temperature



Source Hsiang et al. (2013)

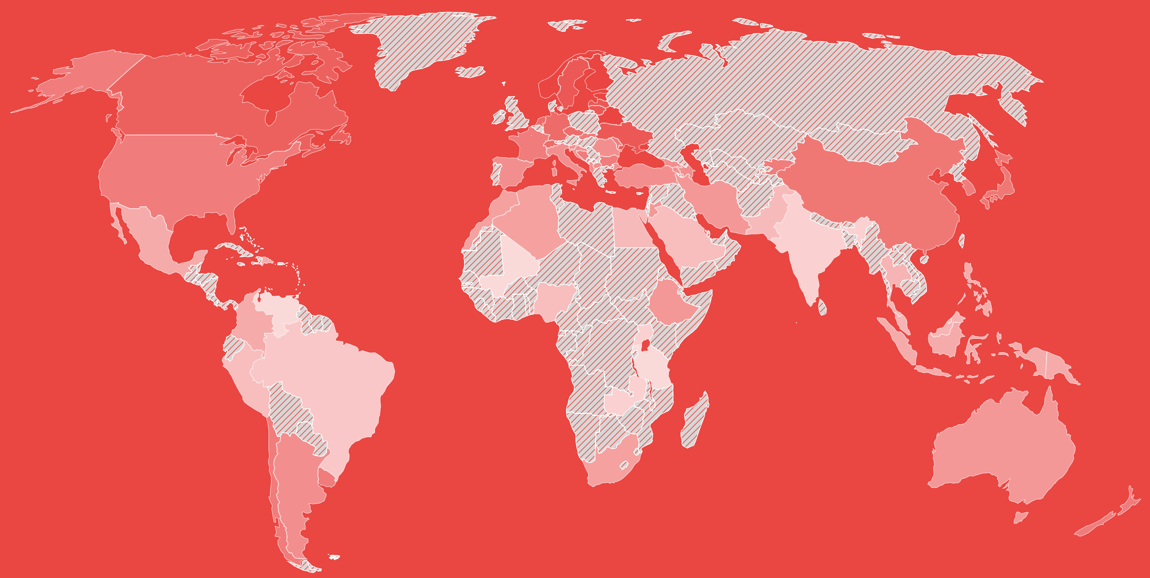
A related analysis in the United States estimated that rising temperatures due to climate change may be expected to result in 200,000 additional cases of rape and 3.6 million additional assaults between 2010 and 2099.[23] In the short-to-medium term, victims of violent crime report experience a 0.4-point drop in life satisfaction on average, which in the United States, translates into a wellbeing burden of 0.05 WALYs lost on average per crime committed.[24] However, it also important to note that victims of crime are not the only ones affected. A 10% increase in fear of crime also has also been found to have a negative effect on wellbeing of 0.004 WALYs lost. **Taken together, this would imply a loss of 3.04 million WALYs due to rising crime rates in the United States brought on by climate change by 2100.[25] To put this figure in context, it is larger than the total wellbeing burden of ulcers, lung disease, and Parkinson's among adults in Europe, combined.[26]**

Variable weather patterns have also been shown to have more direct effect on life satisfaction. With worsening climate change, increases in weather variability can in turn lower average levels of wellbeing across entire communities. In the remainder of this section, we will model these impacts by considering first how climate variability currently impacts wellbeing levels between countries, and then estimate how climate change may be expected to affect wellbeing in the future.

A study published in the journal *Ecological Economics* considered the relationship between subjective wellbeing and weather variability by estimating means, extremes, and the number of hot, cold, wet, and dry months using a panel dataset of 67 countries.[27] The authors found that, even after controlling for background societal characteristics, increased weather variability strongly predicted decreases in self-reported levels of wellbeing. Each change in degree month, controlling for GDP and other background conditions, decreases average wellbeing by 0.012 life satisfaction points. Using projections provided by the Intergovernmental Panel on Climate Change (IPCC), the authors then used these results to predict potential changes in wellbeing given expected changes in weather variability in the baseline projection scenario of continued unmitigated climate change until 2030.

Using these estimates in conjunction with average happiness levels provided by the World Happiness Report, we can then calculate expected WALYs lost per capita due to changes in climate variability by 2030.[28] These projections are represented graphically in Figure 3.4.[29] We find considerable variation in changing wellbeing levels due to temperature fluctuations around the world. In line with related analyses on the impacts of climate change, we find that negative impacts are expected to fall disproportionally on low- and middle-income countries. In some countries, wellbeing levels are expected to decrease by up to 18 percent. In high income countries, climate variability is expected to decrease, which may even lead to gains in self-reported happiness levels of 10 percent. This is yet another crucial reminder that the burdens of climate change, although primarily caused by activities in high income countries, are likely to primarily affect more low- and middle-income countries.

Figure 3.4 Wellbeing changes due to climate variability



WALYs lost (per capita)

-0.18 00 0.10

Note Authors calculations using data provided by the World Happiness Report and coefficients provided by Rehdanz & Maddison (2005).

Stability impact

Societal impact of natural disasters

Thus far we have considered the potential contribution of unsustainable agricultural production to pollution levels in Europe, crime rates in the United States, and climate variability around the world. The first we considered as a direct health effect, while the latter two we considered as community effects. Of course, the boundaries between these channels are often porous. Wellbeing impacts operating through health channels often have community implications, and vice versa. Each can also have broader societal impacts if they produce large enough economic and social burdens in societies. When it comes to climate change and food production, dynamic impacts across wellbeing domains are likely to be even more common. There is perhaps no phenomenon that illustrates these complexities more starkly than natural disasters. Natural disasters can have obvious and substantial impacts on individual health, community wellbeing, and societal stability. In the remainder of this chapter, we will consider these relationships and investigate the relationship between climate change and natural disasters around the world. Here we will primarily focus on the societal stability channel, although it is worth keeping in mind that the effect of natural disasters can have multiple spill-over effects.

While it is notoriously difficult to isolate the causal impact of climate change on any one natural disaster, a growing body of evidence has begun to link general increases in both the prevalence and intensity of disaster events to worsening climate change.[30] In turn, these events can have profound impacts on societal stability and wellbeing. According to a widely cited report by the United Nations, natural disasters killed more than one million people between 1998 and 2017, and left billions injured and displaced.[31] Most of these consequences were attributable to floods and storms, both of which have increased dramatically over the last several decades (Figure 3.5).

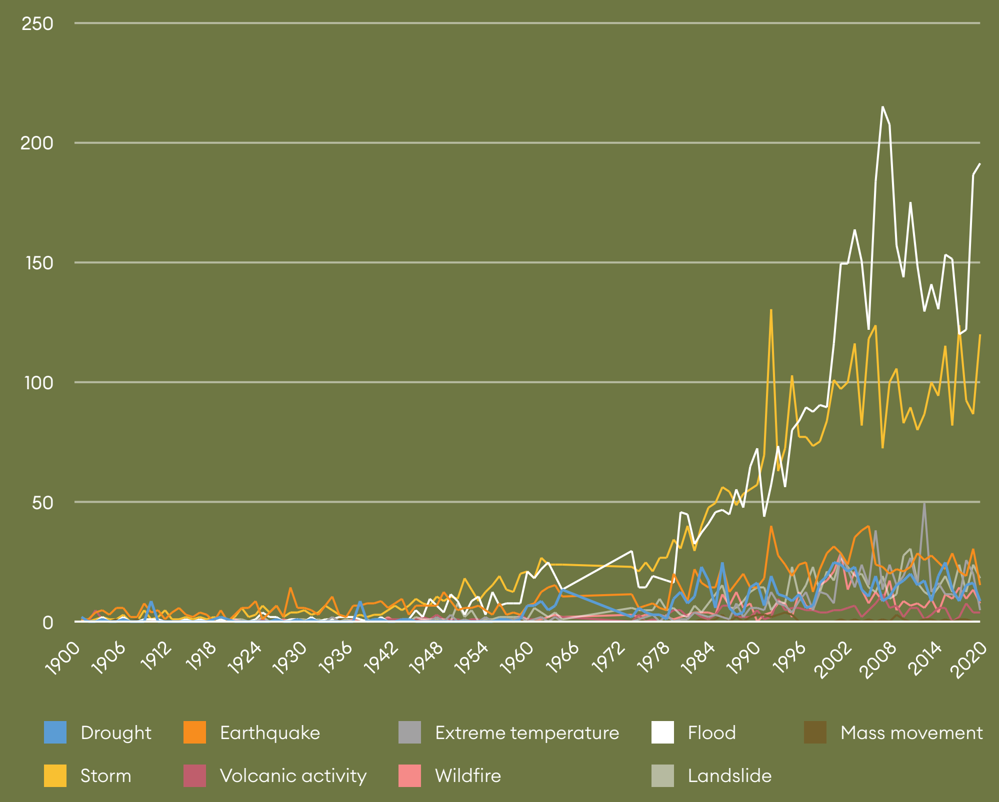
To better understand the wellbeing burden of these events, we can estimate WALYs lost due to deaths, lower levels of wellbeing recorded among affected populations, and economic costs associated with each event. First, following our methodology laid out in the introduction, each life lost to a natural disaster will be set equivalent to one WALY lost in the year of the event. However, natural disasters also have been documented to have negative wellbeing externalities on populations who are indirectly affected. One analysis using German panel data from 2000 to 2011 looking at the wellbeing consequences of extreme weather events found that, average life satisfaction levels in the entire country declined by 0.02 points on average in the wake of an extreme weather event.[32] Finally, to account for the wellbeing burden of economic losses associated with natural disasters, we can again theoretically convert the financial costs to income to estimate what the equivalent losses in Wellbeing Adjusted Life Years.

When we aggregate all three sources together – wellbeing losses associated with death, indirectly affected populations, and economic costs – we find that, while there is substantial variability from year to year, the wellbeing burdens associated with natural disasters has been steadily increasing since 1970 (Figure 3.6). While deaths due to disasters have been encouragingly declining in recent years, wellbeing burdens associated with those who are affected by natural disasters, as well as economic burdens, have been growing.

Overall, we find aggregate wellbeing burdens of more than 29.6 million WALYs lost due to major natural disasters over the past four decades. These burdens have also been increasing at a rate of roughly 11,500 WALYs lost each year. If these trends remain constant, it suggests that 18.9 million WALYs could be last due to natural disasters over the next thirty years. As noted earlier, the environmental impact of agriculture contributes to 26% of global emissions, leading to global warming and climate change. This figure has also remained largely stable since 1990.[33] **Ultimately, this implies that, continuing with business as usual, agricultural production could be responsible for roughly 4.9 million WALYs lost due to natural disasters from 2021 to 2050. Cutting this figure by even a small fraction has the potential to produce enormous and cascading wellbeing benefits in the years to come.**

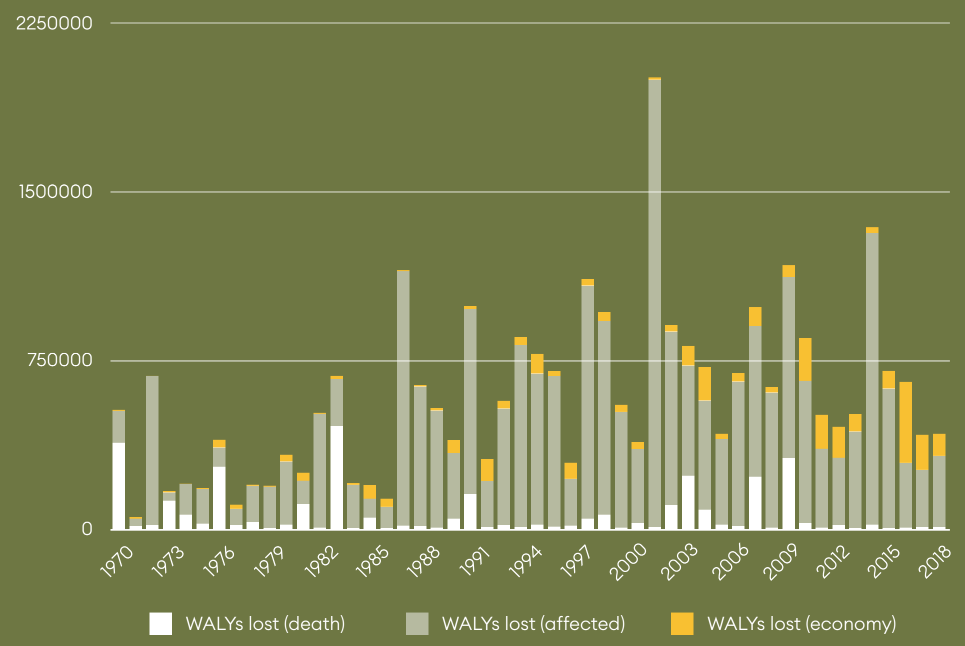
LEAP 03 // Stability impact

Figure 3.5 Frequency of natural disasters from 1900 to 2020



Note Author's calculations using EM-DAT data: www.public.emdat.be/data

Figure 3.6 Global wellbeing burdens of natural disasters (1970-2019)



Note Author's calculations using data from the World Happiness Report, coefficients from von Möllendorff & Hirschfeld (2016), and event estimates from EM-DAT.

Impact summary

In this chapter, we looked at some of the existing wellbeing burdens connected with the global food system, as well as the potential wellbeing impact from successfully reducing the associated environmental costs.

Health impact

Our analysis suggests that across Europe an average loss of 0.039 WALYs per person due to air pollution, of which 5% can be attributed to agriculture. This implies that more than 1 million WALYs could be saved annually by eliminating agricultural contributions to air pollution. It is also predicted that doing so will save 21,000 WALYs in terms of lives saved.

Community impact

Rising temperatures due to climate change are linked to increasing numbers of violent crimes and assaults. It is estimated that rising temperatures will result in 200,000 additional cases of rape and 3.6 million additional assaults between 2010 and 2099 in the US, which, according to our predictions, translate into a loss of 3.04 million WALYs based on the expected loss of wellbeing for victims and the rising fear of violence by non-victims.

Stability impact

Natural disasters are one of the most significant environmental costs of climate change. We estimate that more than 29.6 million WALYs have been lost owing to major natural disasters over the last four decades, taking into account mortality, the well-being of those impacted, and the associated economic costs. Furthermore, these burdens have been increasing at a pace of approximately 11,500 WALYs per year, and if current trends continue, 18.9 million WALYs could be lost due to natural catastrophes over the next thirty years. Given that agriculture accounts for 26% of global emissions, we can estimate that between 2021 and 2050, agricultural production will be responsible for 4.9 million WALYs lost due to natural disasters.

Endnotes

1 Roser et al. (2013).
2 Ritchie (2020).
3 Swinburn et al. (2019).
4 Dietz et al. (2020).
5 Dietz et al. (2020).
6 Gilden et al. (2010).
7 World Health Organization (2019).
8 Clayton et al. (2014).
9 Hsiang et al. (2013); Ranson (2014).
10 Rehdanz & Maddison (2005).
11 Lustgarten (2020).
12 Dinas et al. (2019); Fasani et al. (2020).
13 For more information on the EEA, visit: https://www.eea.europa.eu. For more information on the Eurobarometer survey, visit: https:// data.europa.eu/euodp/en/data/dataset/S2070_419_ENG
14 European Environmental Agency (2019).
15 European Environmental Agency (2019).
16 Liu et al. (2020); Welsch (2006).
17 Welsch (2006).
18 Happiness Research Institute and Leaps by Bayer (2020).
19 According to the EEA, 14% of all deaths in Europe can be attributed to pollution, roughly 1 in 8, most commonly due to lung and respiratory diseases and complications. For more information, see European Environmental Agency (2019).
20 Based on authors own calculations. Contact for more information.
21 National Centers for Environmental Information (2019).
22 Hsiang et al. (2013)
23 Ranson (2014).
24 Johnston et al. (2017); Helliwell et al. (2020).
25 Assumed average happiness levels from WHR in USA in 2018. 0.3 point reduction in life satisfaction with doubling of fear, 0.03 reduction with 10% increase. Here we very conservatively assume that for every one crime committed, 100 more people experience 10% increase in fear of crime: (200000*.4) + (3600000*.4)+(((200000+3600000)*10)*.004).
26 Happiness Research Institute and Leaps by Bayer (2020).
27 Rehdanz & Maddison (2005).
28 This analysis assumes constant average life satisfaction levels over the next ten years.
29 Based on authors own calculations. Contact for more information.
30 Hallegatte (2016); Banholzer et al. (2014).
31 Wallemacq & House (2018).
32 von Möllendorff & Hirschfeld (2016).
33 IPCC (2014)

Leap 04

Prevent and cure cancer

The problem

Cancer is the second leading cause of death in the world, second only to cardiovascular diseases.[1] In 2017, cancers were responsible for one out of every sixth death, totaling to almost 9.6 million lives lost. Most of these (70%) occurred in low to middle income countries.[2] However, even these figures underestimate the true burden of the disease. They do not account for its second and third order effects on family members, loved ones, friends, caretakers, and medical professionals. Given these dynamics, overcoming cancer is one of the most urgent and consequential medical challenges facing humanity today.

Cancer itself is a generic term to describe a class of diseases characterized by the production and rapid spread of abnormal cells, which can lead to tumors and threaten healthy functioning of vital organs. There are more than 100 types of cancer, the most common occurring in the lungs, colon, stomach, liver, and breast. Cancer has also been linked to wide array of behavioral, genetic, and environmental risk factors. Tobacco use is the most significant risk factor, accounting for 22% of all cancer deaths.[3] Another 10% can be attributed to other behavioral risks including poor diet, physical inactivity, obesity, and alcoholism. In the developing world, complications resulting from infectious diseases including hepatitis and HPV are particularly prevalent, accounting for approximately one out of every six cancer diagnoses.[4] Cancers can also be caused by exposure to ultraviolet rays from the sun or other types of radiation that damage DNA.

Like all other significant diseases and disorders, cancer has negative effects not only on patients, but also on family members, friends, caregivers, communities, and society writ large.

What if?

What if every woman had access to a breast cancer vaccine? What if next-generation therapies could target some of the most resistant types of cancer and brain tumors? These goals may not be as far away as they seem. Vaccines for HPV have shown promise in preventing cervical cancers when administered to adolescents, and promising research into gene-based therapies has begun to pave the way for revolutionary new types of treatments.[5] These innovations would not only save lives, but also deliver benefits that extend far beyond patients themselves.

In the sections that follow, we will highlight some of these dynamics in greater detail, and comment on the potential wellbeing burdens that could be alleviated by developing new cures and treatments for cancer in the years to come.

Health impact

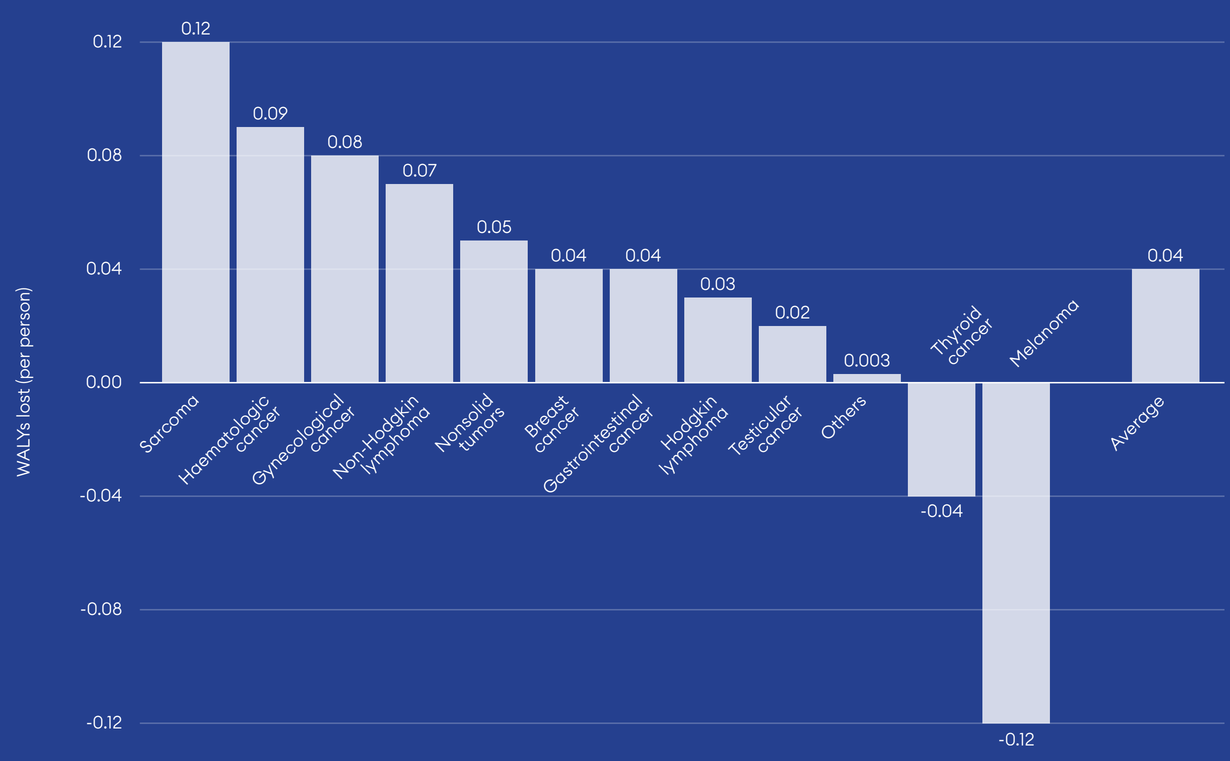
Conceptualizing the wellbeing lost by cancer patients

The relationship between cancer and patient subjective wellbeing is a complicated one. Three factors are worth considering. First, given the highly divergent array of cancers, bundling them into one category to estimate the overall effect of cancer on patient wellbeing is bound to be fraught. Some types of skin cancer have survival rates over 90%, while survival rates for leukemia can drop as low as 25%.[6] Patients diagnosed with different types of cancer are affected differently. Second, patient wellbeing is also likely to be affected by the stage of cancer and time of diagnosis. There are generally considered to be five stages of cancer, each referring to progressing phases of the disease over time. Early detection is crucial for decreasing mortality, minimizing side effects, and reducing burdens associated with treatment. As a result, even patients with the same type of cancer may experience the disease in very different ways at different points in time. Third, patients with the most severe forms of the disease are unlikely to be represented in surveys, making it difficult to reliably estimate the high toll it can take on their subjective wellbeing.

