Food and Agriculture Organization of the United Nations

zef Center for Development Research University of Bonn

INVESTMENT COSTS AND POLICY ACTION OPPORTUNITIES FOR REACHING A WORLD WITHOUT HUNGER (SDG 2)

Center for Development Research (ZEF) of the University of Bonn in cooperation with the Food and Agriculture Organization of the United Nations (FAO)

OCTOBER 2020

IMPRINT:

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ACKNOWLEDGEMENTS

This study has been prepared by the Center for Development Research (ZEF) of the University of Bonn, in cooperation with the Food and Agriculture Organization of the United Nations (FAO). It was funded by the German Federal Ministry for Economic Cooperation and Development (BMZ).

Under the overall guidance of Professor Joachim von Braun, the Director of Center for Development Research (ZEF) and Dr Maximo Torero Cullen, the Chief Economist at FAO, the overall coordination and direction of preparing this report was carried out by Dr Bezawit Beyene Chichaibelu (from ZEF) and Dr Jose Rosero (Director of Statistics of FAO). Contributing authors are Dr Bezawit Beyene Chichaibelu, Dr Lukas Kornher, Dr Zaneta Kubik, Henry Kankwamba and Dr Maksud Bekchanov from ZEF and Jose Rosero, Carlo Cafeiro and Anne Kepple from FAO. Chapter 2 and Chapter 3.2 is based on Part 1 of The State of Food Security and Nutrition in the World (FAO, IFAD, UNICEF, WFP & WHO, 2020).

The authors gratefully acknowledge Dr Heike Baumüller and Dr Nicolas Gerber for their inputs and guidance, Anastasiia Gordienko, Ergi Take and Madina Japakhova for their technical support and assistance, and Dr Katharina Friederike Gallant for her careful review of the report. The authors are also grateful to Dr Joe Hill for the proof reading and editing of the report, and to Katharina Zinn for the layout design of the report.

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung

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ABBREVIATIONS

AARR	Average Annual Rate of Reduction
AfCFTA	African Continental Free Trade Area
AFSI	L'Aquila Food Security Initiative
AIM/GCE	Asia-Pacific Integrated Model/ Computable General Equilibrium
BAU	Business As Usual (scenario)
BMZ	Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)
CAADP	Comprehensive Africa Agriculture Development Programme
CC	Climate Change (scenario)
CGE	Computable General-Equilibrium (model)
CGIAR	Consultative Group for International Agricultural Research
COMP	Comprehensive Investment in Agriculture Scenario
COVID-19	Coronavirus Disease 2019
CRS	Creditor Reporting System
CV	Coefficient of Variation of food consumption
CV|r	Coefficient of Variation of food consumption linked to differences in energy requirements
DAC	Development Assistance Committee, of the OECD
DDA	Doha Development Agenda
DES	Dietary Energy Supply
DHS	Demographic and Health Surveys
DRC	Democratic Republic of the Congo
ENVISAGE	Environmental Impact and Sustainability Applied General Equilibrium (model)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FDI	Foreign Direct Investment
FIES	Food Insecurity Experience Scale
FSWG	Food Security Working Group, of the G7
G7	The Group of Seven, an intergovernmental economic organization
GAPS	Global Agriculture Perspectives System
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GFS	Government Finance Statistics, IMF
GHG	Greenhouse Gas
GLOBIOM	Global Biosphere Management Model
GNI	Gross National Income
GTAP	Global Trade Analysis Project
HDI	Human Development Index
IARAN	Inter-Agency Regional Analysts Network
ICTs	Information and Communication Technologies
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
JME	Joint Malnutrition Estimates
kcal	Kilocalorie
LAC	Latin America and the Caribbean
LDCs	Least Developed Countries
LIFDCs	Low-Income Food-Deficit Countries
LiST	Lives Saved Tool
LMICs	Lower- and Middle-Income Countries
MaCC	Marginal Cost Curve
MACC	Marginal Abatement Cost Curve
MAFAP	Monitoring and Analysing Food and Agricultural Policies, FAO
MAGNET	Modular Applied GeNeral Equilibrium Tool
MDCs	More Developed Countries
MDER	Minimum Dietary Energy Requirement
Mha	Million Hectares
MICMAC	Impact Matrix Cross-Reference Multiplication Applied to a Classification
MIRAGRODEP	Modelling International Relationships under Applied General Equilibrium for agRODEP
NARS	National Agricultural Research Systems
NCDs	Non-Communicable Diseases
NoCC	No Climate Change Scenario
ODA	Official Development Assistance

OECD	Organization for Economic Co-operation and Development
pc	per capita
PE	Partial-Equilibrium
PoU	Prevalence of Undernourishment
p.p.	Percentage Points
PPP	Purchasing Power Parity
R&D	Research and Development
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
SPEED	Statistics on Public Expenditures for Economic Development
SSP	Shared Socioeconomic Pathways
SSS	Stratified Societies Scenario
TSS	Towards Sustainability Scenario
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
UNSCN	United Nations System Standing Committee on Nutrition
VA	Value Added
WDI	World Development Indicators, of the WB
WEO	World Economic Outlook, of the IMF
WFP	World Food Programme
WGI	Worldwide Governance Indicators, of the WB
WHA	World Health Assembly, the decision-making body of the WHO
WHO	World Health Organization
WTO	World Trade Organization
ZEF	Center for Development Research (Zentrum für Entwicklungsforschung)

EXECUTIVE SUMMARY

Objectives of the study

At the heart of the 2030 Agenda was a promise to prioritize two objectives: to eradicate poverty and end hunger and malnutrition in all their forms. While global hunger, measured by the prevalence of undernourishment, had been on the decline, the absolute number of hungry people remained very high. In response, heads of states at **the G7 Summit in Elmau in 2015** committed to lift 500 million people out of hunger and malnutrition by 2030 as part of a broader effort undertaken with partner countries to support the 2030 Agenda for Sustainable Development, i.e. **Sustainable Development Goal (SDG 2) to end hunger and malnutrition by 2030**. Nevertheless, the number of undernourished people in the world kept rising, from 653 million people in 2015 to 690 million people in 2019, highlighting the challenge of achieving the goal of Zero Hunger and malnutrition by 2030.

This study reviews the food security situation and change therein in light of recent developments, including COVID-19. It also analyses to which extent G7 countries responded to the challenge and their commitment in terms of development assistance and outlines promising investment opportunities to meet the 2030 targets.

Obviously, more and different investments and policy actions are needed to reach the goal of a world without hunger. This study is about what needs to be done to reduce hunger by development partners, by countries that have large population shares of undernourished people, and by other stakeholders. The study conceptualizes ending hunger from different perspectives: as an important and feasible investment opportunity from human rights perspective, as a humanitarian obligation, and for economic development. The incremental **investment costs of ending hunger** and malnutrition are identified.

Recent and anticipated progress towards eradicating hunger and malnutrition

The study focuses on SDG 2 indicators – the prevalence of undernourishment (PoU), the prevalence of moderate or severe food insecurity based on the food insecurity experience scale (FIES), and indicators of malnutrition – to **assess the progress** made to date in achieving the goal of ending hunger and malnutrition by 2030. The majority of the world's undernourished – 381 million – are found in Asia while the fastest growth in the number of undernourished people is in Africa where more than 250 million of the world's undernourished live. Considering the total number of people affected by moderate or severe levels of food insecurity, an estimated 2 billion people in the world did not have regular access to safe, nutritious and sufficient food in 2019, and 3 billion people could not afford healthy diets. A recent global projection of hunger shows that the world is not on track to achieve Zero Hunger by 2030. If recent trends continue, the number of people affected by hunger will surpass 840 million by 2030, or 10 percent of the global population. The world is also not on track to achieve the 2025 and 2030 targets for child stunting and low birthweight, and for exclusive breastfeeding.