With these intricacies in mind, several investigations have begun to reveal important insights into the effects of cancer on patient wellbeing. One analysis of 514 young adult patients in Germany found sarcomas to have the most severe effects on patient life satisfaction compared to other types under consideration.[7] By comparing these estimates to national life satisfaction averages in Germany, we can estimate the wellbeing burden of each cancer in terms of Wellbeing Adjusted Life Years (WALYs) lost. These individual burdens are plotted in Figure 4.3. **On average, cancer patients under the age of 40 in Germany lose 4% of the wellbeing relative to healthy counterparts. Among older adults (50+), using data from the Survey of Health, Aging, and Retirement (SHARE) in Europe, we also find that patients lose approximately 0.039 WALYs, or 4% of the wellbeing they would be expected to experience without their disease.[8] To put this figure into context, it is roughly on par with the life satisfaction difference between divorced and married adults.[9]**

Somewhat surprisingly, in the German study, patients with melanomas and thyroid cancer appear to be slightly happier than their healthy counterparts. This finding could potentially be explained by the relatively small number of observations used in the analysis (Figure 4.3). Alternatively, given the high survival rates associated with both forms of cancer in Germany, they may be more reflective of a positive response shift. When evaluating their own lives, cancer patients with relatively mild or survivable forms of the disease may compare themselves to other patients or consider the degree to which their diagnosis could have been worse. This can cause them to review their lives more favorably than may be expected. Some cancer patients also report finding new sources of meaning and appreciation in their lives after diagnosis and successful treatment. These dynamics have been observed in a variety of studies.[10]

Figure 4.1 Individual wellbeing burden of cancers



Sourse Leuteritz et al. (2018)

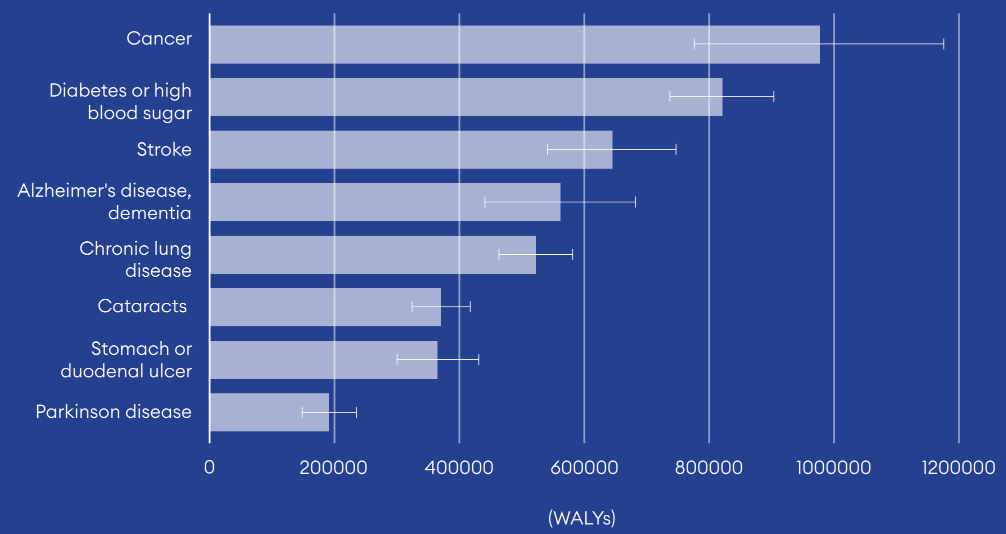
Even among patients who survive, many face challenging roads to recovery. Women recovering from breast cancer often face significant wellbeing burdens. One analysis of 725 women recovering from breast cancer in Sweden found that, among women who did not need to undergo breast cancer surgery, 65.2% reported feeling satisfied with their lives. Among those who underwent mastectomies, this percentage dropped to 55.2%.[11] Among healthy counterparts without cancer, 70% report feeling satisfied with their lives. Importantly, the most important predictor of wellbeing among both groups proved to be emotional support. Of those who received emotional support, 67.1% reported feeling satisfied with life across both groups. Of those who did not report receiving adequate emotional support, only 24.7% were satisfied with their lives.[12] The crucial importance of social support in promoting among cancer patients was also replicated in another analysis of German adolescents.[13]

Encouragingly, over the long term many cancer survivors do seem to recover to levels of wellbeing that are on par with healthy counterparts. In an analysis of 6,389 cancer survivors in the United States, on average they were not less satisfied with their lives overall relative to those who were not diagnosed with the disease, six years after their initial diagnosis.[14] This finding was replicated in a similar analysis of American seniors over the age of 50 using data provided by the Health and Retirement Study.[15]

Population wellbeing burdens of cancer

In the last section, we considered the wellbeing burden of cancer on individual patients. However, regardless of its individual impact, the high prevalence of the disease coupled with its high mortality rate render the total wellbeing burden of cancer almost unparalleled among other physical diseases. On a population level, cancer is responsible for more total wellbeing lost than almost any other major disease group (Figure 4.2,). Using life satisfaction data drawn from the Survey of Health, Aging, and Retirement in Europe (SHARE), alongside prevalence and mortality rates provided by the Global Burden of Disease Study, we find that the total wellbeing burden of cancer among European adults (50+) for instance outweighs diabetes, stroke, Alzheimer's disease, lung disease, cataracts, ulcers, and Parkinson's disease (Figure 4.2).[16]

Figure 4.2 Population wellbeing burdens of physical disease among European adults



Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, marital status education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

Fortunately, survival rates for cancer are increasing globally. Advances in early diagnostic testing and treatment have started to beat back the high death toll of the disease. On average, patients diagnosed with cancer today are 15% less likely to succumb to their disease than a patient diagnosed 30 years ago.[17] However, the combination of population growth and demographic aging have kept overall trend lines stubbornly persistent. With more people on the planet, and more of those people living well into old age, overall prevalence and mortality rates for cancer have mostly remained constant over the past several decades.

Carried forward into the future, continuing to make progress in preventing, treating, and eventually curing cancer could therefore have enormous wellbeing implications for populations around the world. Following past studies, if we conservatively assume that cancer patients lose 0.04 WALYs (or 4%) of the wellbeing they could potentially experience following a cancer diagnosis and simultaneously keeping prevalence and mortality rates constant at 2017 levels, rough **projections suggest that developing a cure for cancer could save more than 28 million WALYs per year globally, or over 850 million WALYs over the next thirty years. In essence, curing cancer would allow for future patients to experience 850 million years lived in full wellbeing that would otherwise be lost. Included in these estimates are upwards of 286 million lives that could be saved by discovering successful methods to prevent, treat, and cure cancer.[18]** This would surely represent one of the greatest single leaps forward for humanity in history.

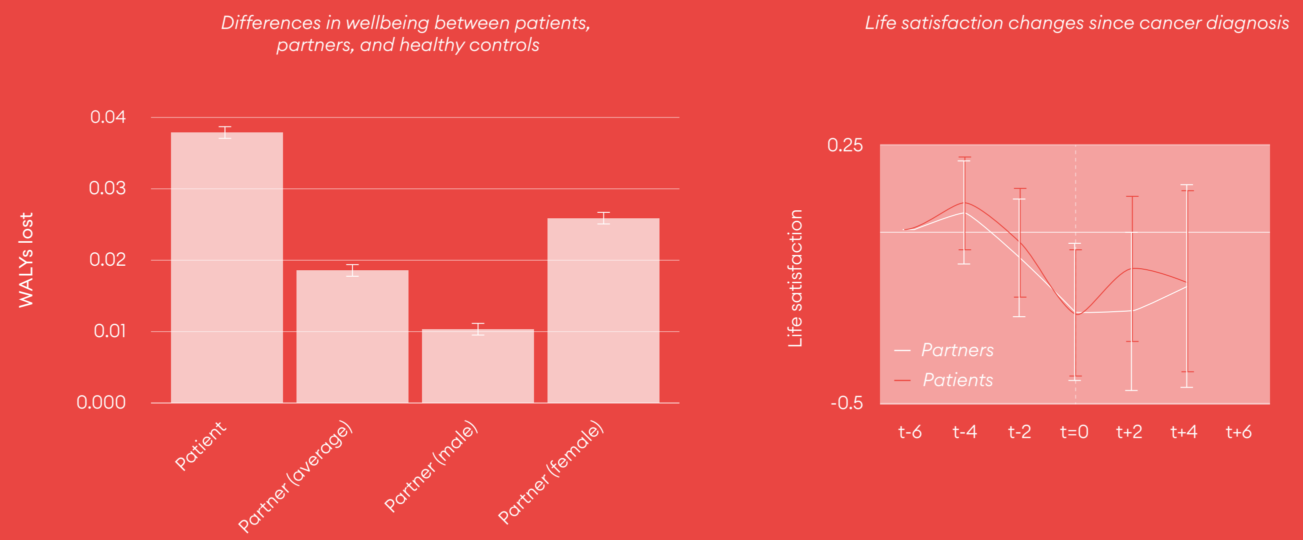
Community impact

Impacts of cancer on caregivers and communities

Thus, we have considered direct wellbeing burdens of cancer on patients on an individual and population level. However, as the writer Terry Tempest Williams noted, “An individual doesn’t get cancer, a family does.” To truly account for the cost of the disease, we ought to consider its effects on patients’ loved ones, communities, and caregivers.

The caregiving burden of cancer on partners in particular has received increased attention in recent years. One recent meta-analysis of 25 empirical studies found that female spousal caregivers in particular experienced “lower mental health, lower physical health, poorer health-related quality of life, lower life satisfaction and decreased marital satisfaction” relative to male spousal caregivers and healthy counterparts.[19] Using SHARE data on European adults, we also find significant wellbeing burdens among partners of patients with diagnoses, which also does seem to be particularly challenging for women. **Compared to healthy counterparts, partners of patients with cancer lose approximately 0.02 WALYs they could have otherwise experienced. This is roughly 50% of the wellbeing burden experienced by cancer patients themselves. Among female partners, this rises to almost 70% of the wellbeing burden experienced by patients.**

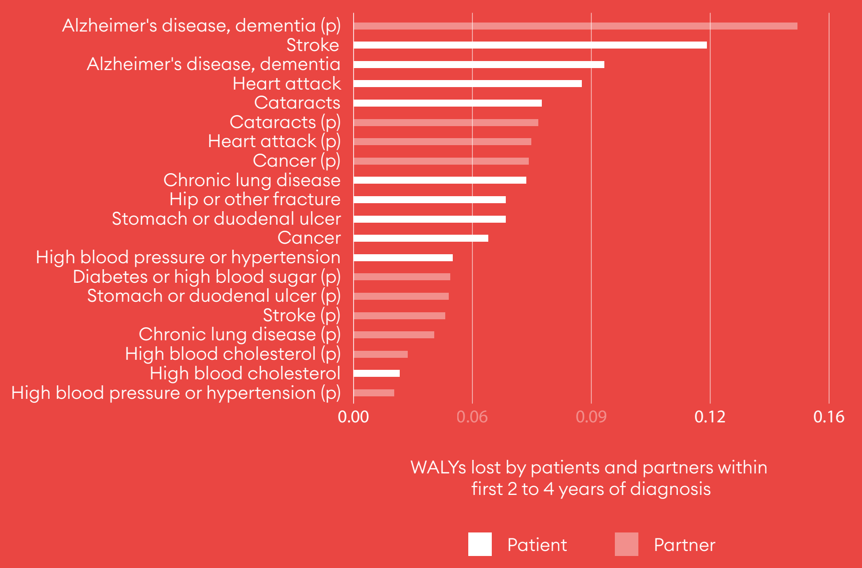
Figure 4.3 Wellbeing burdens of cancer on partners



Note Authors’ calculations using SHARE data. Estimated using OLS regressions with added controls for age, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

From a longitudinal perspective, these effects become even more pronounced. Thus, we have considered the wellbeing of partners of patients with cancer relative to counterparts with healthy partners. However, we can also consider the evolution of their own subjective wellbeing over time. Among European adults, partners of patients diagnosed with cancer are on average 0.3 points less satisfied with their lives in the first 2-4 years after the diagnosis than they were while their partners were still healthy six years earlier. When viewed from this perspective, the wellbeing burden of cancer experienced by partners in these first few years actually becomes larger than the wellbeing burden experienced by patients themselves. In the figure below, we plot WALY losses associated with a variety of physical diseases among both patients and partners. Partners of patients with cancer also lose more wellbeing than they would if they themselves were diagnosed with chronic lung disease, hip fractures, ulcers, high blood pressure, or high cholesterol (Figure 4.4).

Figure 4.4 Wellbeing burdens of cancer on partners relative to other diseases



Unfortunately, the wellbeing burdens of cancer experienced by children, parents, and siblings of patients have received comparatively less attention in the literature. Nevertheless, it is highly likely that these too would emerge as highly significant. Investigating these dynamics provides an urgent and important fruitful avenue of further research. Given the high cost of cancer observed for partners, when considering the true wellbeing burden of the disease, it is imperative to keep these second, third, and fourth order sources of wellbeing losses in mind.

Stability impact

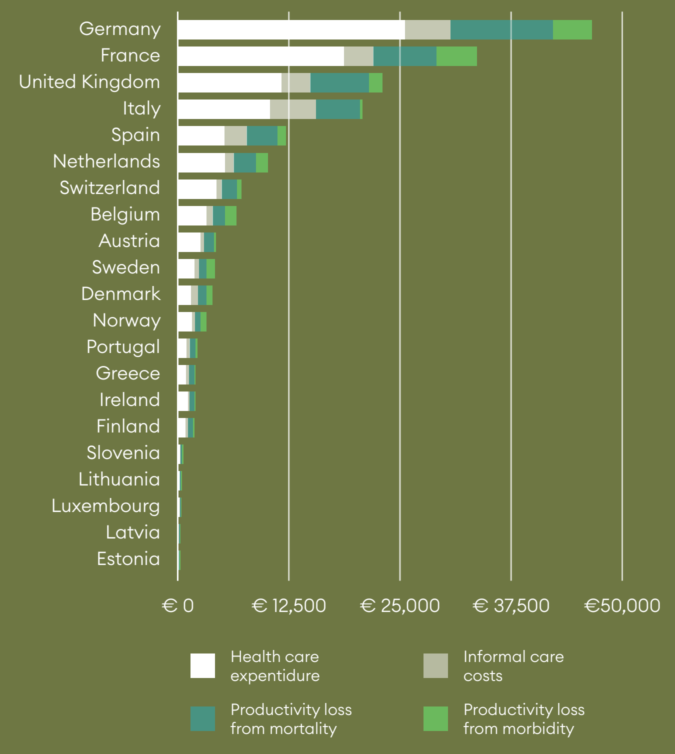
Understanding the economic cost of cancer

In this section, we will consider the broader social cost of cancer. While the disease takes a substantial toll on patients and communities, it also has a considerable economic impact on society writ large. Particularly in developed countries, trends of demographic aging are leading to larger numbers of patients suffering from cancer, and increasingly straining healthcare systems and resources. These resources are often essential to caring for patients and their families. Nevertheless, with the burden of cancer relieved, these resources would then be saved and could be devoted elsewhere in society. To better understand these broader costs of the disease, we will focus on both direct healthcare and informal care costs, and well as indirect losses to productivity associated with both morbidity and mortality. Our analysis in this case will focus on European nations.

A comprehensive assessment of the economic burden of cancer by Hofmarcher et al. (2018) was recently published in the *European Journal of Cancer*.[20] Using international data provided by Eurostat, the OECD, and the World Bank, alongside health data published by national healthcare systems and statistical agencies, the researchers estimated both per capita and total costs of cancers in the European Union. Direct costs included hospital stays, drugs and treatments, medical staffing, and related expenses. Indirect costs included lost earnings and informal care costs of family and caregivers. Final breakdowns for each country are presented in Figure 4.5. Overall, across all countries considered, direct healthcare expenditures were generally the largest burden, and varied between 5 and 10% of the total healthcare spending in each country. In Germany and France in particular, national health services reimburse more costly cancer drugs, contributing to the especially large healthcare expenditures associated with cancer in both countries.[21] Productivity losses also proved to be substantial, amounting to about one third of the total economic burden of the disease. **Overall, the researchers calculated the economic burden of cancer in Europe to be almost 200 billion euros, most of which was attributable to Germany, France, the United Kingdom, Italy, and Spain.**

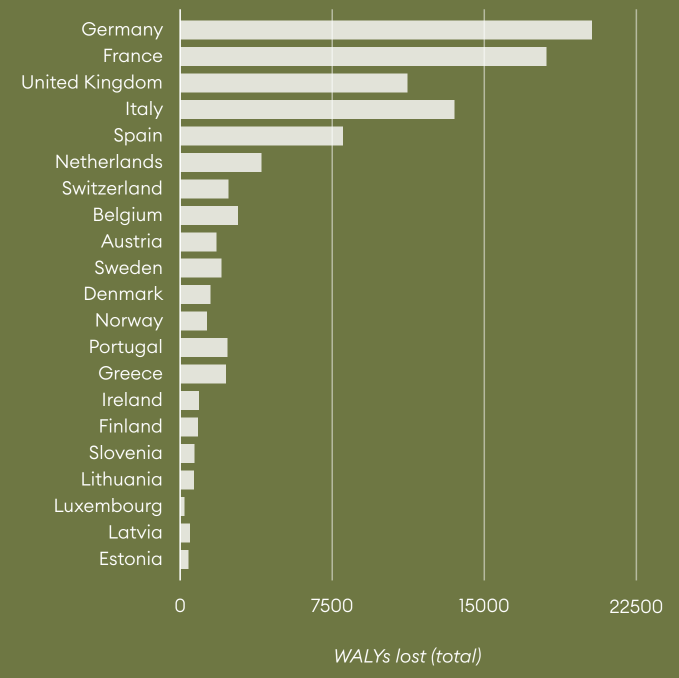
These are enormous figures. But what do they suggest in terms of wellbeing lost or gained? As in other chapters of this report, we can convert these economic burdens to theoretical wellbeing losses by considering them as income. These conversions are presented in Figure 4.6.[22] Shown this way, we once again find that Germany and France suffer large wellbeing burdens associated with the societal cost of cancer. This is again largely attributable to the large cancer patient population in both countries, but in this case the wellbeing burdens in France prove to be larger than the corresponding economic burden. Although there are less cancer patients in France than Germany, the average income in the former is smaller than the latter. Italy also suffers a considerable wellbeing burden, relative to the economic costs associated with the disease. In this case, the cost per patient is relatively lower, yet because overall life satisfaction levels and median incomes are relatively lower in Italy than other Western European countries, the wellbeing burden associated with cancer is estimated to be more burdensome. Further down the list, we see some additional discrepancies with regard to Austria, Sweden, and Denmark. While there are again some differences in income between each county, in this case economic efficiency also plays a role. Although there are more cancer patients in Austria than in Denmark, the economic burden per patient is roughly half of what it is in Denmark, primarily because the latter spends much more on a per patient basis than the former.[23] As a result the wellbeing burden in the former country is slightly less burdensome when considered from the perspective of WALYs lost, rather than considering it in purely economic terms.

Figure 4.5 Economic burden of cancer in 2018 (in millions)



Source Hofmarcher et al. (2018)

Figure 4.6 WALYs lost due to economic burden of cancer



Note Author's calculations using data from Hofmarcher et al. (2018) alongside happiness data provided the World Happiness Report and median income data provided by Gallup.

Impact summary

In this chapter, we have estimated the wellbeing impacts of eradicating cancer on both the individual, the partners of the patients and on the economy.

Health impact

Our projections suggest that developing a cure for cancer could save more than 400 million WALYs over the next thirty years. In essence, curing cancer would allow for future patients to experience 400 million years lived in full wellbeing that would otherwise be lost. Included in these estimates are upwards of 320 million lives that could be saved by discovering successful methods to prevent, treat, and cure cancer.

Community impact

Compared to healthy counterparts, partners of patients with cancer lose approximately 0.02 WALYs they could have otherwise experienced. This is roughly 50% of the wellbeing burden experienced by cancer patients themselves. Among female partners, this rises to almost 70% of the wellbeing burden experienced by patients.