A review of **foresight exercises** provide alternative scenarios in which challenges are addressed to varying degrees, building on historical trends of factors that determine the performance of socio-economic and environmental systems. Foresight studies agree that without a determined effort to fight climate change and mitigate its negative consequences, the adverse effects as well as widening gaps of inequality will make it very difficult to achieve the goal of ending hunger and malnutrition by 2030. COVID-19 is expected to worsen the overall prospects for food security and nutrition. Food insecurity may appear in countries and population groups that were not previously affected. A preliminary assessment suggests the pandemic may add up to 132 million people to the total number of undernourished in the world in 2020, potentially increasing the number of undernourished to 909 million by 2030.

Trends in G7 development assistance for food and nutrition security

To achieve the SDG 2 targets by 2030, concerted efforts are needed to increase financial investments and aid contribution to food and agriculture to foster food and nutrition security. We evaluate the patterns and progress of these efforts. Using official development assistance (ODA) data from the Organization for Economic Co-operation and Development (OECD), this study assesses the follow up to the G7 commitments expressed by heads of states at Elmau in 2015 to increase bilateral and multilateral assistance to achieve SDG 2. Analyses of the ODA data concerning the goal of ending hunger and malnutrition shows that in 2018, the total **ODA from G7 countries specifically allocated to food security and rural development was US$ 17 billion**, a 109 percent increase compared to the value in 2000. By and large these ODA allocations are targeted at countries with a relatively higher prevalence of undernourishment, mostly in Sub-Saharan Africa. A further breakdown of these ODA flows shows that in 2018, a significant portion of G7 member countries' ODA were allocated to agricultural development, with water and sanitation, food aid and environmental protection also receiving substantial investments. The data show that Germany added the most and Japan and France also significantly increased ODA allocated to these sectors in recent years.

Lessons from successful countries

An in-depth evaluation of 19 countries that achieved substantial progress in reducing hunger over the period 2000-2017 points at opportunities. These **best performing countries** achieved on average more than 50 percent reduction in hunger (PoU). While the role of agriculture, both in terms of value added and employment is still very important in those countries, manufacturing is gaining importance and labour is gradually moving out of agriculture, and also out of rural areas. The countries spend a lot more on agriculture, had relatively high growth in agricultural value added as well as higher capital formation and GDP growth. These findings emphasize that hunger reduction goes hand in hand with improvements in various human and macro-economic development outcomes, such as poverty reduction and fiscal attention to agriculture – which is particularly important from the perspective of achieving the SDG 2.

Targeting investment costs to meet the G7 Elmau commitments and SDG to end hunger

While investments needed to end hunger and all forms of malnutrition are likely to be extensive, costly and difficult to implement, it is a fair question to ask "costly relative to what alternatives?", or in economic terms, "are they costly relative to the benefits of a world without hunger?" As policymakers still need to prioritize the allocation of resources, identifying optimal and least-cost investment options is important for practical policy. In this regard, the findings of various model- and cost-benefit and impact studies on hunger reduction measures are systematically used in this study to identify the cost-effectiveness of interventions.

As an original contribution, this study provides a **marginal cost curve** (MaCC) to identify a mix of least-cost investment options with the highest potential for reduction in hunger and malnutrition. Twenty-four different interventions are considered for reducing PoU and malnutrition. The information about the interventions are drawn from best available evidence-based literature, including modelling studies and impact assessments. Some of them are more short-term interventions (such as social protection), and some are more long-term (such as agricultural R&D, or soil fertility management). This MaCC can be considered when asking "what are the costs of ending hunger?", depending on the number of people who are to be brought out of risk of hunger by 2030. The assessment can broadly guide global and country efforts to achieve the SDG2 targets by 2030. The results from the MaCC indicate that:

1. Achieving SDG2 would not be prohibitively expensive, provided that **a mix of least-cost measures with large hunger reduction potential** are prioritized. To achieve the 2030 goal of ending hunger, not only is it urgent to act now and not to lose any more time, but also to optimally phase investments. Investments that have more long-term impacts should be frontloaded in the decade in order to reap their large benefits soon before 2030. A balanced approach is needed to reach the hungry poor soon – including those adversely affected by COVID-19 with job losses and other socio-economic consequences - with social protection and nutrition programs.
2. A bundle of promising investments that deliver long-term and short-term impacts would meet the **G7 commitment of lifting 500 million people out of hunger** by 2030. An incremental average annual investment ranging between about **US$ 11 and 14 billion** would be required for this mix of least-cost intervention options. They include agricultural R&D,

agricultural extension services, ICT - agricultural information systems, small-scale irrigation expansion in Africa, female literacy improvement, scaling up existing social protection programs. Development partners and national investors should not just target their investments at least-cost short-term interventions but consider a portfolio of short- and long-term interventions. In view of the above mentioned additional US$ 11 to 14 billion needed, a doubling of the G7's ODA for agriculture, food and rural development (from the US$ 17 billion in 2018) could go a long way toward achieving the Elmau 500 million commitment.

3. To create **a world without hunger by 2030** actually means preventing a trend that otherwise - as mentioned above - would lead to about 909 million hungry people by 2030, including incremental hunger due to COVID-19. Preventing this level of hunger would require total annual investments in a range of about **US$ 39 to 50 billion** (which includes the above-mentioned investments of US$ 11 to 14 billion). The types of these additional investments include establishing new social protection programs including to address COVID-19 related hunger, crop protection, integrated soil fertility management, African continental Free Trade Agreement (AfCTA), fertilizer-use efficiency, and child nutrition programs. It is no surprise that the investment required to lift the first 500 million people out of hunger is lower than what is required for the remaining 400 million people who live in more protracted circumstances. Overcoming hunger related to complex emergencies combined with violent conflicts and wars is not include in these calculations.

It is important to note that the marginal cost curve elements include many investments that contribute to **long term development and sustainability,** beyond 2030 and not restricted to hunger reduction. The composition of the investments facilitates an increase in resilience for populations affected by hunger today or at risk of hunger in this decade. As each intervention measure in the MaCC is considered independently with its marginal costs and hunger reduction effects, beneficial synergies among interventions are not captured. This implies that costs are probably overestimated, and hunger reduction impacts underestimated, i.e. the MaCC indicates conservative estimates of mixes of interventions. These MaCC-estimates should be combined with and compared with comprehensive modelling that may capture synergies and tradeoffs. Moreover, the MaCC reflects interventions at a global scale, therefore, the appropriate bundle of interventions need to be established for individual countries. The above mentioned insights from best performing countries provide some guidance in that respect, but countries need to develop and implement their own strategies and consider their specific contexts.

1 INTRODUCTION

In 2014, after decades of steady decline, world hunger as measured by the prevalence of undernourishment began to rise again. By 2019 the number of undernourished people in the world reached nearly 690 million. At the G7 Summit in Elmau, Germany in 2015, as a contribution to the 2030 Agenda for Sustainable Development, the G7 member states announced that, "As part of a broad effort involving our partner countries, and international actors, and as a significant contribution to the Post 2015 Development Agenda, we aim to lift 500 million people in developing countries out of hunger and malnutrition by 2030" (Leaders' Declaration, 2015).[1] This declaration, known as the Elmau 500 million commitment, was widely applauded as it underlined the G7's commitment to reduce global hunger in spite of the Sustainable Development Goals' general approach of leaving implementation to sovereign nations (UN, 2012, p. 14).

Achieving targets 2.1 and 2.2 of Sustainable Development Goal No. 2 (SDG 2),[2] to end hunger and all forms of malnutrition by 2030, remains a challenge. With respect to the Elmau commitment, the rise in global hunger raises questions about the prospects of the goal of lifting 500 million people out of hunger and malnutrition by 2030:

- How are G7 countries and their international partners contributing to addressing global hunger and malnutrition?
- What needs to be done to counter the current negative trend and to end hunger and malnutrition by 2030?
- Which interlinkages (synergies and trade-offs) should be considered when addressing the issue of global hunger?