Stability impact

The economic burden of cancer in Europe is considered be almost 200 billion euros, most of which are attributable to Germany, France, the United Kingdom, Italy, and Spain. If those cost could be freed (in those five countries), the WALYs generated would range from 7,500 (Spain) to 20,000 (Germany) according to our estimates.

Endnotes

1 Roser & Ritchie (2015).
2 World Health Organization (2018).
3 World Health Organization (2018).
4 World Health Organization (2018).
5 Martinez-Lage et al. (2018); Franco & Harper (2005).
6 Data from the United States in 2015. For more information, see: https://seer.cancer.gov/csr/1975_2017/results_single/sect_01_table.04_2pgs.pdf
7 Leuteritz et al. (2018).
8 Author's calculations using SHARE data.
9 Happiness Research Institute & Leaps by Bayer (2020).
10 de Camargos et al. (2020); Ellis et al. (2019); VanderZee et al. (1996).
11 Among healthy counterparts in Sweden without cancer, 70% reported feeling satisfied with their lives. For more information, see: Olsson et al. (2019).
12 Olsson et al. (2019, p. 676).
13 Leuteritz et al. (2018).
14 Ellis et al. (2019).
15 Sullivan et al. (2018).
16 Author's estimations. This excludes mental and social health. Heart disease is not available, though may be the only physical disease expected to be larger.
17 Roser & Ritchie (2015).
18 Amounting to a total WALY burden of 9,534,619 + (472,397,254*.04) = 28,430,509 WALYs lost per year.
Over the next 30 years = 852,915,270 WALYs lost, of which 286,038,570 would be accounted for by lives lost.
19 Li et al. (2013).
20 Hofmarcher et al. (2020).
21 Cheema et al. (2012).
22 WALYs calculated using the following formula: WALYs lost (individual) = 0.3 x log (Median household income/(Median household income - Disease related costs)). Total WALYs lost then derived by multiplying the individual WALYs lost by the number of cancer patients within each country. Prevalence and population data drawn from IHME Global Burden of Disease Study. Median income figures drawn from Gallup. Costs of cancer burdens drawn from Hofmarcher et al. (2018).
23 €2204 to €5904, relatively.

Leap 05

Protect the brain and mind

The problem

According to the OECD, 17.3% - or what is equivalent to every 1 in 6 – suffer from a mental health disorder[1] and globally it is estimated that nearly 1 billion people are directly affected.
In addition, mental health disorders are responsible for 7% of all global burden of disease as measured in DALYs and 19% of all years lived with disability.[2]

Mental health issues are so pervasive that it can almost be hard to grasp why great solutions to prevent and treat them are not a top priority for impact investment and government. The current convergence of social, political, and technical challenges, however, may be forcing this to shift.

Table 5.1 Share of population with depression

	Anxiety disorders	Depressive disorders	Alcohol and drug use disorders	Bipolar disorders and schizophrenia	Others	Mental disorders
Finland	4%	6%	4%	1%	4%	18,8%
Netherlands	7%	5%	2%	1%	3%	18,6%
France	6%	5%	3%	1%	4%	18,5%
Ireland	6%	5%	3%	1%	4%	18,5%
Portugal	6%	6%	2%	2%	4%	18,4%
Estonia	3%	5%	6%	1%	3%	18,3%
Spain	6%	4%	2%	1%	5%	18,3%
Sweden	5%	5%	2%	1%	4%	18,3%
Germany	6%	5%	3%	1%	3%	18,0%
Lithuania	3%	6%	5%	1%	3%	17,9%
Belgium	5%	5%	2%	2%	4%	17,9%
United Kingdom	5%	5%	3%	1%	4%	17.7%
Greece	6%	5%	2%	2%	4%	17.7%
Austria	6%	4%	3%	2%	4%	17.7%
Luxembourg	6%	4%	2%	2%	4%	17.6%
EU28	5.4%	4,5%	2.4%	1,3%	4%	17.3%
Latvia	3%	5%	5%	1%	3%	17,3%
Cyprus	6%	4%	2%	2%	4%	17,0%
Malta	6%	4%	2%	2%	4%	17,0%
Italy	6%	4%	1%	1%	4%	16,9%
Denmark	6%	4%	3%	1%	3%	16,9%
Slovenia	4%	4%	3%	1%	4%	15,7%
Croatia	4%	4%	3%	1%	4%	15,5%
Hungary	4%	4%	3%	1%	4%	15,4%
Slovak Rep.	4%	3%	3%	1%	4%	15,2%
Czech Rep.	4%	4%	3%	1%	4%	15,1%
Poland	4%	3%	3%	1%	4%	14,9%
Bulgaria	4%	4%	2%	1%	4%	14,8%
Romania	4%	3%	2%	1%	4%	14,3%
Norway	7%	4%	3%	1%	3%	18,5%
Iceland	5%	4%	2%	1%	4%	16,7%
Switzerland	6%	4%	2%	2%	4%	17,5%

Source Authors' calculations using SHARE data

What if?

What if the technological breakthroughs paired with political focus on early detection and prevention could ensure that more people could get treatment, and in a more effective and timely manner?

Today, scientists are constantly discovering more about the possible role of genetics, neurology, and endocrinology for our mental health. Some research has even documented the links between the gut microbiome and the brain. These scientific breakthroughs are subsequently translated into practical tools and solutions. Genomic testing and screenings for mental illnesses and machine-learning-enabled systems that improve diagnostics by leveraging patient registered data to improve treatment are only a few examples of such.

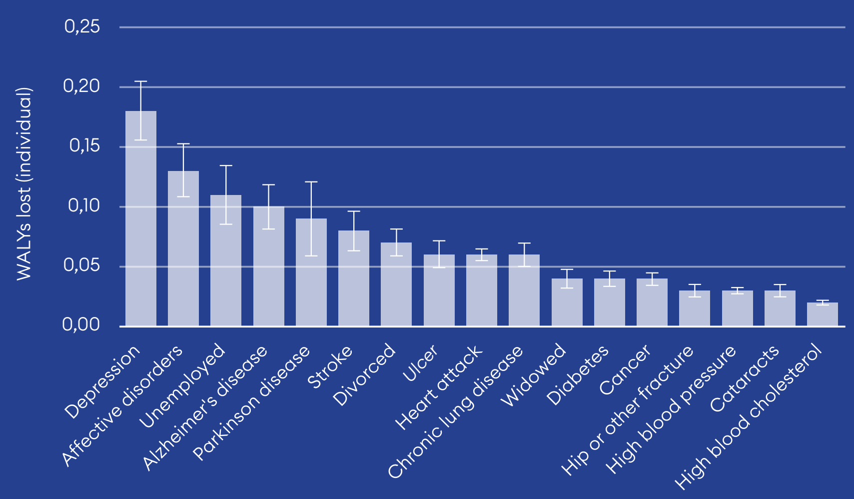
In what follows, we will discuss the wellbeing impact of depression on both the patients, the caregivers and the economy. In doing so, we will bring to light some of the potential benefits of improved screening and treatments targeted to alleviate the respective wellbeing burden.

Health impact

Depression and anxiety are two of the diseases that have the greatest impact on people's wellbeing and on the population. According to Layard (2018), these mental illnesses are producing nearly as much of the misery that exists in the world as poverty does.[3]

According to our estimates, depression and anxiety are the conditions that have the greatest impact on life satisfaction and thus on WALYs lost (Figure 5.1).[4] Specifically, a person with depression loses 18% of the wellbeing he or she could enjoy if they had not been diagnosed with depression. This is significantly more than the burden associated with unemployment, Alzheimer's disease, Parkinson's disease, and strokes.

Figure 5.1 Individual weelbeing burdens of major diseases



Moreover, when considering the prevalence of depression (36 million people in Europe), **we can assume that approximately 6,3 million WALYs are lost each year owing to depression in Europe.[5] To put this into perspective, if this well-being burden could be completely alleviated, the benefits would be similar to combined impact of providing jobs to all unemployed people in Brazil and ending food insecurity in Bangladesh.[6]**

Community impact

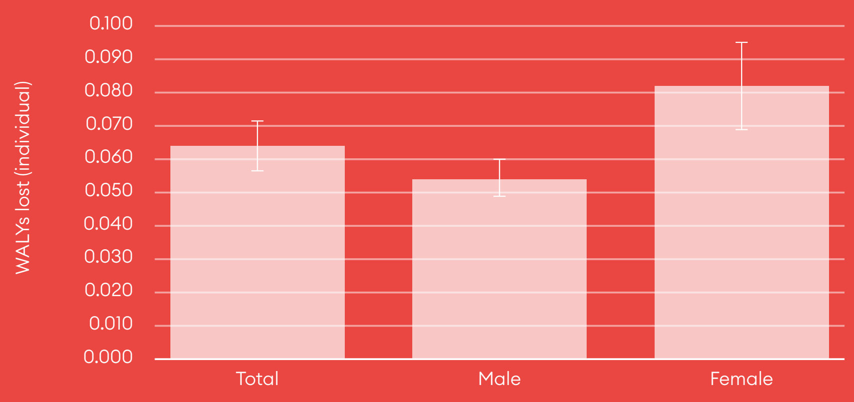
Community burdens of depression on family caregivers

Depression does not only affect patients. When we analyze the effect of depression on a patient's spouse or partner, it is evident that these people too are subject to significant wellbeing losses. In fact, in many circumstances, being the partner of someone who suffers from depression is worse for your wellbeing than suffering from a chronic illness yourself.

Using data from six waves from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development with more than 650 couples per wave, Jia J. Yan et al. (2020) found causal pathways between depression and the quality of the relationship. For women, reporting high levels of intimacy in their relationship in one wave predicted decreases in depressive symptoms in the following wave (the reverse, however, was not true). For men, showing low depressive symptoms in one wave predicted increases in self-perceived relationship intimacy in subsequent waves.[7]

Furthermore, our own findings imply that a depression diagnosis for one member of the household has an immediate influence on the remainder of the household. The graph below shows how living with a depressed person has a major impact on one's own well-being; men lose roughly 5.5% of the life satisfaction they could have experienced if their partners were not depressed, while women lose up to 8%.[8]

Figure 5.2 partner and wellbeing burdens of depression



However, it is uncertain whether this association is causal. The quality of the relationship may be influenced by one of the partners' depressed symptoms, but it's also possible that the relationship's quality is responsible for protecting or promoting the depressive symptoms.

Stability impact

The financial benefits of ending depression

Depression also has a negative impact on the economy. When we consider that depression affects the most active part of the population, absenteeism is extremely essential. Mental health issues are the leading cause of work absences,[9] accounting for one-third of all new disability claims in OECD countries.[10]

A study including 15,152 employees of a major U.S. corporation found that employees treated for depression incurred annual per capita health and disability costs of $5,415. This is a lot more than the expense of hypertension. In addition, depressive illness was linked to 9.86 annual sick days, which was significantly higher than heart disease, diabetes, hypertension, and back pain.[11] In the U.S., depression is a leading cause of disability for people aged 15-44 years, resulting in almost 400 million sick days per year.[12]

Moreover, Greenberg and his colleagues estimate that in a country like the United States, about $210.5 billion are lost due to direct costs related with major depressive disorder (45% of the total costs), suicide-related costs (5%), and workplace costs (50%) including absenteeism (missed days from work) and presenteeism (reduced productivity while at work) [13]. In other words, **depression costs each American ·$680, the equivalent to 0.013 WALYs lost[14] per inhabitant. In sum, 4 million WALYs could be saved in the United States alone from the financial benefits of eradicating depression (1.8 million WALYs through direct costs, 200,000 WALYs through suicide-related costs and 2 million WALYs through workplace costs). To put this in perspective, this amount of WALYs saved is one-and-a-half times more than WALYs that could hypothetically be saved if all unemployed people in the United States were given a job.[15]**

Impact summary

In this chapter, we've mapped the wellbeing burdens related to depression, and by that, quantified the potential impact of successful screenings and treatments patients.

Health impact

A person with depression loses 18% of the wellbeing he or she could enjoy if they had not been diagnosed with depression. In Germany, approximately 338,000 WALYs are lost each year owing to depression, making the potential impact of curing depression greater than eliminating all unemployment in this country.

Community impact

Though depression neurologically in confined to one person, it is not experienced in a vacuum. According to our analyses, men lose roughly 5.5% of the life satisfaction they could have experienced if their partners were not depressed, while women lose up to 8%.

Stability impact

Depression is also putting economic stability into jeopardy. Each year, depression – as well as other mental health problem – are causing enormous economic losses through increased consumption of healthcare and social care, more sick days and productivity losses. In terms of wellbeing, we estimate that 4 million WALYs could be saved in the United States alone from the financial benefits of eradicating depression (1.8 million WALYs through direct costs, 200,000 WALYs through suicide-related costs and 2 million WALYs through workplace costs).

Endnotes

1 OECD/EU (2018).
2 https://ourworldindata.org/grapher/dalys-from-mental-health-and-substance-use-disorders
3 Layard, R. (2018).
4 Own estimations using SHARE data.
5 Own estimations using SHARE data and Global Burden og Disease data.
6 Using our own estimations from the World Values Survey in 2017, reducing unemployment to zero in Brazil would generate 3,302,644 WALYs, while ending food insecurities in Bangladesh would generate 3,063,811 WALYs.
7 Transactional Associations Between Couple Relationship Intimacy and Depressive Symptoms Across 10 Years
8 Own estimations using SHARE data.
9 Henderson, M, et al. (2005)
10 Matrix, I (2013).
11 Druss, B. G., et al. (2000).
12 Merikangas K. R., et al. (2007).
13 The economic burden of adults with major depressive disorder in the United States (2005 and 2010). Paul E Greenberg et al (2015)
14 Assuming median per-capita income from Phelps, G., & Crabtree, S. (2013). For the transformation between income and life satisfaction we use the coefficient and equation extracted in Davies, C. (2018). Increase in life satisfaction - 0.3 * log(Median Income / (Median Income – Treatment)).
15 Using our own estimations from the World Values Survey in 2017, reducing unemployment to zero in the US would generate ~2,590,000 WALYs in total

Leap 06

Reverse autoimmune diseases and chronic inflammation

The problem

Autoimmune diseases are among the top 10 causes of death in female children and women in all age groups, it is estimated that about 5-8% of the population is affected by autoimmune diseases. In addition, chronic inflammatory diseases have been recognized as the most significant cause of death in the world today, with more than 50% of all deaths being attributable to inflammation-related diseases. Both conditions have one component in common: the immune system.

The immune system is a collection of special cells and chemicals that fight infection-causing bacteria and viruses. However, for about 5-7% of the global population, the immune system mistakenly attacks their own body tissues. This is what we know as autoimmune diseases.

It is estimated that about 80-100 different autoimmune diseases exist, ranging in severity from mild to disabling. Together, these form the third most common group of diseases after cardiovascular and tumor diseases. They are usually chronic, currently incurable and can cause severe, life-threatening health issues.[1]

Additionally, autoimmune diseases have been reported to be on the rise in recent years, especially in developed countries. In the UK, the disease is increasing at ranges between 3% and 9% year on year for different conditions[2], and in the US, researchers found that the prevalence of antinuclear antibodies (the most common biomarker of autoimmunity) had increased from 11.0% in 1988-1991, to 15.9% in 2011-2012.[3]

Increasing prevalence of autoimmune diseases is bad news – especially for women. Autoimmune diseases affect women up to 75 percent more often than men. The cause of this gender disparity is not fully known.

These recent trends have also brought into question the factors contributing to this increased incidence. The constancy of genetics, the environmental factors, and in particular, the Western lifestyle, are considered potential causes. Over the last few decades, significant changes in Western dietary habits, environmental surroundings, pollution exposure, and stress load, have led to a parallel rise in autoimmune diseases.[4] This place autoimmune diseases in the center of the discussion on environmental impacts on public health.

What if?

What if we could permanently reverse the autoimmune process? At present, autoimmune conditions cannot be cured. This means that for most people who develop an autoimmune condition, a lifetime of daily management, potential health complications and lost wellbeing may lie ahead.

In this chapter we estimate the potential WALYs saved if we cure autoimmune diseases. The chapter focuses explicitly on type 1 diabetes, psoriasis, rheumatoid arthritis, and multiple sclerosis.

Table 6.1 Percent of adult population with autoimmune conditions

	Brazil	China	5-EU	Japan	Russia	U.S.
Diagnosed (%)	3%	5%	6%	2%	3%	7%
Male	32%	51%	40%	37%	40%	40%
Female	68%	49%	60%	63%	61%	60%

Source Kantar (2019)

Table 6.2 Selection of common types of Autoimmune diseases

	Description
Rheumatoid arthritis	For rheumatoid arthritis, the immune system produces antibodies that attach to the linings of joints. Immune system cells then attack the joints, causing inflammation, swelling and pain. If untreated, rheumatoid arthritis causes gradually permanent joint damage. Treatments for rheumatoid arthritis can include various oral or injectable medications that reduce immune system overactivity.
Type-1 diabetes	For Type 1 diabetes, the immune system antibodies attack and destroy insulin-producing cells in the pancreas. At diagnosis, people with type 1 diabetes require insulin injections to survive.
Psoriasis	Psoriasis causes inflammation in the body, which speeds up skin cell growth. Normal skin cells completely grow and fall off in a month. With psoriasis, skin cells do this in only three or four days. However, instead of falling off, the skin cells pile up on the surface of the skin, which can raise plaques and scales on the skin. Some people report that psoriasis plaques itch, burn, and sting. Plaques and scales may appear on any part of the body, although they are commonly found on the elbows, knees, and scalp.
Lupus	People with lupus develop autoimmune antibodies that can attach to tissues throughout the body. The joints, lungs, blood cells, nerves and kidneys are commonly affected in lupus. Because the disease can attack so many different parts of the body, it can cause a lot of different symptoms.
Inflammatory bowel disease	Inflammatory bowel disease (IBD) is a term mainly used to describe two conditions: ulcerative colitis and Crohn's disease. When suffering from IBD, the immune system attacks the lining of the intestines, causing episodes of diarrhea, rectal bleeding, urgent bowel movements, abdominal pain, fever and weight loss.
Multiple sclerosis	Multiple sclerosis (MS) is a condition that affects your brain and spinal cord. The immune system attacks nerve cells, causing symptoms that can include pain, blindness, weakness, poor coordination and muscle spasms.
Graves' Disease	Graves' disease is an autoimmune disease that leads to a generalized overactivity of the entire thyroid gland, which causes excess amounts of thyroid hormone to be released into the blood (hyperthyroidism). Symptoms of Graves' disease can include bulging eyes as well as weight loss, nervousness, irritability, rapid heart rate, weakness and brittle hair. Destruction or removal of the thyroid gland, using medicines or surgery, is usually required to treat Graves' disease.

Health impact

The wellbeing burden of Type 1 diabetes, psoriasis, and rheumatoid arthritis

In this section we will provide case studies of four auto-immune diseases: type 1 diabetes, psoriasis, rheumatoid arthritis, and multiple sclerosis. These case studies will help us identify the wellbeing potential of curing autoimmune diseases for patients around the world.

When identifying the wellbeing benefit of a potential cure to autoimmune disease, it is important to acknowledge that although all autoimmune diseases share the common thread of autoimmunity, they vary widely in terms of symptoms and therefore also in terms of wellbeing.

Type 1 diabetes for instance creates limitations and demands attention as the patient is forced to take insulin for the rest of her or his life. Not doing so can result in ever-increasing blood sugar levels and dangerous complications. However, while these restrictions and limitations surely convert to lost wellbeing on average, type 1 diabetes can, in relative terms, be categorized as one of the less burdensome autoimmune diseases. **In Europe, diabetics on average lose 4.1% or their potential wellbeing.**[5]

Compared to type 1 diabetes, rheumatoid arthritis poses a greater threat to wellbeing – likely because the everyday symptoms - pain, stiffness, and mobility issues - are more pronounced. **The annual wellbeing lost to rheumatoid arthritis in Europe is estimated to be 6.8% per patient on average.**[6]

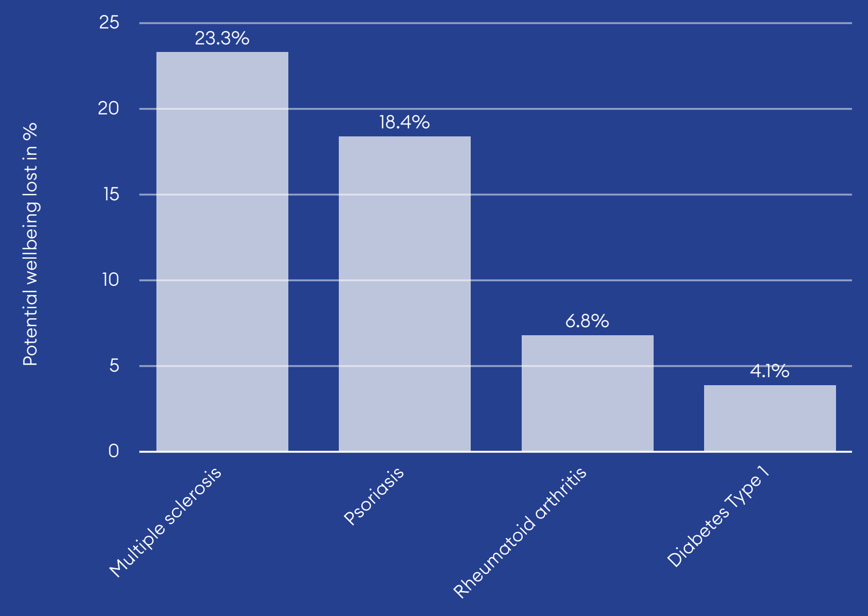
Psoriasis is a disease which to some may seem less troublesome, as the most common symptoms - patches of skin that are dry, red, and covered in scales – may not be as physically painful as the symptoms described above for rheumatoid arthritis. However, the true burden of this disease often lies in its cosmetic consequences that can degrade self-esteem and subjective wellbeing. In a survey by the National Psoriasis Foundation, almost 75% of patients believed that psoriasis had a moderate to large negative impact on their quality of life.[7] The World Psoriasis Happiness Report has also documented that psoriasis is strongly linked to loneliness, mental health disorders, low self-esteem, and stress.[8]

In terms of wellbeing, a Polish study found that people living with psoriasis experienced significantly reduced life satisfaction compared with healthy counterparts.[9] **Measured in terms of WALYs, this loss of life satisfaction due to psoriasis equals an average loss of potential wellbeing of roughly 18.4%.**[10]

Not surprisingly, the loss of wellbeing due to psoriasis is largely dependent on the patient's body image. The same study found that poor levels of body image for psoriasis patients significantly reduced wellbeing levels – on the order of **57.5%**[11] – while patients with favorable outlooks on body image actually experienced higher levels of life satisfaction than the healthy counterparts – specifically, **an average increase in wellbeing of 12.2%.**[12]

Lastly, multiple sclerosis (MS) is perhaps the most burdensome of all the autoimmune diseases under consideration. With its long list of potentially disabling symptoms and its high mortality rates, it is no surprise that this disease takes a significant toll on wellbeing. According to an Italian study of MS patients, caregivers, and a healthy control group,[13] **MS patients lose what equals about 23.3% of their potential wellbeing every year.**[14]

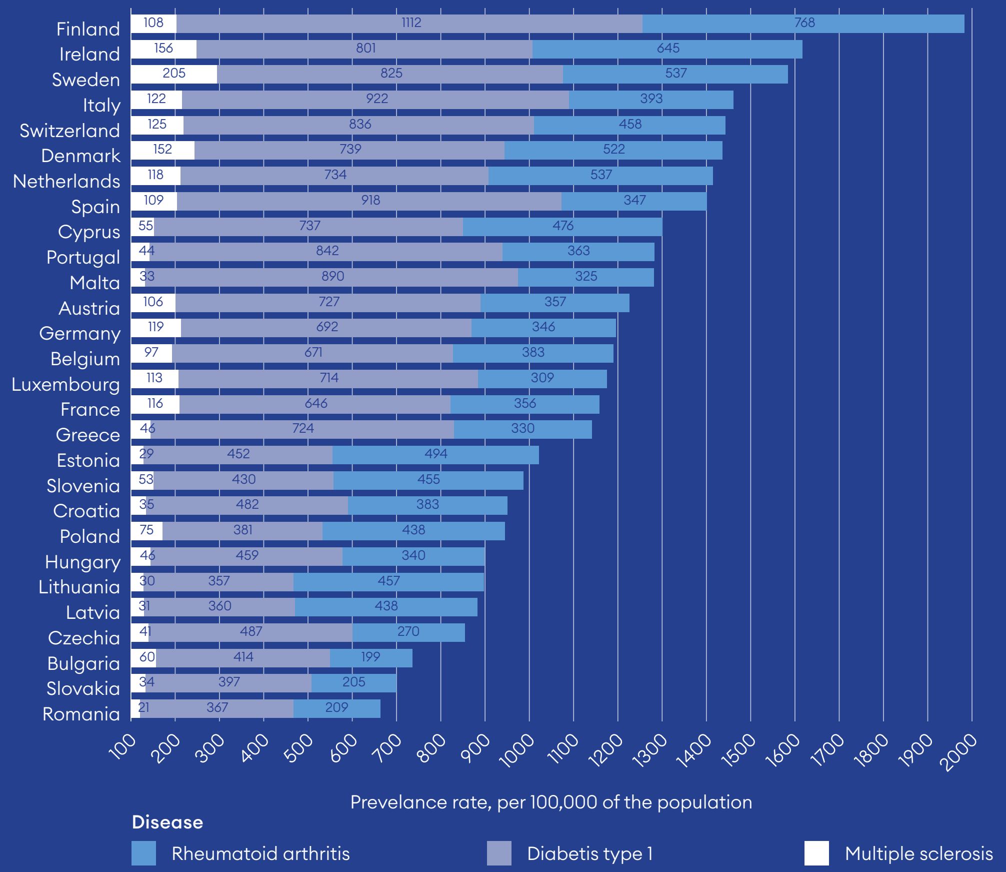
Figure 6.1 Wellbeing burdens of autoimmune diseases



Source Authors' calculations using WALY data presented in this chapter.

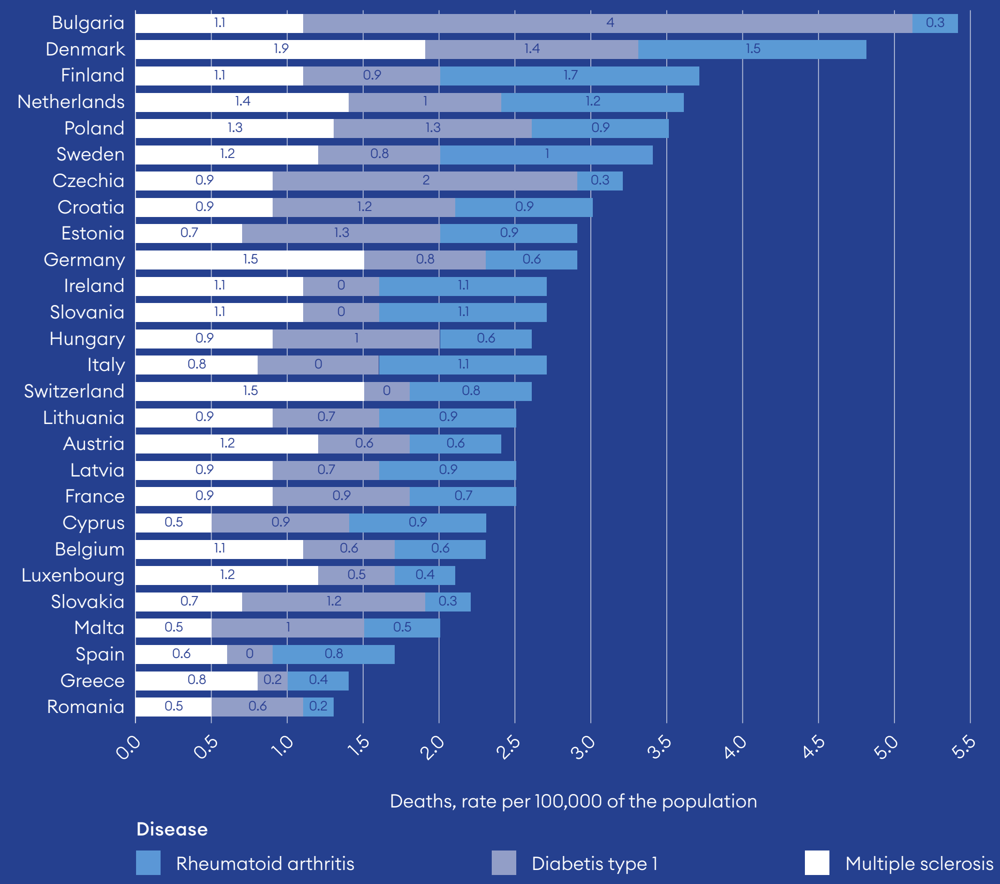
The death toll of each disease is also worth taking into account. Per 100,000 people, between 0.2 (Greece) and 4 (Bulgaria) deaths can be attributed to type 1 diabetes (Figure 6.3). For rheumatoid arthritis this number ranges from 0.2 (Romania) to 1.7 (Finland), and for multiple sclerosis it ranges from 0.5 (Romania) to 1.9 (Denmark). According to the Global Burden of Disease study, no deaths are associated with psoriasis.

Figure 6.2 Prevalence of type 1 diabetes, rheumatoid arthritis and multiple sclerosis (per 100,000)



Source Global Burden of Disease Collaborative Network (2020)

Figure 6.3 Deaths due to type 1 diabetes, rheumatoid arthritis, and multiple sclerosis (per 100,000)



Source Global Burden of Disease Collaborative Network (2020)

Community impact

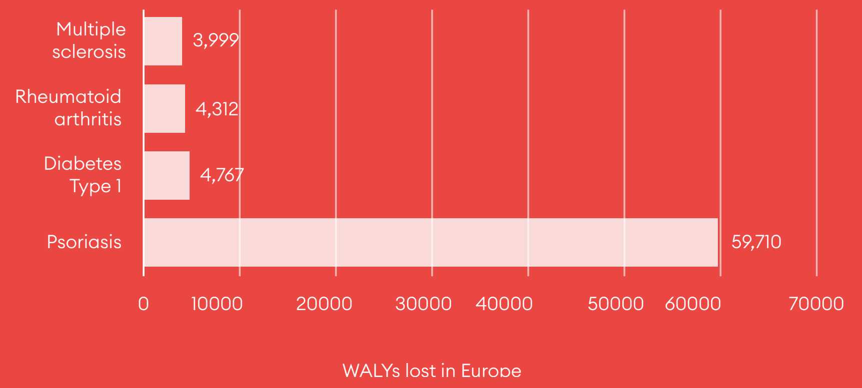
The wellbeing impacts of reversing autoimmune diseases

In the last section, we considered the wellbeing burdens associated with type 1 diabetes, rheumatoid arthritis, multiple sclerosis, and psoriasis. We found that these burdens can vary significantly. However, as also noted in the last section, it is not only the individual burdens that vary between patients, but prevalence and mortality levels also differ between countries.

To get a broader picture of the total wellbeing burdens of these diseases, we will consider the prevalence, mortality, as well as the individual wellbeing burdens of each. In doing so, we can estimate the potential population-level benefits in developing cures to treat them.

To estimate the overall potential benefit of developing a cure for autoimmune diseases, we first need to account for the number of patients in Europe and combine these rates with the individual wellbeing burdens of the patient groups. Using life satisfaction data from SHARE, combined with prevalence and mortality rates provided by the Global Burden of Disease Study, we find that the total wellbeing burden of psoriasis heavily outweighs the burdens of rheumatoid arthritis, type 1 diabetes, and multiple sclerosis. This is due to the combination of its high prevalence rate and considerable wellbeing burden on individual patients.

Figure 6.4 Total WALYs lost to type 1 diabetes, rheumatoid arthritis and multiple sclerosis



Source Authors' calculations using GBD data and WALY data presented in this chapter.

By aggregating the burdens of the four diseases, it becomes clear that the autoimmune diseases vary in their impact on wellbeing across countries. In France, the population loses around 106,000 WALYs a year due to these four diseases, while the total burden in Spain reaches roughly 60,000 WALYs (Figure 6.5). This means that the French population loses 76% more WALYs a year due to these diseases than the Spanish population, even though the population size is only 43% bigger. This is not because it is worse to experience autoimmune diseases in France than in Spain, but simply because autoimmune diseases are more prevalent in France.

At a global level, the prevalence of autoimmune disease is roughly 4%.[15] Assuming that the individual burden of the diseases ranges between the burdens presented for type 1 diabetes, rheumatoid arthritis, psoriasis, and multiple sclerosis (an average of 13.2% lost wellbeing annually), it can be assumed that **a cure for all autoimmune diseases could save more than 3.9 million WALYs in Europe.[16] This effect would be similar to the effect of securing a job for all unemployed people in Nigeria or making all people in Russia feel safe in their neighborhoods.[17]**

Figure 6.5 WALYs lost to type 1 diabetes, rheumatoid arthritis and multiple sclerosis in Europe (total)

Source Authors' calculations using GBD data and WALY data presented in this chapter.

Stability impact

Partner burdens of rheumatoid arthritis and diabetes

Being close to someone who suffers from an autoimmune disease can have direct implications for one's own quality of life. In this section, we look beyond the wellbeing impacts on patients and instead consider the cascade effects on their immediate social environments. Here we are primarily considering type 1 diabetes, rheumatoid arthritis, and multiple sclerosis.

Just as autoimmune diseases vary in terms of their impact on patients, their impact on the caretakers and family members also ranges from marginal to devastating. For both rheumatoid arthritis and diabetes, we identify significant but minor negative impacts on partners of patients. Partners of patients of rheumatoid arthritis and type 1 diabetes lose 1.8% and 1.3% of their potential wellbeing, respectively. In both cases we can identify some gender differences: the burden of diabetes is larger for male partners and the burden of rheumatoid arthritis is larger for female partners.

Figure 6.6 WALYs lost to partners of patients with rheumatoid arthritis and diabetes

Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, education, employment, income, wealth, residential area, number of children, year, and country. Bars represent 95% confidence intervals.

However, wellbeing burdens experienced by partners of patients increase drastically when we draw our attention to multiple sclerosis. Partners, parents, and children of patients with multiple sclerosis tend to take on a caregiver role – a role that is often associated with feelings of anxiety and depression.[18] The constant need to readjust to the demands of the disease also negatively affects the caregivers and increased symptom severity has also been shown to correspond to increased depression in caregivers.[19]

Taken together, it may come as no surprise that the disease is particularly burdensome for caregivers. One study comparing the life satisfaction of caregivers to multiple sclerosis patients with a control group documents a burden equivalent to an annual loss of 18.9% of potential wellbeing.[20] If this is taken to be representative, it translates into a burden that is almost three times greater than the burden experienced by partners of rheumatoid arthritis patients.

Economic burdens of autoimmune diseases

Autoimmune conditions place enormous economic burdens on patients and healthcare systems around the world. Ultimately, the costs devoted to caring for patients with autoimmune diseases could be directed elsewhere if a cure becomes available. In this section, we will turn our attention to a case study of type 1 diabetes patients in Denmark, as well as psoriasis patients in Spain and Germany, to answer the question: what are the current economic costs of autoimmune diseases worth in terms of wellbeing?

A recent report found that direct and indirect costs for just three autoimmune conditions alone – type 1 diabetes, rheumatoid arthritis and multiple sclerosis – currently add up to more than £13 billion per year in the United Kingdom.[21] In the US, Director Dr. Anthony Fauci of the National Institutes of Allergy and Infectious Diseases (NIAID) estimated that treatment costs for autoimmune diseases were greater than $100 billion annually – and this was back in 2001.[22] Since then, the incidence of autoimmune diseases has been steadily rising. This makes autoimmune diseases a threat to the sustainability of global economies – but also to human wellbeing.

If we take type 1 diabetes, one cost-of-illness-study in Denmark finds average cost of 7,174 dollars annually per patient, if we only consider direct effects (healthcare services, drug consumption and nursing services). For the whole patient group (of 28,000 patients) that adds up 200,872,000 dollars a year.

If these costs were freed and directed to other areas, this would bring a significant gain in WALYs for the population. **If society saved 200,872,000 dollars a year from a cure for type 1 diabetes in Denmark, this would be equivalent to a value of 427 additional years of life lived in potential wellbeing.**[23]

What's more, if indirect cost (lost productivity) and additional cost are added to the equation, **the total costs of Type 1 Diabetes add up to roughly 406 million dollars a year, equivalent to a value of 881 WALYs (Table 6.3).**

It is, however, very important to note that the fact that the economic-related burden outweighs the health-related burden, doesn't mean that these healthcare services currently directed at type 1 diabetes are not cost-effective. It may just as well indicate that these treatments are highly successful at reducing the burdens for the patients. Either way, this analysis makes clear that finding a cure for type 1 diabetes and alleviating its associated financial costs could represent a substantial wellbeing gain.

Table 6.3 Cost of type 1 diabetes in Denmark

		Direct costs per patient	Indirect costs per patient	Total cost per patient	Direct costs population	Indirect costs costs population	Total population costs
Denmark	$	7,174	7,313	14,487	200,872,00	204,764,000	405,636,00
	WALYs	0,02	0,02	0,06	427	454	881

Source Sortsoe, C., et al. (2016)

Compared to Type 1 Diabetes, the healthcare costs for psoriasis are not quite as substantial when considering the per patient direct and indirect costs. However, due to the particularly high prevalence rates of the disease, psoriasis makes up a sizable economic burden for societies (Table 6.4 [24]).

Table 6.4 Cost of psoriasis in Germany, Spain and Italy

		Direct costs per patient	Indirect costs per patient	Total cost per patient	Direct costs population	Indirect costs costs population	Total population costs
Germany	$	2,135	2,156	4,293	3,941,645,540	3,980,415,824	7,925,753,772
	WALYs	0,001	0,001	0,01	11,661	11,661	23,611
Spain	$	2,133	448	2,557	2,294,186,544	481,854,464	2,750,227,376
	WALYs	0,02	0,002	0,02	14,486	3,010	17,516
Italy	$	2,177	N/A	N/A	2,630,580,127	N/A	N/A
	WALYs	0,02	N/A	N/A	17,703	N/A	N/A

Source Burgos-Pol, R. et al. (2016)

Finally, we can use the values of both tables to create a rough estimate of the total cost of autoimmune disease in Europe. If diabetes and psoriasis could constitute the ends of a per patient cost spectrum in Europe, we could set the range of cost for autoimmune diseases to equal a WALY value of 0.01 to 0.06. With an average prevalence of autoimmune diseases in Europe of 4% (which is likely a conservative estimate for Europe)[25] **we can then expect that alleviating the economic burden of autoimmune diseases in Europe would save between 299,138 and 1,794,833 WALYs a year.**[26]

Impact summary

In this chapter, we have answered the question: what would the wellbeing impact be of curing all autoimmune diseases?

Health impact

4% of the global population live with an autoimmune disease. Assuming that the individual burden of such diseases is 13.2% lost wellbeing annually (an average across the burdens of type 1 diabetes, rheumatoid arthritis, psoriasis, and multiple sclerosis) it can be assumed that a cure for all autoimmune diseases could save 3.99 million WALYs in Europe.

Community impact

Being close to someone with an autoimmune disease can have a direct impact on one's own quality of life, but just as autoimmune diseases vary in terms of their impact on patients, so do their effects on caregivers and family members. For both rheumatoid arthritis and diabetes, we identify significant but minor negative impacts on partners of patients. Partners of patients of rheumatoid arthritis and type 1 diabetes lose 1.8% and 1.3% of their potential wellbeing, respectively.

Stability impact

If we could cure autoimmune diseases, the costs devoted to caring for the respective patients could be directed elsewhere. In our analysis, we used the costs of diabetes and psoriasis to constitute a range of cost for autoimmune diseases. Then, we converted these costs to wellbeing values to make a rough prediction of the WALYs that could be saved alone from freeing economic costs related to autoimmune diseases in Europe. We find that we can expect that alleviating the economic burden of autoimmune diseases in Europe would save between 299,138 and 1,794,833 WALYs a year.