Through its accountability process, the G7 regularly monitors and reports progress on the Elmau 500 million commitment. The G7 Food Security Working Group (FSWG) has developed a financial resource tracking system to add value to the monitoring efforts. Since 2017, the G7 have published an annual Financial Report on Food Security and Nutrition, which presents aggregated data for each G7 member state on bilateral and multilateral financial commitments in sectors relevant to food and nutrition security. Numerous qualitative aspects of the Broad Food Security and Nutrition Development Approach, as laid out at Elmau, are summarized in a scorecard which serves as a methodology for G7 accountability reports.

Efforts to monitor progress of the G7's Elmau commitment are important and useful. Yet five years on from Elmau and with ten years remaining to the SDG 2 goal of 2030, there is a felt need to complement the G7's ongoing accountability work to contribute to the international discussion on SDG 2, foster analysis and action, and provide further impulse for achieving SDG 2. This study takes a fresh look at SDG 2 implementation based on new data and analysis, thus deepening the monitoring of the G7's Elmau commitment of 2015 beyond what is produced through the G7 accountability process and FSWG financial reports. In light of increasing global hunger, this study seeks to provide an impetus for further national and international engagement with regard to SDG 2. Therefore, the objectives of the study are to:

- Undertake an independent assessment of SDG 2 status (undernourishment, food insecurity and malnutrition), considering relevant SDG 2 indicators in developing countries,
- Take stock of G7 and national and international engagement towards achieving SDG 2 in developing countries and assess G7 engagement,
- Analyse and identify further policy actions and investments needed in order to achieve SDG 2,
- Compile a set of recommendations directed at all relevant stakeholders, for their consideration regarding further engagement towards achieving SDG 2.

Following this introduction, the report is structured into five further chapters:

1 For the complete declaration on food security made by G7 heads of states at the G7 Summit in Elmau in 2015, see Box 1 in Annex 1.

2 For the complete text of the target of Sustainable Development Goal No. 2 (SDG 2), see Box 2 in Annex 1. This report is mainly concerned with the first two targets of SDG 2, namely ending hunger and all forms of malnutrition. The term SDG 2 is therefore used throughout much of the report to refer to targets 2.1 and 2.2 only.

- Chapter two presents the trends in hunger, food insecurity and various forms of malnutrition, between 2005 and 2030.[3]
- Chapter three reviews the state of current research on outlooks towards meeting the SDG 2 goals by 2030, including the implications of the COVID-19 pandemic.
- Noting that development aid is only one part of development cooperation, chapter four reports on the financial contributions (Official Development Assistance – ODA) of the G7 which relate to SDG 2, and empirically tests the causal impact of ODA on hunger reduction.
- Chapter five examines the low- and lower-middle income countries that achieved remarkable progress in hunger reduction over the period 2000–2017, to identify the factors that contributed to their success and highlight the strategies that should be prioritized by other countries in their fight against hunger.
- Chapter six reviews recent estimates of the investments required to achieve the goals of SDG 2 and ends by identifying the costs of reducing hunger and malnutrition.

3 Data on PoU for the period 2005 to 2030 is used to present trends in hunger; data on FIES is used for the period 2014 to 2019 for food insecurity; and indicators for the period 2012 onwards are used for nutrition.

2 FOOD SECURITY AND NUTRITION AROUND THE WORLD IN 2020

In 2015, the countries of the United Nations committed to the 2030 Agenda for Sustainable Development. This agenda recognized the importance of looking beyond hunger towards the goals of ensuring access to safe, nutritious and sufficient food for all people all year round, and eradicating all forms of malnutrition (SDG 2 Targets 2.1 and 2.2). Five years into the 2030 Agenda, it is now time to assess progress and to question whether continuing the efforts implemented thus far will allow countries to reach these objectives. For this reason, this chapter presents an assessment of the state of food security and nutrition in the world with projections of what the world may look like in 2030 if the trends of the last decade continue. Importantly, as the COVID-19 pandemic continues to evolve, this report attempts to foresee some of the impacts of this global pandemic on food security and nutrition. However, given that the devastation that COVID-19 will cause is still largely unknown, it is important to recognize that any assessment at this stage is subject to a high degree of uncertainty and should be interpreted with caution.