Endnotes

1 NIH (2020).
2 Connect Immune Research (2018)
3 Dinse GE et al. (2020).
4 Lerner, A. et al (2015).
5 Analysis based on data from SHARE
6 Analysis based on data from SHARE
7 De Korte, J. et al. (2004).
8 LEO Innovation Lab, The Happiness Research Institute (2018).
9 Rzeszutek, M. et al. (2020).
10 Life satisfaction: Patient group: M= 16.90; Control group: M=19.13 (On 7-35 scale).
Converted to 0-10 scale: Patient group: M= 3,5; Control group: M=4,3.
11 Life satisfaction: Patient group: M= 12.15; Control group: M=19.13 (On 7-35 scale).
Converted to 0-10 scale: Patient group: M= 1,8; Control group: M=4,3.
12 Life satisfaction: Patient group: M= 20.61; Control group: M=19.13 (On 7-35 scale).
Converted to 0-10 scale: Patient group: M= 4,9; Control group: M=4,3.
13 Delle Fave, A. et al. (2017).
14 Life satisfaction: Patient group: M= 3,8; Control group: M=4,65 (On 1-7 scale).
Converted to 0-10 scale: Patient group: M= 4,67; Control group: M=6,1.
15 NSCF (accessed 2020, December)
16 Assuming a European total population of 747,858,113 people per 27th December 2020 (source: www.worldometers.info)
17 Equivalent WALY burdens: Unemployment in Nigeria 3,585,362 WALYs. Feeling unsafe in neighborhood in Russia: 3,805,907 WALYs
18 Janssens, AC. et al. (2003); Costa-Requena, G et al. (2012).
19 Bambara, J. K. et al. (2014).
20 Delle Fave, A. et al. (2017). Life satisfaction: Patient group: M= 4,14; Control group: M=4,87 (On 1-7 scale).
Converted to 0-10 scale: Patient group: M= 5,2; Control group: M=6,45.
21 Connect Immune Research (2018)
22 American Autoimmune Related Diseases Association (2011) The Cost Burden of Autoimmune Disease: The Latest Front in the War on Healthcare Spending
23 In this calculation we assume that the money saved would be deducted from the taxes of the population as a whole ($34 received by each one of the 5,800,000 inhabitants in Denmark). Using the Fujiwara (2013) formula, and assuming a median per capita income in Denmark of $18,260 according to Phelps & Crabtree (2013), each individual would increase their life satisfaction by 0. 3*log(18,260/(18,260-34)) - 0.00056 (0.00007 WALY's), which aggregated across the population as a whole would equate to 5.8 million people X 0.00007 WALYs = 428 WALY's gained in total.
24 All the calculations in this table use Fujiwara (2013) formula 0. 3*log (Median income/(Median income – Extra income)), where Median income equals 7,284 (Spain), 6,874 (Italy) and 14,100 (Germany) based on Phelps & Crabtree (2013)
25 According to the Kantar (2019) the prevalence of autoimmune diseases in EU5 is about 6%.
26 Assuming that 4% of the European population (747,846,939 as of Wednesday, December 16, 2020: source: Worldometers.info) live with an autoimmune disease = 29,913,878

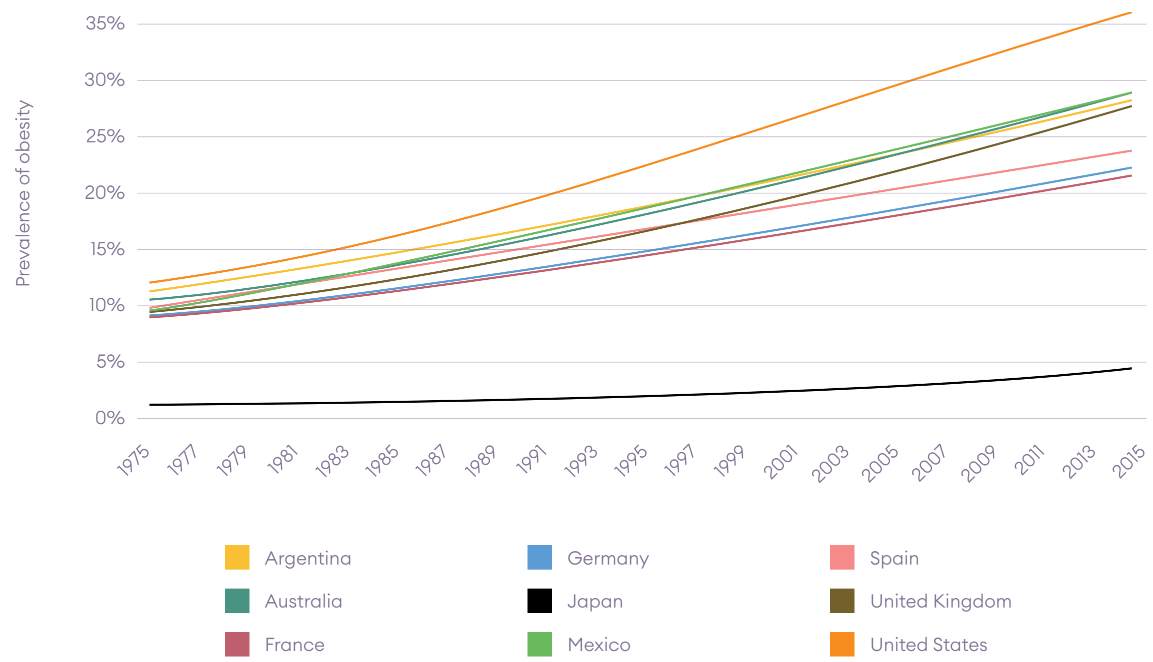
Leap 07

Provide the next generation health crops

The problem

Since 1975, worldwide obesity has roughly tripled. In 2016, more than 1.9 billion adults aged 18 and older were overweight, of which 650 million were considered obese.[1] The pace of change has been observed to be even quicker among children and adolescents aged 5 to 19. In 1975, just 1% of children and adolescents were obese, whereas in 2016 124 million (6% of females and 8% of boys) were obese.[2]
Moreover, today overweight and obesity are associated with more deaths than underweight. Globally, there are more obese individuals than underweight people, except for parts of Sub-Saharan Africa and Asia.[3]
While there are multiple linked fundamental causes for the obesity epidemic, one critical aspect is the production system of crops. Production systems have been skewed for a long time to promote efficiency, resulting in the optimization of only a few crops like wheat, soybeans, and corn. However, critics allege that systemic support for these few crops has led farmers to ignore other crops like fruits, vegetables, and mixed cereals, resulting in a consumer market flooded with unhealthy products made from these commodities.[4]

Figure 7.1 Prevalence of obesity in selected countries, 1975-2016



Source Ourworldindata.com/obesity

What if?

What if we could fix our production systems so they could provide crops that meet the nutrition and consumer preferences of our global population? Today's trends of de-commoditization and consumer preferences are making their way to farms, increasing demand for new crops. Transformational new technologies to improve plants and growing systems, such as vertical farming, could potentially address this demand.

In this chapter we map the wellbeing burdens associated with obesity and ask, "what if we could end this obesity pandemic by offering healthier crops?".

Health impact

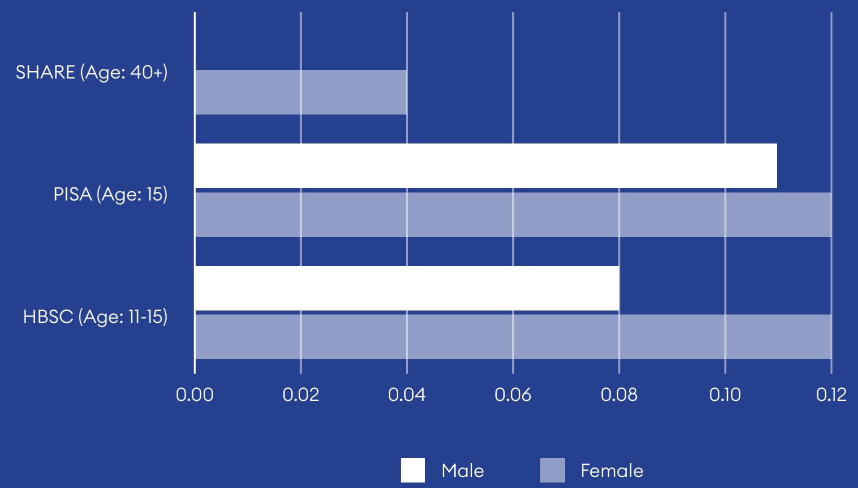
Wellbeing burdens related to obesity

Having an unhealthy body mass index has negative implications on human wellbeing. This has been found to be true in the US[5] as well as in the UK, Germany, and Australia.[6]

The general reasoning behind this correlation is that obesity has a negative effect on a wide range of conditions, which in turn has negative implications on subjective wellbeing. This including heart disease and diabetes,[7] lower levels of self-confidence, self-esteem, worse social relationships, and a higher likelihood for depression.

To estimate how much wellbeing an obese individual could save if healthier crops could reduce his or her weight to an average body mass index (of 20 Kg/m²) we have analyzed data from PISA[8] (15 years old), HBSC[9] (11-15 years old) and SHARE [10] (40-70+ years old).

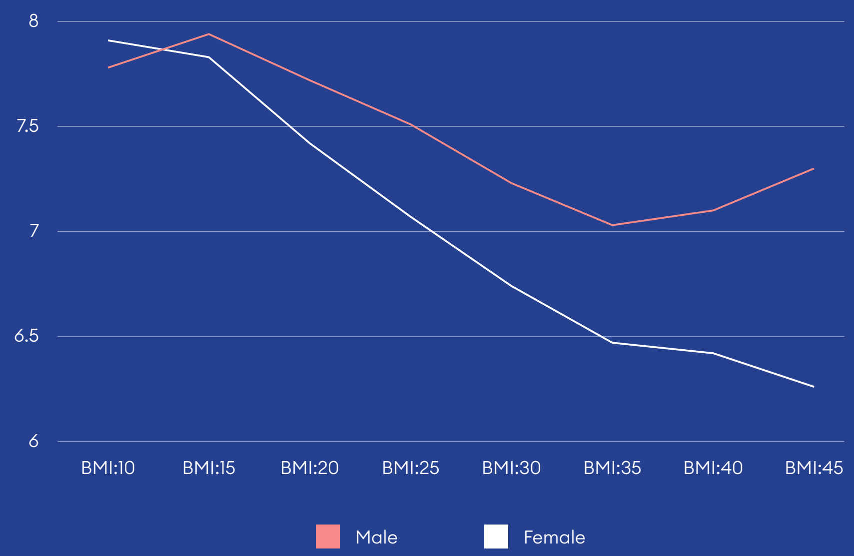
Figure 7.2 Potential WALY impact from eradicating obesity



Note Authors' estimates using OLS linear regressions, with added controls: (SHARE) country, marital status, job status, income, education, age; (HSBC) country and age; (PISA) country.

To put these results into context, **a 15-year-old male whose BMI is between 30 and 35 kg/m² (obesity type I) could save 0.08 to 0.11 WALYs if he reduced his weight to a healthy level (20-25). On the other hand, older males (40 to 70+ years old) would benefit from weight loss only from a BMI greater than 40 (0.1 WALYs gained). Similarly, a 15-year-old woman whose BMI is between 35-40 kg/m² could save 0.12 WALYs (same result shown in PISA and HBSC) with a healthy weight reduction, relative to 0.04 WALYs when older than 40 years old.**

Figure 7.3 Life satisfaction by body mass index among children



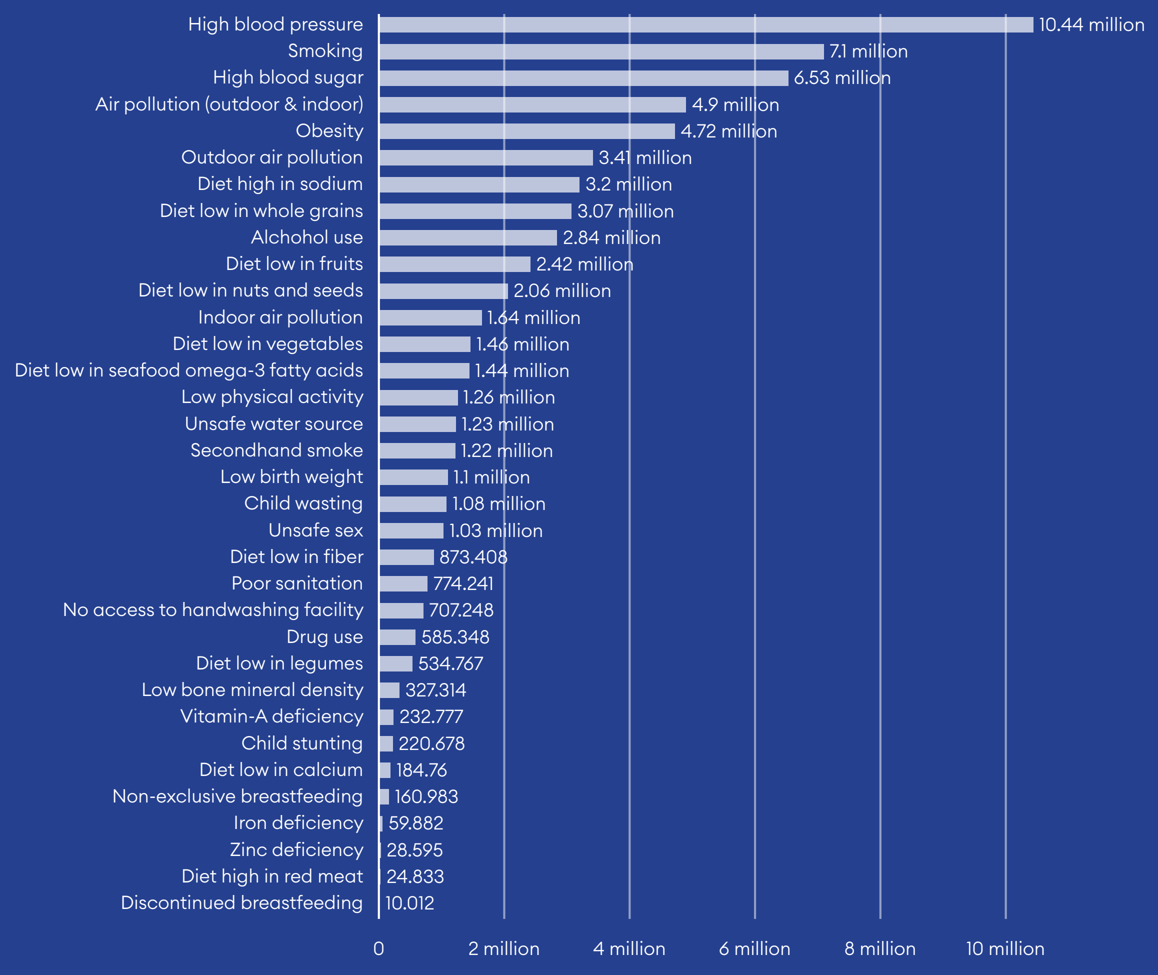
Note Authors' estimates using HSBC Data from 2001 to 2014 (n=562,875).

Figure 7.3 depicts the same estimations. As can be seen, a high BMI is more burdensome for women than it is for men.

Moreover, obesity not only affects individual life satisfaction but can also reduce life expectancy. Obesity ranks as the fifth biggest behavioral or environmental associated with premature death, according to the Global Burden of Disease research, with 4.7 million people dying prematurely as a result of obesity in 2017.
For the purposes of this report, any death any year is set to '1 lost WALY'. This implies that living a life at the lowest value on the life satisfaction scale (=0) for a full year is equivalent to being dead.

LEAP 07 // Health impact

Figure 7.4 Deaths in the world by cause



Source Our World in Data, IHME, Global Burden of Disease (GBD)

Adopting such method suggest that the total number of WALYs lost in a given country is equal to the total number of deaths associated with obesity each year, plus the level of wellbeing loss this condition causes. To specify these figures, we have estimated the total WALYs lost in the UK.[11] **This analysis suggests that, in the UK, approximately 500,000 WALYs could be saved in one year if obesity was eradicated. This is 18 % more than the amount that could be saved if unemployment was reduced to zero in the UK.[12]**

Community impact

Community burdens of obesity on family caregivers

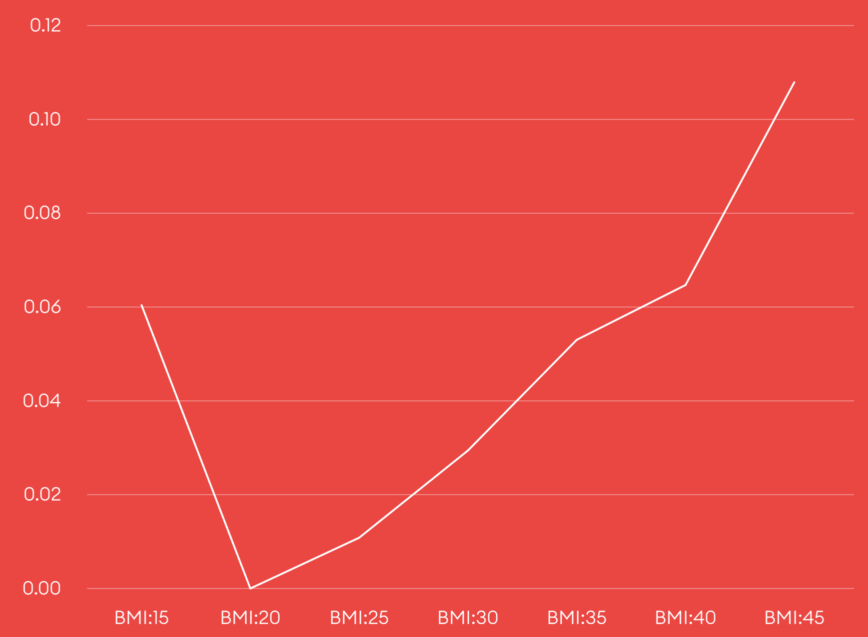
As mentioned in the previous section, obese people are more likely to deal physical and mental health problems, can harm relationships or whole families, and in the most extreme cases, couples and families may have to act as caregivers, with the consequent effect on their wellbeing.

A WALY analysis can shed light on these general dynamics by comparing the life satisfaction of partners to someone who is obese with partners to non-obese people.

According to our predictions, individuals who live with a partner with a healthy BMI, experience no loss of wellbeing. Yet, beyond healthy BMI, the partners' wellbeing begins to experience a loss of wellbeing. At a BMI of 30, partners lose 0.03 WALYs on average; at a BMI of 40, the loss doubles to 0.06 WALYs; and at a BMI of 45, partners lose 0.11 WALYs on average (Figure 7.5).

These are significant community burdens, as even the less severe case (partner to people with a BMI of 30) carries a burden comparable to what we discovered in chapter 1 when estimating the impact of heart attacks on partners.

Figure 7.5 Individual WALYs lost depending on partner's BMI



Note Authors' calculations using SHARE data. Estimated using OLS regressions with added controls for age, gender, BMI, education, employment, income, wealth, residential area, number of children, year, and country.

Stability impact

The financial benefits of eradicating obesity

There are two types of financial costs associated with obesity: The direct costs from the associated health related services – surgery, drug therapy, etc., and indirect costs from days missed from work, short and long-term absences, premature deaths, and insurance expenditures (life insurance are higher for employees who are obese).

To give a few specific examples, from a societal perspective, the total costs for obesity and related comorbidities in Germany have been estimated to be around €2,701 to 5,682 million per year, with direct treatment expenditures alone ranging between €1,343 and 2,699 million.[13] Obesity-related health-care expenses in the Netherlands range from 1% to 5% of overall healthcare spending, whereas they account for 5.7% in the United States.[14]

If obesity rates could be reduced, all those expenses could be devoted elsewhere in society, which in turn could generate additional WALYs. While such potential impacts can be difficult to accurately predict, we can make a simple conversion of the costs into WALYs by considering the wellbeing impact of deducting the respective costs from individual taxes.

For instance, the direct and indirect costs of overweight and obesity in Germany were projected to be €11.01 billion in 2009 (approximately 134€ per capita).[15] **If these costs could be alleviated completely, individual life satisfaction would be expected to increase by 0.002, with the potential to reach up to 40,000 WALYs if applied to the entire population (Table 7.4).**

However, basing the estimations on GDP measures result in much higher numbers. According to recent OECD estimates, obesity and overweight diminish GDP per capita by 3.3 percent on average in OECD nations (with the lowest impact in Japan (-1.6 percent) and the biggest impact in Mexico (5.2 percent)).[16] **In Germany, alleviating this burden would be equal to 107,900 WALYs saved in total.[17] These kinds of GDP-based assessments are more precise since they account for not just treatment and absenteeism costs, but also additional indirect costs such as family and community income losses.**

People in poor areas are typically assumed to have poorer habits and diets than those in wealthier ones, yet obesity itself can be a cause of poverty in some situations, owing to higher unemployment and absenteeism.[18] As a result, treatments that reduce obesity in a cost-effective and easy manner may be the key to reducing societal economic disparities.

Table 7.1 Direct and indirect costs of obesity and related conditions

Study	Costs included direct	Cost included indirect	Direct cost	Indirect costs	Results total (€ 2009)	Potential WALYs gained
Anis et al. 2010, Canada	Hospital inpatient and outpatient visits, physician services, drug costs, health research and other health care	Morbidity due to both long and short-term disability	CA$5.96 billion	CA$5 billion	$10.96 billion (€7.3 billion 2009)	24,416
Konnopka et al. 2011, Germany	Inpatient and outpatient treatment, rehabilitation and non-medical costs (administration, research etc)	Sickness absence, early retirement and mortality using human capital approach	€4.854 billion (2.1% of total healthcare costs for 2002)	€5.019 billion	€9.873 billion (€11.01 billion 2009)	41,425
Finkelstein et al. 2010, US	All Medical costs	Absenteeism and Presenteeism	$30.3 billion	$42.8 billion	$73.1 billion (€51.92 billion 2009)	179,293
Finkelstein et al. 2010, US	Hospital inpatient costs only	Lost productivity due to increased mortality	SEK 2.17 billion	SEK 2.93 billion	SEK 5.1 (€0.54 billion 2009)	1,450

Impact summary

In this chapter we have calculated the wellbeing burdens associated with obesity for individuals, partners, and society to map the potential impact of ending the obesity pandemic.

Health impact

Obesity takes a greater toll on wellbeing for young people. Our projections suggest that a 15-year-old male who experiences obesity (BMI between 35 and 40 kg/m2) could gain 8-11% wellbeing (0.08 to 0.11 WALYs) if he reduced his weight to a healthy level, whereas a male adult (age 40+) would only benefit from a weight loss if he has a BMI greater than 40. Similarly, a 15-year-old woman who experiences obesity could gain 0.12 WALYs with a healthy weight reduction, while women older than 40 would gain 0.04 WALYs from a healthy weight reduction.

Community impact

Individuals who live with a partner who has a healthy BMI should experience no loss of wellbeing, according to our predictions. However, at a BMI of 30, partners lose 0.03 WALYs on average; at a BMI 40, the loss doubles to 0.06 WALYs; and at BMI 45, partners lose 0.11 WALYs on average

Stability impact

Obesity is linked to several economic cost such as consumption of health-related services (surgery, drug therapy, etc.) increase in sick days and higher insurance expenditures (life insurance is more expensive for employees who are obese). In Germany, the cost of overweight and obesity in Germany was projected to be €11.01 billion in 2009. If these costs could be alleviated completely, it would be expected to generate up to 40,000 WALYs. (Table 7.4). However, if we consider additional economic losses by basing our prediction on 'lost GDP due to obesity' we find that alleviating the wellbeing burden of obesity would be equal to 107,900 WALYs saved in total.

Endnotes

1 WHO (2021)

2 Ibid.

3 Ibid.

4 Fields, S. (2004).

5 Forste, R., & Moore, E. (2012).

6 Katsaiti, M. S. (2012).

7 Habibov, N. et al. (2019).

8 Program for International Student Assessment (PISA), an international assessment that measures 15-year-old students' reading, mathematics, and science literacy every three years.

9 Health Behaviour in School Children. Since 1982 HBSC has been a pioneer cross-national study gaining insight into young people's well-being, health behaviours and their social context.

10 The Survey of Health, Ageing and Retirement in Europe (SHARE) is a research infrastructure for studying the effects of health, social, economic and environmental policies over the life-course of European citizens and beyond

11 Authors' calculations using HSBC, SHARE, and GBD data as well as prevalence numbers from Conolly, A. et al. (2019)

12 Our own estimation using data from the World Values Survey in 2018. Unemployment accounts for ~427,000 WALYs lost in the UK

13 Sander & Bergemann (2003).

14 Seidell (1995); Wolf & Colditz (1998).

15 Dee et al. (2014).

16 OECD. (2019).

17 Using estimations from a pooled OLS regression from all Gallup available surveys from 2005 to 2019, we know that average life satisfaction in a given country increases by 0.31 points for every point increase in log GDP per capita. Therefore, a 3.3% increase in the GDP per capita due to the eradication of obesity would mean an increase of 0.009 points in the average national life satisfaction (~0.0013 WALYs per capita). In total, extending that amount to the entire population of Germany (83M), 107,900 WALYs could be gained through obesity treatment costs.

18 Lissner (1997).

Leap 08

Develop sustainable protein supply

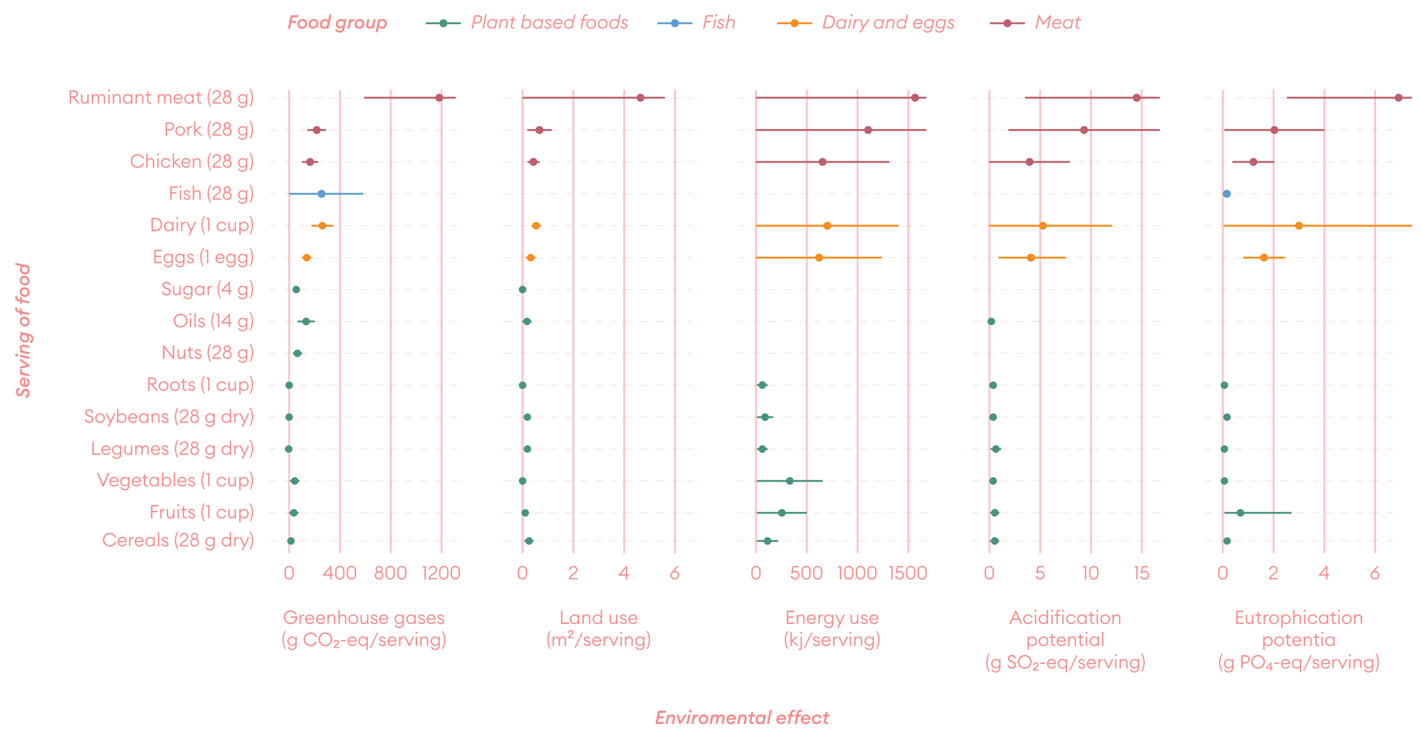
The problem

In Chapter 3 we introduced several of the most pressing health-related risks and opportunities associated with the future of agriculture. In this chapter, we will expand on that analysis by paying particular attention to the wellbeing opportunities related to how we *produce* the food we consume.

Around the world, animal husbandry accounts for 77% of all land devoted to agriculture – which covers half of all habitable land on the planet.[1] This substantial percentage stems from the resources required to raise and sustain the animals themselves. Overall, livestock farming and fisheries account for 52% of all food-related greenhouse gas emissions, and 14% of the global emissions worldwide.[2] In addition to greenhouse gas emissions and land use, protein-rich foods including beef, pork, chicken, fish, and dairy products also take higher environmental tolls than plant-based foods in terms of energy use, acidification, and eutrophication (Figure 8.1).[3] Addressing the environmental impact of animal food products is therefore central to addressing the challenges posed by climate change.

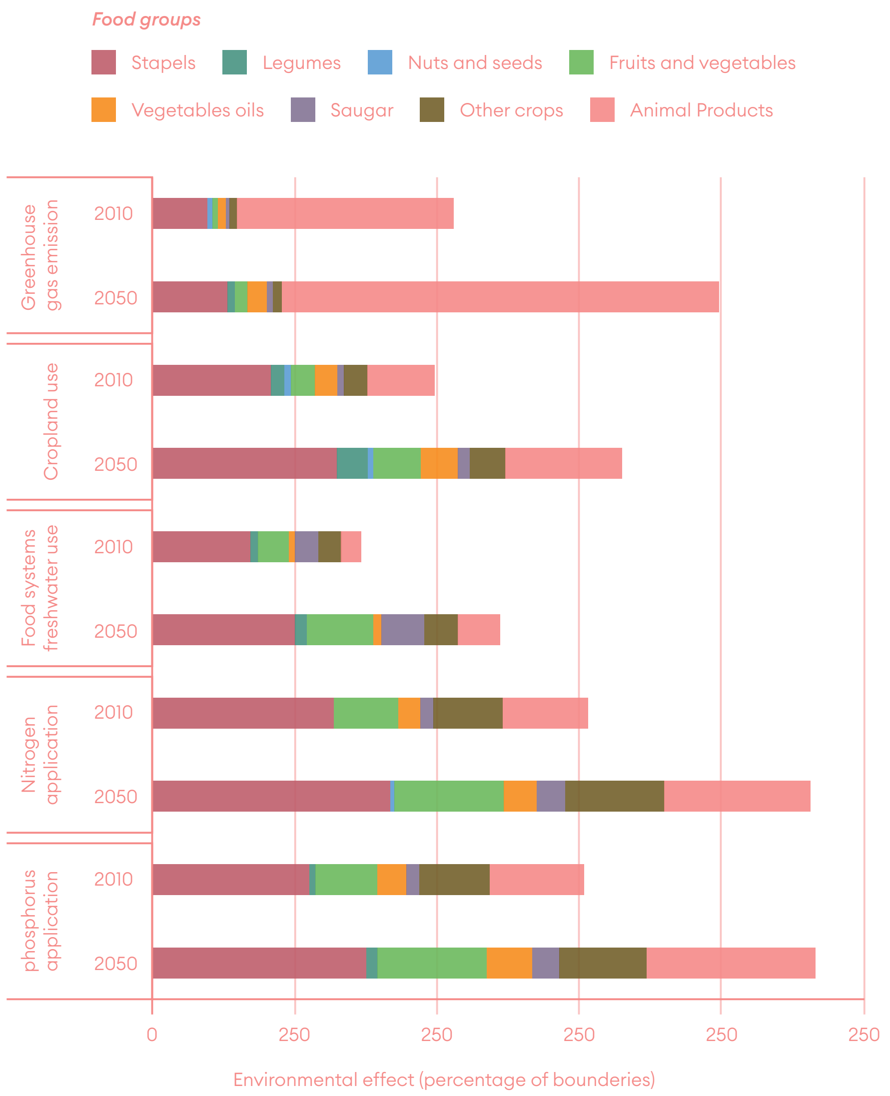
Without significant changes to global diets and food production supply chains, these burdens are expected to increase substantially in the years to come. Two primary channels influence the global supply and demand of food: population growth and economic development. Most middle-of-the-road projections anticipate that the global population will grow by one third between 2020 and 2050, reaching a total of roughly ten billion people.[4] This will put additional pressures on global and local food chains to meet the growing demand for food. With continued economic development, dietary patterns are also expected to change. As populations around the world get richer, the demand for meat and dairy products is increasing[5]. A recent report by a commission of more than 30 scientists found that, along a business-as-usual trajectory, the environmental burdens associated with animal products is expected to increase substantially over the next three decades and may push human civilization beyond sustainable planetary boundaries (Figure 8.2).

Figure 8.1 Environmental impacts per serving of food (Lancet)



Note Bars are mean (SD). CO2=carbon dioxide. Eq=equivalent. PO4=phosphate. SO2=-Sulphur dioxide (Willett et al. 2019).

Figure 8.2 Projected environmental impacts of food based on business-as-usual trajectory (Lancet)



Source (Willett et al. 2019).

What if?

What if we could reduce our dependence on unsustainably produced meat and dairy? What if grocery stores could offer sustainably produced cultured or artificial meat substitutes, from filet mignon to chicken breasts? Like all pathways towards sustainable development, many of these dynamics come with trade-offs, costs, and benefits that are not equally distributed. In the sections that follow, we will touch on some of these dynamics and illustrate ways in which health, community, and stability wellbeing burdens associated with climate change could be alleviated by transitioning to more sustainable farming.

Specifically, we will consider the health impacts of vegetarian diets, the community impacts beef production and deforestation and the economic implications of switching to sustainable agricultural production. While the analyses presented in this chapter are again not intended to be exhaustive or comprehensive, they are designed to illuminate several channels by which the demand and supply of foods can impact upon on subjective wellbeing, now and in the years to come.

Health impact

Wellbeing impact of vegetarianism

The most straight-forward way to reduce the environmental impact of animal products is simply to eat less of them. While global rates of meat consumption have increased over the last several decades – driven by increases in low- and middle-income countries – more and more adults in high income countries have begun reducing their consumption of animal products.[6] Switching to a predominately plant-based diet can have implications for both physical health and subjective wellbeing.

Overconsumption of meat has been associated with a number of negative health outcomes including increased risk of diabetes, heart disease, stroke, and cancer.[7] In Figure 8.3, using data from the Global Burden of Disease Study, we present an overview of the total wellbeing burden of all diseases combined that can be attributed to the overconsumption of red and processed meat.[8] Wellbeing burdens associated with meat overconsumption are substantial in Eastern European countries including Romania and Bulgaria in particular, followed by Latvia, Lithuania, Greece, and Portugal.

Figure 8.3 Wellbeing burdens of deaths due to overconsumption of meat in Europe

Note Authors' calculations using SHARE and GBD data.

However, when we compare the subjective wellbeing adults who eat meat every day to adults who rarely eat meat, we find somewhat mixed results.[9] In an analysis of SHARE data, we find that both men and women who eat meat are slightly more satisfied with their lives than non-meat-eating counterparts.[10] At the same time, somewhat surprisingly, we also find that these adults are less likely to be satisfied with their health. When asked to rate their subjective health on a scale from 1 to 5, adults who rarely eat meat are on average 15% more satisfied with their health than those who eat meat every day.[11]

The analysis suggests that there may be important trade-offs associated with reduced meat consumption in high income countries. While there are likely to be both objective and subjective health benefits, switching to a plant-based diet may imply trade-offs in terms of wellbeing.

Community impact

The community impact of beef production and deforestation

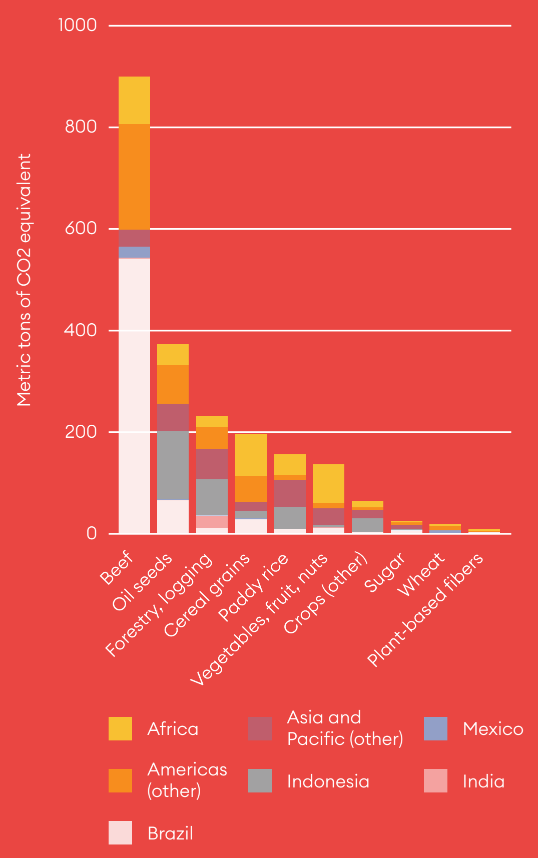
Deforestation is one the most important contributors to climate change. Past estimates suggest that deforestation accounts for roughly 12-20% of all carbon emissions, making it the second largest source of greenhouse gas emissions, behind fossil fuel combustion.[12] In terms of wellbeing, this suggests that **deforestation is responsible for roughly one-fifth of all climate-related WALY losses documented in this report.** Its substantial contribution to global warming is driven by three sources:

- First, forests are "carbon sinks" that help to absorb excess carbon in the atmosphere. Around the world, forests absorb 7.6 billion metric tons of CO_2 per year, 50% more than the annual carbon emissions of the United States.[13] By cutting them down, we lose a crucial ally in the fight against climate change.
- Second, at the same time, when trees are cut down, they release the excess carbon they have been storing, driving emissions even higher.
- Third, perhaps most importantly, newly cleared forest land is most often replaced with unsustainable livestock and crop farming.

Agriculture drives roughly 60-80% of all deforestation on the planet.[14] This staggering figure puts food production and management at the center of the fight to reduce deforestation and global warming. Yet once again, not all types of food production have equal impacts. Beef production in particular is responsible for roughly 40% of all carbon emissions driven by deforestation (Figure 8.4) In other words, four out of every ten trees cut down in forests around the world are cleared to make way for cattle grazing.

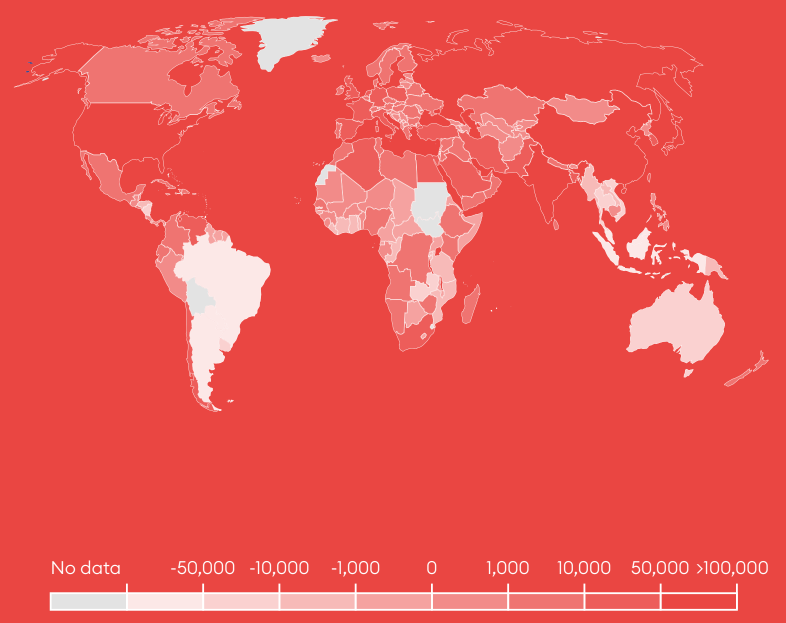
A large portion of deforestation is also driven by foreign demand. In Figure 8.5, this dynamic is graphically represented as the amount of global deforestation is embedded in each countries import and export trade patterns. High-income countries including China and the United States are among not only the world's largest emitters themselves, but also among the largest drivers of foreign and domestic deforestation. Developing sustainable sources of meat production in these countries is therefore poised to have a major impact at reducing deforestation and combating climate change in the years to come.

Figure 8.4 Drivers of global forest carbon emission



Source Pendrill et al. (2019)

Figure 8.5 Net deforestation embedded in global trade patterns (hectares)



Note Deforestation represented here as hectares of forest lost. Countries that contribute to deforestation in other countries are considered to be net importers of deforestation. Source: Ritchie & Roser (2021).

Stability impact

Employment implications of transitioning to sustainable agriculture

Leap 08' (Develop sustainable protein supply) and 'Leap 09' (Prevent crop and food loss) are concerned with the challenge of production and management of food, respectively. From a wellbeing perspective, the wellbeing burdens and opportunities associated with the stability impact channel are overlapping, for which reason this section represent the insights for both chapters.

Throughout this report, we have explored a variety of channels through which climate change, exacerbated by unsustainable agriculture, can impact wellbeing through health, community, and stability channels. In the previous sections of this chapter, we explored the potential impacts of eating less meat on individual health and wellbeing, as well as the potential community risks of rising food insecurity in the future and the current impact on wellbeing through preventable excessive energy use associated with producing food that gets lost. In this last section, we will touch on one more possible channel through which climate change can impact wellbeing on a societal scale – employment.

Employment has long been identified as one of the most important individual contributors to individual wellbeing and societal stability. On an individual level, becoming unemployed can have a substantial negative effect on life satisfaction in particular. In a previous report, we found that European adults who were unemployed were on average 0.7 points less satisfied with their lives than employed counterparts on a scale from 0 to 10.[15] These sorts of observed differences have also been replicated in several related studies.[16] On a societal level, high levels of unemployment can also have worrying implications for socioeconomic stability. Among high income countries, a one percent increase in the unemployment rate predicts a decline in average country life satisfaction of 0.8 points on average.[17] Increases in unemployment have also been associated with anti-immigrant sentiment, crime, and political instability.[18]

There are numerous potential interactions between climate and employment.[19] For the purposes of this chapter, they can broadly be summarized by two countervailing channels. On one hand, many jobs and sectors depend directly on a sustainable supply of natural resources, including agriculture, mining, and energy. However, at the same time, many of these same jobs and sectors contribute directly to climate change through greenhouse gas emissions and other environmental pressures. As a result, as the world moves to more sustainable business models, especially sustainable farming and livestock production, trade-offs are likely to emerge, many of which may not be equally distributed.

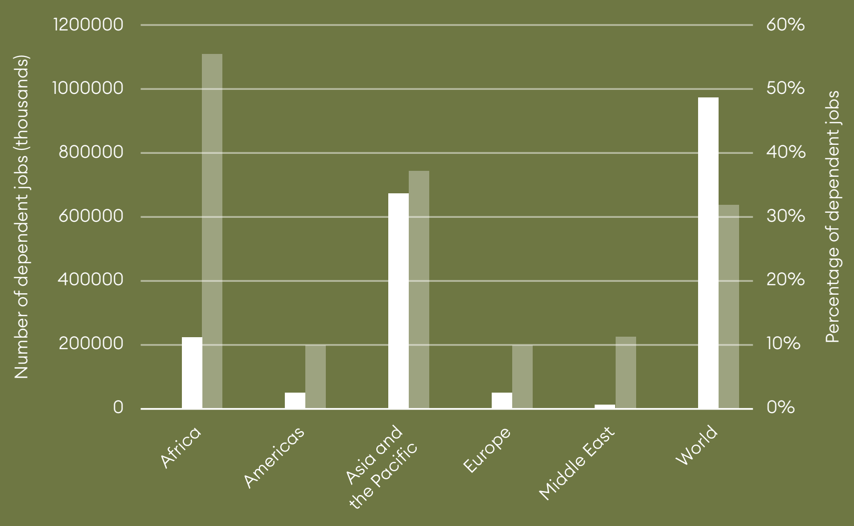
To dive deeper into the employment implications of transitioning to sustainable farming, we rely on modeling estimates and data for five world regions provided by the International Labour Organization (2018). In this case, we are again primarily interested in the agricultural sector. In Figure 8.6, we plot total and percentage estimates of agricultural jobs in each world region that depend on ecosystem services. In absolute terms, there are more people with environmentally dependent jobs in Asia and the Pacific than in any other world region – roughly 700 million in total. In Africa, slightly more than 200 million workers perform agricultural work that is vulnerable to climate change, accounting for more than half of the total workforce on the continent. Around the world, 1 billion workers, or roughly 1 out of every 8 people on the planet, work in agricultural jobs that could jeopardized by worsening climate change. Given both the individual and societal wellbeing benefits of employment, and potential wellbeing burdens of unemployment, these figures provide an urgent motivation to address global warming and mitigate its worst effects.