2.1 Progress Towards Global Hunger Reduction Targets

The main indicator for monitoring progress on the eradication of **hunger** in the Sustainable Development Goals global indicator framework is the prevalence of undernourishment (PoU).[4] It is computed from aggregated country-level data on food available for human consumption (compiled annually for most countries in the world in FAO's Food Balance Sheets) and on less frequently obtained data on food consumption from surveys, available for a growing (but still partial) number of countries. For each country, the distribution of average, daily dietary energy consumption in the population is compared with the distribution of dietary energy needs (derived from the composition of the population by age, gender and physical activity levels) to produce an estimate of the proportion of the population that is chronically undernourished, i.e. lacking enough dietary energy for a healthy, active life.

4 Throughout the report, hunger and PoU are used interchangeably.

In extending the projections of the PoU to assess the prospects for achieving the Zero Hunger target by 2030, an approach was followed based on projecting each of the three fundamental components of the PoU estimates separately for each country. The PoU and number of undernourished (NoU) values were then aggregated at the regional and global levels. First, projected population size and composition (median variants), readily available from the World Population Prospects, were used. This allowed the projections of values of Minimum Dietary Energy Requirement (MDER) and coefficient of variation of food consumption linked to differences in energy requirements (CV|r) up to 2030. Second, the current time series of total dietary energy supply (DES) from 2005 to 2017/2018 were forecast to 2030 using a simple version of Exponential Smoothing, which treats weighted averages of past observations with the weights decaying exponentially as the observations get older. In other words, the more recent the observation, the higher the associated weight. The total DES was then divided by the projected population numbers to provide an indication of its evolution at per capita levels. Finally, trends in the coefficient of variation of food consumption (CV) as estimated from 2015 or from the date of the last available survey were extended to 2030, following the same principle that guided the update of the CV up to 2019.

The three most recent editions of The State of Food Security and Nutrition in the World offer evidence that the decades-long decline in hunger/PoU across the world has ended. Additional evidence available this year and several important data updates, including a revision of the entire PoU series for China back to 2000, show that almost 690 million people in the world (8.9 percent of the world population) are estimated to have been undernourished in 2019 (Figure 1).[5] The latest report's revisions confirm the conclusion of past editions that the number of people affected by hunger across the world continues

5 All statistical series published in The State of Food Security and Nutrition in the World are carefully revised prior to the publication of each new edition to reflect all the new information the FAO received since the release of the previous edition. The process implies possible backward revisions of the entire series and readers are warned against comparing values of the indicators across different editions of the report and encouraged to always refer to the series as presented in the most current report.

to increase slowly. This trend started in 2014 and extends to 2019. There are nearly 60 million more undernourished people now than in 2014, when prevalence was 8.6 percent. Between 2018 and 2019 the number rose by 10 million people (FAO et al., 2020).[6]

Several reasons underlie the observed increase in hunger over the past few years. Much of the recent increase in food insecurity can be attributed to a greater number of conflicts, often exacerbated by climate-related shocks. Even in some peaceful settings, food security has deteriorated as a result of economic slowdowns threatening access to food for the poor.