However, addressing the employment challenges posed by climate change may not be as straight forward as it seems. To model the effects of transitioning away from unsustainable agriculture, the International Labour Organization (2018) has also projected potential employment outcomes in the agricultural sector if one third of all agricultural production transitioned to sustainable farming practices by 2030.[20] In Figure 8.7 we project these changes per 100,00 workers, in terms of both absolute employment and WALY equivalents. Given the reduced resource inputs and employment levels required for sustainable farming, agricultural employment would be expected to decline in every world region except Europe.

This analysis is intended to demonstrate the relative trade-offs of transitioning to sustainable farming in the agricultural sector, and by implication reduced consumption of animal products. However, it may not be the end of the story. Workers who no longer find employment in agriculture may begin to find more and better job opportunities elsewhere in sustainable industries. On the other hand, without addressing climate change, these workers may find themselves unable to sustain a living in their professions that rely on ecosystem services in the first place. In any case, it is unquestionable that the global food system is inevitably and inextricably linked to the health of the environment. As a result, it will be important to keep the potential wellbeing trade-offs of transitioning to sustainable agriculture in mind in the years to come.

LEAP 08 // Stability impact

Figure 8.6 Jobs in agriculture that depend on ecosystem services



Source: International Labour Organization (2018)

Figure 8.7 Employment projections with sustainable transitions in the agricultural sector by 2030

Source: International Labour Organization (2018)

Impact summary

In this chapter, we have mapped how different wellbeing burden associated with climate change could be alleviated by transitioning to more sustainable farming

Health impact

The most straight-forward way to reduce the environmental impact of animal products is simply to eat less of them. However, when we compare the subjective wellbeing of adults who eat meat every day to adults who rarely eat meat, we find somewhat mixed results. In our analysis, we find that both men and women who eat meat are on slightly more satisfied with their lives than non-meat-eating counterparts. Yet, at the same time, we also find that these adults are less likely to be satisfied with their health. When asked to rate their subjective health on a scale from 1 to 5, adults who rarely eat meat are on average 15% more satisfied with their health than those who eat meat every day.

Community impact

Deforestation is one the most important contributors to climate change. Past estimates suggest that deforestation accounts for roughly 12-20% of all carbon emissions, making it the second largest source of greenhouse gas emissions, behind fossil fuel combustion. In terms of wellbeing, this suggests that deforestation is responsible for roughly one-fifth of all climate-related WALY losses documented in this and previous chapters.

Stability impact

There are numerous potential interactions between climate and employment, which in turn generate numerous scenarios for human wellbeing when transitioning away from unsustainable agriculture. However, one way to estimate the potential wellbeing impact is by rooting the estimate on existing projections by the International Labour Organization on potential employment outcomes in the agricultural sector. This analysis suggests a highly unequal distribution of benefits, with only Europeans anticipated to profit, while individuals in other regions, particularly Africa, are expected to experience a loss of WALYs.

Endnotes

1 Ritchie (2020).
2 Ritchie (2020); Poore & Nemecek (2018).
3 Willett et al. (2019).
4 This projection is based on the Shared Socioeconomic Pathway 2. For more information, see: Willett et al. (2019).
5 Alexandratos & Bruinsma, J. (2012).
6 Leahy et al (2010); Ritchie (2017).
7 Global Burden of Disease Collaborative Network (2020).
8 In this case, we are only concerned with the wellbeing losses associated with deaths. We do not consider wellbeing burdens among living patients as the Global Burden of Disease data does not provide disease prevalence estimates associated with behavioral risks.
9 In this case, our sample consists in adults who eat meat at least once per day, and those who eat meat less than once per week, the lowest frequency category available in the data.
10 Based on authors' own calculations. Contact for more information.
11 The specific prompt is as follows: "How would you perceive your own health?" Answer choices include: poor, fair, good, very good, excellent.
12 Van der Werf et al. (2009)
13 Harris et al. (2021)
14 Carter et al. (2017)
15 Happiness Research Institute & Leaps by Bayer (2020).
16 Clark et al. (2019).
17 Authors calculations using 2018 data from the World Happiness Report and the International Labour Organization. This relationship becomes weaker when low and middle income countries are included in the sample as unemployment as a concept becomes less meaningful in countries where large portions of the labor force work in informal sectors.
18 Azeng & Yogo (2013); Altindag (2012); Cochrane & Nevitte (2014).
19 For more information, see ILO (2018).
20 In developed countries, this would mean a transition to organic agriculture. In developing countries, this would mean a transition to conversation agriculture. For more details, see: ILO (2018).

Leap 09

Prevent crop and food loss

The problem

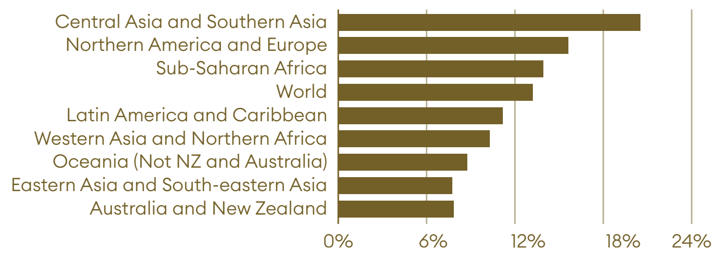
Drought, freezing temperatures and other extreme weather events are becoming increasingly severe and unpredictable. Soil is under increasing strain to support the world's food crops. According to recent estimates, 1.6 billion tons of food (worth around $1.2 trillion) is lost or wasted along the supply chain, accounting for over one-third of all food produced for human consumption.[1] According to BCG, in 2030, these annual estimates will hit 2.1 billion tons (worth $1.5 trillion).[2]

Food loss has become such a critical issue that in 2015 the United Nations General Assembly included 'Target 12.3' within the Sustainable Development Goals, which aims to cut food loss and waste in half by 2030.[3]

Progress towards Target 12.3 is measured by 'Indicator 12.3.1', which is split into two sub-indicators: the Food Loss Index and the Food Waste Index.[4] While Food loss refers to the losses that occurs along the food supply chain from harvest up to, but not including, the retail level, food waste occurs at the retail and consumption levels.[5] According to Food and Agriculture Organization of the United Nations (FAO), almost 14% of food produced in 2016 was lost from the farm up to the retail stage.[6] At the regional level, estimates range from 5–6 % in Australia and New Zealand to 20–21% in Central and Southern Asia (Figure 9.1). In terms of commodity groups, roots, tubers, oil-bearing crops, fruits, and vegetables report the highest level of loss, making 'grown food' a particular challenge (Figure 9.2).

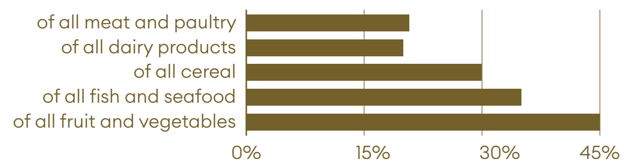
With less than ten years to achieve SDG Target 12.3, all governments, communities, and businesses participating in the food supply chain must act quickly to set reduction goals and develop effective and appropriate solutions.

Figure 9.1 Food loss per region



Source FAO (2019).

Figure 9.2 Percentage food lost by commodity group



Source FAO (2019).

What if?

What if groundbreaking technologies could assist farmers all around the world in managing their soil for long-term health and ensuring sustainable production? Or what if we could regulate the quantities of mycotoxins, bacteria, and ethylene in newly grown food to keep it fresher for longer and prevent food waste?

Today, better methods are needed to connect farmers closer to customers and reduce the distance that food travels, lowering the financial and environmental costs of food spoilage – and, ultimately, the costs on human wellbeing.

In what follows, we will discuss the wellbeing implications of reducing food insecurity by minimizing food loss and promoting more sustainable agriculture.

Health impact

By pairing these food loss data with wellbeing coefficients from Edgar et al. (2020) as well as average life satisfaction population scores from the World Happiness Report, we can predict how a reduction of food loss (to the level where it solves food insecurities) converts to WALYs per country.
In Figure 9.4 we have ranked the ten countries with the greatest untapped wellbeing impact potential from reducing food loss. Unsurprisingly, all ten of the top ten countries are from the Global South.

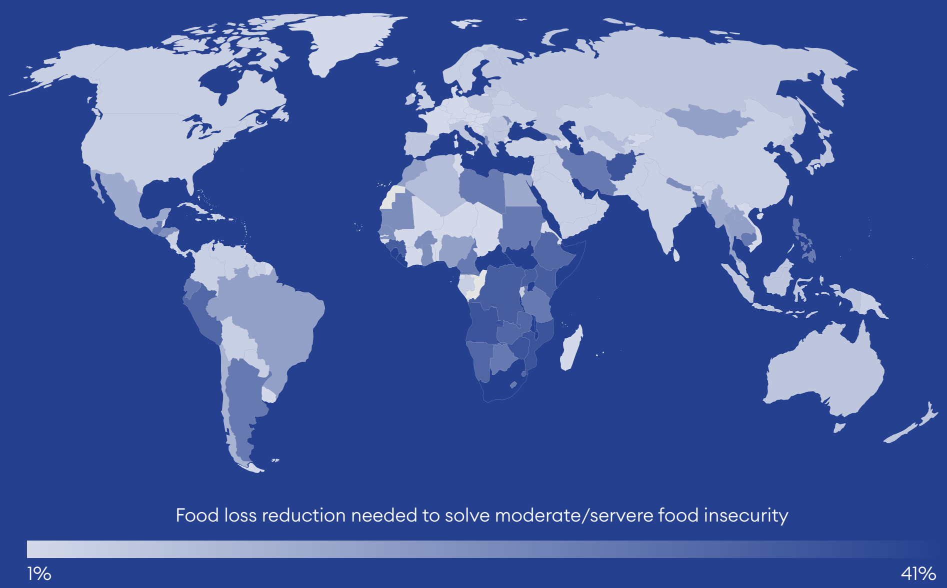
11,6 million individuals in top-ranking Nigeria are regarded to experience moderate or severe food insecurity, yet a reduction in food loss of only 16% in this country would be enough to eradicate these problems altogether and save 3,82 million WALYs.

The implications of food loss on food insecurity and wellbeing

As defined by the United Nations, food security is defined by "all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life."[7] From a historical perspective, the world has made substantial progress in promoting this goal. Since 1990, the total number of people who are undernourished around the world has declined by 200 million, even as the global population has increased by 2 billion.[8] Nevertheless, considerable challenges persist. Since 2014, the number of undernourished people has been increasing, totaling 820 million in the most recent estimates from 2019.[9] This trend is also likely to be exacerbated by the COVID-19 pandemic.

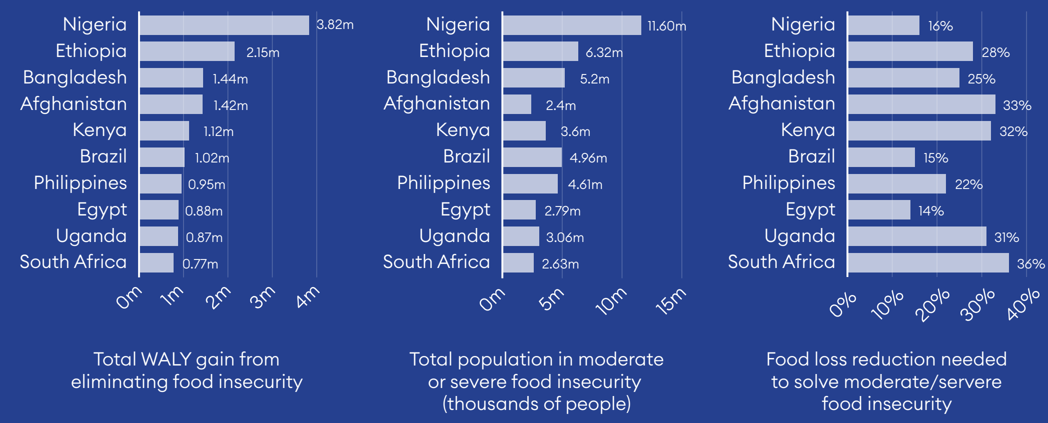
Yet, if we want to improve food security and end hunger, we should not produce more food. Rather, we should ensure we do not lose the food we have already produced. By applying global food loss data and food insecurity data from the United Nations[10] and by assuming a diet of 4 pounds of food per day (equivalent to 0.66 metric tons per year) is sufficient to end food insecurity for 1 person, we can derive that reducing food loss by 15% on average across the globe could solve moderate to severe food insecurity. Looking across countries these percentages span from 41% in Congo to only 1% in Switzerland (Figure 9.3).

Figure 9.3 Percentage food loss reduction needed to solve moderate/severe food insecurity



Note Authors' calculations using UN data

Figure 9.4 WALYs saved if food insecurities could be eliminated



Note Authors' calculations using UN data

Food loss is a wicked problem

As documented, food loss is a major problem in low-income countries, but the benefits of reducing the losses are equally significant. Reductions in losses allow farmers to improve their own diets due to increased food availability, but it may also increase their incomes if they are selling part of their goods. Moreover, it may also result in higher supply and lower pricing for consumers, contributing to further reductions in food insecurity. However, reducing food waste may result in reduced demand for farmers' goods, resulting in lower income and decreasing food security.[11]

Reduced food waste by consumers and retailers in high-income nations may also have a detrimental impact on impoverished farmers in low-income countries if they are the main suppliers in international food supply chains.[12]

Food loss is a so-called 'wicked problem' that must be addressed with technologies and policies that are conscious of potential trade-offs and the people who stand to benefit least from the interventions.

Community impact

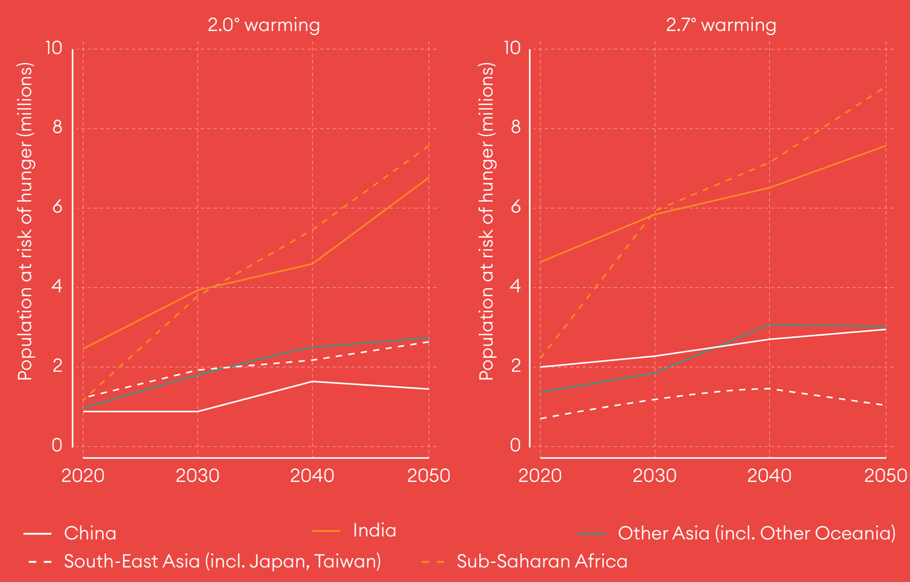
The implications of unsustainable agriculture on food insecurity

The global food system is both a major contributor to climate change, and increasingly vulnerable to its effects, and over time, climate change can increase food insecurity by reducing crop yields and food availability, reducing access to high quality food, and disrupting global food supply chains.[11]

To better understand the potential impact of worsening climate change on food security, we rely on a comprehensive analysis and dataset provided by Hasegawa et al. (2018). Here we focus primarily on potential future scenarios in low- and middle-income countries. In Figure 9.5, we plot the potential increase in food insecurity attributable to climate change in four primary regions: China, India, Asia, and Sub-Saharan Africa. In this case, we assume socio-economic development trends and population growth to be in line with historical trajectories and consider the implications of a global temperature rise of 2.0° and 2.7° Celsius by the end of the century.[12] In all regions under consideration, we find that climate change is likely to increase the total number of people experiencing food insecurity. In India and Sub-Saharan Africa, these increases are expected to be particularly severe, with roughly 8 and 9 million more people being at risk of hunger because of climate change. (Importantly, these figures do not represent the total number of people at risk of food insecurity in either region, but rather the projected increase due to climate change specifically.)

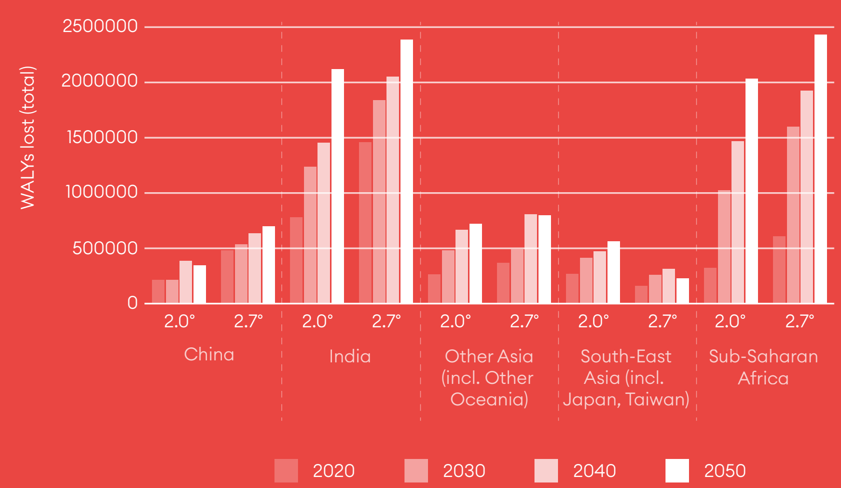
In turn, increasing food insecurity due to climate change is expected to have profound impacts of wellbeing. One recent comprehensive analysis of undernourishment and subjective wellbeing using global data collected from the Gallup World Poll found that, on an individual level, a 25% increase in feelings of food insecurity reduces life satisfaction by 0.5 points on a scale from 0 to 10.[13] In Figure 9.6, using this coefficient in conjunction with average happiness levels for each region under consideration, we plot the associated wellbeing burdens of increased food insecurity as a result of worsening climate change. **Once again, wellbeing losses in India and Sub-Saharan Africa are particularly pronounced. By 2050, WALYs lost by those affected by food insecurity are expected to total roughly 5 million combined. To put this figure into context, it is larger than the current wellbeing burden of Alzheimer's, depression, anxiety, or Parkinson's among European adults.**[14] However, once again, these burdens are only representative of the wellbeing impact of increases in food insecurity due to climate change, and not the total burden of food insecurity writ large. These figures also do not account for wellbeing lost due to deaths associated with malnutrition. Nevertheless, this analysis underlines that addressing and reducing agricultural emissions associated with animal husbandry to tackle climate change can have dramatic and cascading effects on the wellbeing of future generations.

Figure 9.5 Potential increase in food insecurity due to climate change



Note Authors' estimates using data provided by Hasegawa et al. (2018).

Figure 9.6 Potential wellbeing burdens of food insecurity due to climate change



Note Authors' estimates using data and coefficients provided by Hasegawa et al. (2018), the World Happiness Report, and Elgar et al. (2020).

Stability impact

Employment implications of transitioning to sustainable agriculture

Leap 08’ (Develop sustainable protein supply) and ‘Leap 09’ (Prevent crop and food loss) are concerned with the challenge of production and management of food, respectively. From a wellbeing-perspective, the wellbeing burdens and opportunities associated with the stability impact channel are overlapping. Please see Leap 08 for insight on both chapters.

Impact summary

In this chapter, we've discussed how reducing food insecurities has the potential to generate significant quantities of wellbeing globally.

Health impact

Food loss is a major source of food insecurity, yet even slight decreases in food loss can have a significant impact on human wellbeing. According to our estimations, 11,6 million people in Nigeria are in moderate or severe food insecurity, yet a reduction in food loss of only 16% in this country would be adequate to eliminate these issues and save 3,82 million WALYs.

Community impact

Climate change, to which the global food system contributes significantly, is another important driver of food insecurity. In our analysis, we plotted the associated wellbeing consequences of growing food insecurity because of deteriorating climate change, and we discovered that wellbeing losses are most pronounced in India and Sub-Saharan Africa. By 2050, the number of WALYs lost due to food insecurity is estimated to total around 5 million.

Stability impact

See chapter 8.

Endnotes

1 Hegnsholt, E. et al. (2018)
2 Ibid.
3 FAO (2019).
4 FAO (2019).
5 FAO (2019).
6 FAO (2019).
7 For more information, see: www.ifpri.org/topic/food-security
8 Roser & Ritchie (2013).
9 FAO, IFAD, UNICEF, WFP & WHO. (2020).
10 UN data on food loss and food insecurities retrieved from the SDG Global Database: https://unstats.un.org/sdgs/unsdg
11 For a detailed analysis, see Table 5.1 in IPCC (2020).
12 Specifically, our projections are representative of a Shared Socioeconomic Pathway 2 (SSP2) and Representative Concentration Pathways 2.6 (RCP2.6) and 6.0 (RCP6.0) future scenarios. For more information about the model and methodology, see Hasegawa et al. (2018).
13 Elgar et al. (2020).
14 Happiness Research Institute & Leaps by Bayer (2020).