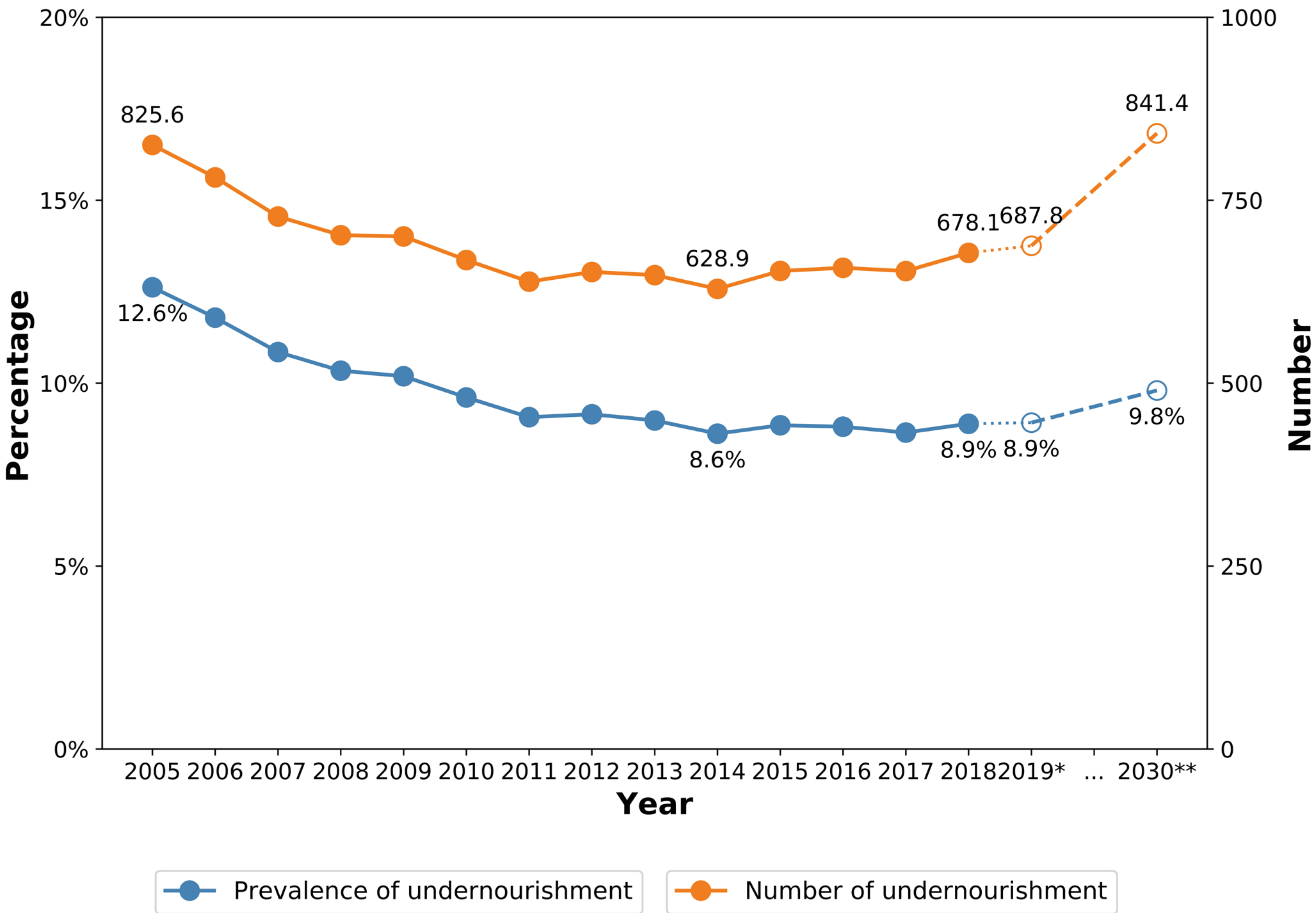
Figure 1 also reveals that the world is not on track to achieve the SDG Target 2.1 of Zero Hunger by 2030. Combined projections of recent trends in the size and composition of the population, in the total food availability, and in the degree of inequality in food access point to an increase of the PoU by almost 1 percentage point. As a result, the global number of undernourished people in 2030 is estimated to exceed 840 million. These projections for 2030 indicate that Target 2.1 of the 2030 Agenda for Sustainable Development – “By 2030 end hunger and ensure access by all people, in particular the poor and people in vulnerable situations including infants, to safe, nutritious and sufficient food all year round” – will not be met unless relevant stakeholders at all levels, from the subnational all the way to the global level, undertake urgent and consistent actions to reverse the current trends. The projected situation in 2030 reflects the trends in recent years, without considering the impact of the COVID-19 pandemic. The pandemic will most likely accelerate the projected increase in the number of hungry people, at least in the immediate future. This reinforces the need for urgent action to get back on track towards achieving the Zero Hunger goal.