Leap 10

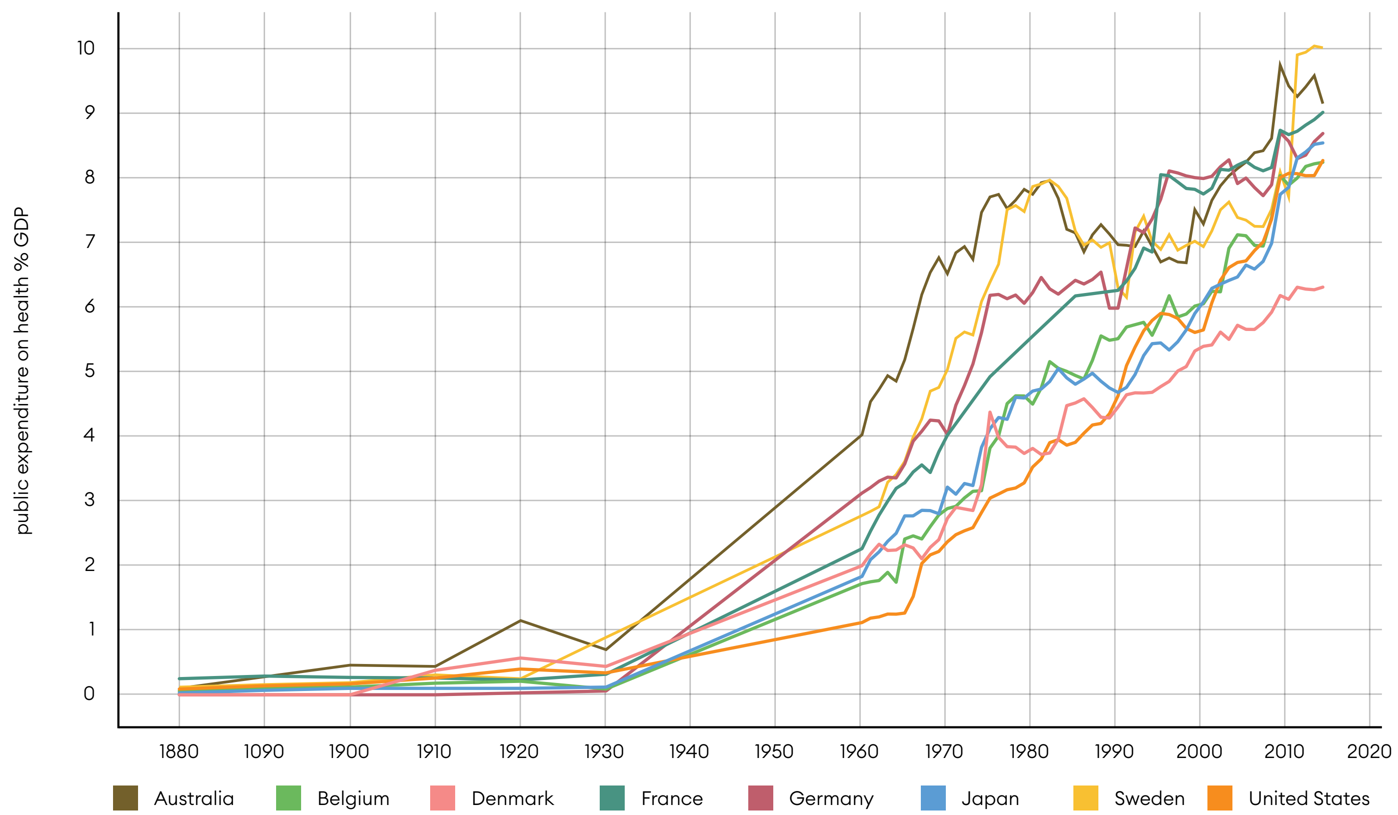
Transform health with data

The problem

The numbers are dreadful: almost half the world's population still lacks access to fundamental healthcare and at least 100 million people are pushed into poverty annually to pay for it.[1] Furthermore, emerging economies – and sub-Saharan African nations - bear the brunt of these dismal statistics, due to their disparities in service provision and people's general inability to afford even the most basic healthcare.

While the lack of healthcare access presents an acute problem in emerging economies, for developed countries there are growing concerns about the long-term sustainability of healthcare systems, particularly in terms of financial stability, as both costs and the ratio of healthcare spending to GDP appear to be increasing.

Figure 10.1 Public expenditures on health (as % of GDP)



Source Our World in Data

As illustrated by Figure 1, health expenditures have historically increased relative to GDP from 1880 to 2014. Using more recent data, this trend seems to be ongoing. For instance, in Australia healthcare spending nearly doubled from 2008 to 2017, and the ratio of healthcare spending to GDP rose from 8.75 percent to 10.28 percent.[2] Similarly, in the United States, health expenditure increased by 50% over the same period, and the ratio of health expenditure to GDP increased from 15.9% to 17.9%.[3] This challenge is primarily driven by a combination of ageing demographics and higher demands of quality treatment, and as a result, different measures are needed to ensure that healthcare is still provided efficiently in the future without causing costs to skyrocket.

For both emerging and developed economies, experts often point toward technological advancements such as telemedicine and artificial intelligence as a partial solution to these complex challenges, and for good reasons. These technologies hold the power to alleviate time constraints, expand coverage and improve care quality, and even predict preventable adverse health effects.

What if?

What if health leaders collaborated with tech giants, allowing us to move from traditional to virtual healthcare in places where it both saves costs and improves patient outcomes? What if telemedicine could help delay or even reverse the spread of non-communicable diseases (NCDs) in Sub-Saharan Africa, ensuring that people's wellbeing grows in tandem with their life expectancy? What if predictive medicine could detect undiagnosed depression or predict cardiovascular risks, saving millions of people from suffering or dying?

The promises and potentials of these innovations are unquestionable, but it is unclear how much of that potential we can in fact realize as many of the early applications of these technologies were generally scattershot, overhyped, and underdelivered. In this chapter we take a semi-optimistic stance exploring the wellbeing potentials in a scenario where these technologies will be delivering effective healthcare in various spaces.

The following chapter varies slightly from the previous of this report. Instead of looking at specific problems through the lens of health, community, and stability, we are instead using a series of cases to demonstrate the proportional WALY impacted if the potential of these technologies could be realized.

Reimagining health with telemedicine

In today's healthcare, there are numerous challenges that will necessitate strategies and solutions to address expanding care coverage, improving care quality, and lowering costs. In this section we will focus on one critical component for achieving this triple target: telemedicine, which uses the power of technology to reimagine how healthcare is delivered.
Telemedicine, also known as telehealth, is the remote diagnosis and treatment of patients through telecommunications and digital technology such as cell phones and computers.[4] This technology has surged during the COVID-19-pandemic where US physicians and other health professionals experienced an increase of 50 to 175 times the number of patients via telehealth than they did before the pandemic.[5] But while telehealth has surely been convenient during lockdowns, the promises of this technology go beyond the COVID-reality.

In a report published by McKinsey,[6] the authors estimated how much of conventional healthcare we could realistically shift into virtual or near-virtual healthcare. The report suggests that virtual care offerings could eliminate 20% of all emergency room visits, 24% of healthcare office visits and outpatient volume, and 9% of "near-virtual" visits. Furthermore, with tech-enabled drug administration, up to 35% of daily home health attendant services could be virtualized, and 2% of all outpatient volume could be transferred to the home environment. In total, these reforms will result in a transition of $250 billion in healthcare spending to virtual or near-virtual treatment in (2020), accounting for 20% of all workplaces, outpatient, and home health spending across Medicare, Medicaid, and privately insured populations.

However, if 20% of all types of healthcare services became virtual or near virtual, it could be argued that the $250 billion currently devoted to healthcare could be minimized as telehealth often comes with the promise of being cost-reducing for specific areas of healthcare.

In terms of the wellbeing impact of a greater transition to telehealth, we can imagine a scenario where the cost of telehealth would be 10% less compared to conventional healthcare for the respective healthcare services, which would lead to a cost save of $25 billion annually. By considering the relationship between subjective wellbeing and income, we can then ask how much wellbeing could be saved from cost-minimizing effects of telehealth. While this is obviously a theoretical exercise, it can help to contextualize the broader benefits.

This exercise suggests that approximately 32,000 WALYs could be saved annually in the US from potential cost minimizing effects of telehealth. To put this figure into context, it would be roughly equivalent to the expected wellbeing benefit of eliminating food insecurities for more than 200,000 Americans.

However, the evidence on the cost-minimizing effects of telehealth is not rock-solid. For instance, one recent scoping-review showed that, even though telehealth shows great potential for productivity gains; it is not established whether these gains actually result in cost savings.[7] What however seem to be clearer according to the same scoping review, is that telehealth provides overwhelmingly positive patient benefits, for which reason the authors argue that implementing telehealth generally should be motivated by benefits rather than cost reductions.

Therefore, even if we do not accept that telehealth is cost-minimizing, relative to conventional healthcare, it still holds the potential to be considered more cost-effective – simply because it would generate more patient benefit (WALYs) per dollar spent.

However, to predict an actual ratio of WALYs to healthcare expenditures between conventional healthcare and telehealth, more experimental analyses are needed.

Can telemedicine slow the rise of NCDs in Sub-Saharan Africa?

The United States and Canada are the homes to about 14% of the world's population, they bear about 10% of the world's disease burden, have 37% of the global health workforce, and invest about half of the world's financial capital on health. Sub-Saharan Africa, on the other hand, which is home 11% of the global population, carries over 24% of the global disease burden, holds only 3% of the global health workforce, and invests less than 1% of global financial capital on health.[8]

Even though the Sub-Saharan countries have seen an increase in life expectancy in more recent years, most countries still see an increase in numbers of years spent in poor health. In 2019, the life expectancy in the region was estimated at 64.5 years, but the healthy life expectancy only accounted for 57.4 years.[9] One of the primary reasons for this state of health is the rapid epidemiological increase of non-communicable diseases (NCDs) – and in particular hypertension - caused by the increased life expectancy, urbanization, and lifestyle changes.[10] Approximately 46% of African adults now experience hypertension, a prevalence rate that surpasses high-income countries (35%).[11]

Despite this epidemic, attempts in this area to prevent and manage hypertension are minimal. According to a new meta-analysis, only 27% of hypertensive individuals in Sub–Saharan Africa were aware of their condition, only 18% of those with a diagnosis were seeking care, and only 7% of those receiving treatment had received blood pressure management.[12] At this stage it is therefore paramount to address the issue of years lived in poor health due to hypertension (and NCDs in general) and help patients who would be otherwise be unable to access the specialist care they require. Telehealth has the opportunity to give these patients in need access to specialist care.

Although many obstacles to realizing the promise of telehealth still exist, Sub-Saharan Africa is undoubtedly a fertile breeding ground for this form of healthcare. Mobile devices and internet connections, the two technologies required for telehealth, are widely embraced in Sub-Saharan Africa.[13] Furthermore, children aged 0 to 14 years make up 43% of the total population in Sub-Saharan Africa, and this age group is more familiar with digital knowledge than their parents, making it fair to expect that their health will improve if high-quality digital health solutions and interventions are introduced on a large scale.[14] Thus, if telehealth could slow or even reverse this trend of increasing numbers of years spent in poor health due to NCDs, what would that mean in terms of wellbeing?

To provide an example of the proportional effects in play, we can use the data provided by World Happiness Report to imagine a scenario where the healthy life expectancy rose with 0.5, 1 and 3 years as an effect of telehealth, and then predict how that would influence wellbeing. The results of this exercise are listed in the table below:

Table 10.1 Potential WALYs saved in sub-Saharan Africa based on three scenarios for improvement in healthy life expectancy

	Current	+0.5 years HLE	+1 years HLE	+3 years HLE
Healthy life expectancy (HLE)	57.4	57.9	58.4	60.4
Life satisfaction	4,495	4,612	4,728	5,194
WALYs saved per individual	0	0.03	0.05	0.14
"WALYs saved in whole region (1,107 billion people)"	0	27,966,063	54,553,934	227,854,240

As illustrated in the table, **if telehealth could drive healthy life expectancy in Sub-Saharan Africa to reach 60.4 years, which is equal to the life expectancy in Iraq, more than 200 million WALYs could be saved annually.**

Compared to other WALY estimates throughout this report, this estimate may strike one as surprisingly large. However, it is important to be aware that WALYs are a measured as a difference between actual and potential wellbeing – and very few places in the world see a greater gap between these two measures than in Sub-Saharan Africa.

Predicting and preventing human suffering with artificial intelligence

Every year millions of people suffer or even die due to undetected physical and mental health problems, social isolation, risk behaviors, and inadequate treatments or assistance.
Resolving this problem is a monumental task for humanity, and one in which the potential of particularly 'Big Data' and 'Predictive Medicine' for detecting risk and tailoring treatments cannot be overlooked.

Big Data
Big data is a term for massive data sets having large, more varied, and complex structure with the difficulties of storing, analyzing, and visualizing for further processes or results.

Predictive Medicine
Predictive medicine is a branch of medicine that utilizes big data to identify patients at risk of developing a disease, thereby enabling either prevention or early treatment of that disease.

The standard approach of defining at-risk groups using data is to use multiple regression models on broad health databases and registers, which allows for the identification of variables that are substantially related to the issue at hand. Such databases, on the other hand, are often overly complex and unstructured, and applying conventional methods for analysis will frequently fall short of identifying causal relations or linking and tailoring predicted outcomes to individual patients. Fortunately, big data and predictive medicine are gradually becoming solutions to this issue.

Big Data allows us to become increasingly capable of aggregating a growing amount of data on the scales of what constitutes a good life for patients: from subjective reporting from survey data to online activity from social media, health states and behavior from wearable devices, and medical records and biological data from health registries. By applying predictive medicine on the scales of human wellbeing we can create better health profiles and predictive models for individual patients, allowing us to diagnose and manage disease more effectively.

The potential for predicting and mitigating human suffering is enormous if we can create a favorable climate for the use of big data and predictive medicine in healthcare. To demonstrate some of these untapped potentials, we created a list of possible future accomplishments for these technologies, along with the number of WALYs they could theoretically save.

Case 1 *What if predictive medicine could effectively detect 1% more of undiagnosed depression?*

Depression is one of the main sources of human suffering and lost WALYs, but this condition is still suffering from underdiagnosis and undertreatment. For example, each year, 7–26% of the US population suffers from depression, with only 13–49% receiving minimally appropriate care. [15]
The application of precision medicine in psychiatry is still in its very early phases compared to fields such as oncology and hematology.[16] But with the emergence of more useful data from clinical trials, neuroimaging, social media, health registers, and biological data, predictors of depression are now increasingly used to impute machine learning models that can have useful accuracy even with small sample sizes. [17]

To give an idea of how much wellbeing that could be saved from helping healthcare professionals and frontline workers detect and diagnose depression more often and more accurately, we can consider the following example:

Considering the most optimistic of the underdiagnosis estimates in the US (49% in treatment) and assuming that the respective treatments (when undertaken) have a success rate of 50%[18] - **even in a scenario where predictive medicine only helped detect and care for 10% more of the sufferers, we will be looking at an annual WALY save of approximately 113,435 WALYs in the US.[19]**

Case 2 *What if AI could predict and prevent 5% of strokes and heart attacks?*

Over the last 50 years, progress toward the elimination of cardiovascular disease has been made through the introduction of lifestyle changes as well as evidence-based therapies that seek to change an identifiable and widely shared cardiovascular phenotype.[20] However, a general reductionistic approach in medicine assumes that patients with similar signs and symptoms also share the same disease phenotype and, as a result, will react similarly to medical and behavioral interventions.[21] Because of advancements in technology and data analysis that allow for more in-depth phenotyping, there now is a growing recognition that this traditional approach may be overly simplistic.

In the field of cardiovascular risks, AI represents a new strategy in the approach to healthcare by targeting prevention while considering individual differences in genetics, exposures, lifestyle, and health factors that are determinants of a person's disease phenotype. This strategy already demonstrates promising results.

It has for example been suggested that AI can quite accurately predict possible time of death for heart disease patients. In one study from 2017,[22] AI software was used to record cardiac magnetic resonance imaging (MRI) scans as well as blood tests of heart disease patients and combined these data with health records. Using the gathered data, the AI software could predict abnormal conditions that might lead to patient death. Additionally, their software was able to predict the survival rates of patients for the next five years with a prediction accuracy of the next year survival of patients of 80%. For comparison, the clinician's accuracy was measured at 60%.

If methods like these were scaled up and adopted broadly by healthcare systems, it is likely that a great amount of cardiovascular related deaths could be avoided. **In wellbeing terms, if we imagined that 5% of heart attacks and strokes could be prevented as a result of AI predictions, that could generate approximately 75.000 WALYs in Europe.[23]**

Impact summary

In this chapter, we have investigated how better data can provide better health. In particular we have looked at how telehealth could make healthcare more cost-effective and how it can could help to delay or even reverse the spread of non-communicable diseases (NCDs) in Sub-Saharan Africa. We also looked into how predictive medicine could be used to detect undiagnosed depression or forecast cardiovascular risks.

Telemedicine

It is believed that some areas of conventional healthcare can be substituted with telehealth, and that this exercise could prove to be either more cost-effective (capable of producing the same patient benefits, but at lower cost) or more cost-efficient (capable of producing more patient benefits at the same cost). In the former case, we estimate that a 10% cost reduction of healthcare spending in the US is capable of generating wellbeing value equivalent to 32,000 WALYs.

Telemedicine also holds a potential massive untapped potential in terms of its ability to delay or reverse the spread og NCDs in Sub-Saharan Africa. As NCDs are currently causing are significant increase in years spent in poor health across Sub-Saharan African countries, but if telehealth could reverse this effect and drive healthy life expectancy equal to the level in Iraq in Iraq (60.4 years), more than 200 million WALYs could be saved annually.

Predictive medicine

'Big Data' and 'Predictive Medicine' can prove to become key when detecting risks and tailoring treatments for patients suffering from everything from depression to cardiovascular disease.

If we imagined a scenario where predictive medicine could detect and care for only 10% more of people suffering from depression in the US, we find an associated wellbeing impact of 113,435 WALYs. Similarly, if we imagined that 5% of heart attacks and strokes could be prevented as a result of AI predictions, that could generate approximately 75.000 WALYs in Europe.

Endnotes

1 World Health Organization. (2017).
2 Australian Institute of Health and Welfare (2018.
3 Sisko, A. M. et al. (2019).
4 World Health Organization. (2010).
5 Palo Alto Medical Foundation (2020)
6 Bestsennyy, O. et al (2020).
7 Snoswell, C. L. et al (2020).
8 Anyangwe, S. C., & Mtonga, C. (2007).
9 The Lancet (2020)
10 Ibrahim, M. M., & Damasceno, A. (2012).
11 Ibid.
12 Ataklte, F. et al. (2015).
13 Holst, C. et al. (2020)
14 Ibid.
15 Eichstaedt, J. C. et al. 2018).
16 Manchia, M. et al. (2020).
17 Ibid.
18 Layard, R. et al (2007).
19 If predictive medicine could raise the number of treated patients with 10% (11,303,860*0.1), 1,303,860 more people would get treatment and 50% of those could be expected to receive successful treatment. In terms of WALYs, this is equivalent to 113,435 WALYs (651,930 treated patients *0,174 WALYs saved per patient).
20 Mensah, G. A. et al. (2017).
21 Leopold, J. A., & Loscalzo, J. (2018).
22 Dawes, T. J. et al. (2017).
23 5% of strokes (744,580*0,05= 37229 WALYs) + 5% of heart attacks (751,877*0,05= 37593 WALYs)

Next steps

Investing in WALYs

Leaps by Bayer and The Happiness Research Institute are committed to continuously improve and establish WALYs as a metric that guide better and more wellbeing-optimal decisions for impact investors.

With our first report 'Wellbeing-Adjusted-Life-Years, 2019' we established the theoretical framework for WALYs that we are still building on, and the following years have been spent on validating the metric and expanding its' analytical applicability. 'Taking 10 Leaps for Humanity, 2022,' is a culmination of this work process, and with this report we have demonstrated WALYs' ability to cover market analysis and estimate unrealized investment potentials.

So, what are the next steps of this journey?

From the start, the ultimate goal of this project was to develop a rigorous wellbeing framework that could be used to analyze the impact of life science ventures and investment opportunities. We are now in the process of delivering.

Currently, we are building a model capable of connecting wellbeing data with venture KPIs to generate comparable WALY estimates across healthcare and sustainable agriculture ventures. This model is now being applied to the Leaps by Bayer's investment portfolio. In 2022, we hope to reveal some of these impact estimates.

By making this final move of applying WALYs to venture analyses and investment decisions, we hope to inspire both public and private investors to consider and adopt WALYs in their decision-making processes.

As this analysis has proven, there is a great deal of untapped well-being potential in the realm of life science. We believe WALYs can help us figure out how to realize them.

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