The situation is most alarming in **Africa**, where it is estimated that in 2019 more than 250 million people were undernourished, or 19.1 percent of the population, up from 17.6 percent in 2014. This prevalence is more than twice the world average (8.9 percent) and is the highest among the world regions (Table 1).[7] The majority of un-

6 The analyses presented in this chapter use input data compiled up to March 2020, but with a reference period that ends in 2019. Hence, the estimates should be understood to represent the food security and nutrition situation before the outbreak of COVID-19.

7 The delineation of the world regions and sub-regions, as given in Tables 1-4, follows that used by the FAO et al. (2020).

Figure 1: Prevalence and number of undernourished people in the world, 2005-2030



Notes: Projected values in the figure are illustrated by dotted lines and empty circles. The shaded area represents projections for the longer period from 2019 to the 2030 target year. The entire series was carefully revised to reflect new information made available since the publication of the last edition of the report; it replaces all series published previously.
Source: FAO et al. (2020).

dernourished people in Africa are found in Sub-Saharan Africa, which shows an increase of about 32 million undernourished people since 2015. Hunger has been on the rise throughout Sub-Saharan Africa since 2014, though the increase has been especially significant in Eastern and Western Africa, as well as in Middle Africa where it affected 29.8 percent of the total population in 2019 (Table 1 and 2). The trends in Africa are driven by a combination of factors, including economic slowdowns and downturns, conflicts and extreme weather events that have affected a number of countries in Africa.

In terms of outlook for 2030 (Table 1), Africa is significantly off track to achieve the Zero Hunger target, even without considering the impact of COVID-19. If recent trends persist, its PoU will increase from 19.1 to 25.7 percent. Undernourishment is expected to worsen, particularly in Sub-Saharan Africa. By 2030, the projected rise in the PoU would bring the number of hungry people in Africa to almost 433 million, 412 million of whom would be in Sub-Saharan countries (Table 2).

Asia is home to more than half of the total number of undernourished people in the world – an estimated 381 million people in 2019. Yet, the PoU in Asia as a whole is 8.3 percent of the total population, below the world average (8.9 percent), and less than half of that of Africa (Tables 1 and 2). In addition, since 2005, the number of hungry people in Asia has reduced by more than 190 million. This outcome reflects progress mostly in Eastern Asia and Southern Asia.[8] The situation in other sub-regions of Asia is stable since 2015, except for Western Asia, where it has been worsening primarily due to widespread protracted crises.[9]

The projections for Asia in 2030 (Tables 1 and 2) show that significant progress has been made in reducing undernourishment in all sub-regions, with the exception of Western Asia where undernourishment is increasing.

8 The two regions showing reductions in undernourishment – Eastern and Southern Asia – are dominated by the two largest economies of the continent, China and India, where hunger has reduced owing to long-term economic growth, reduced inequality, and improved access to basic goods and services. In Southern Asia, in countries like Nepal, Pakistan and Sri Lanka, significant progress has also been made in reducing hunger in the past ten years, owing largely to improved economic conditions.

9 Conflicts and instability are the primary drivers behind the rise in hunger in Western Asia.

Table 1: Prevalence of undernourishment (%) in the world, 2005-2019

	Prevalence of undernourishment (%)							
	2005	2010	2015	2016	2017	2018	2019*	2030**
WORLD	12.6	9.6	8.9	8.8	8.7	8.9	8.9	9.8
AFRICA	21	18.9	18.3	18.5	18.6	18.6	19.1	25.7
Northern Africa	9.8	8.8	6.2	6.3	6.6	6.3	6.5	7.4
Sub-Saharan Africa	23.9	21.3	21.2	21.4	21.4	21.4	22	29.4
Eastern Africa	32.2	28.9	26.9	27.1	26.8	26.7	27.2	33.6
Middle Africa	35.5	30.4	28.2	28.8	28.7	29	29.8	38
Southern Africa	4.9	5.4	7	8	7	7.9	8.4	14.6
Western Africa	13.8	12.1	14.3	14.2	14.6	14.3	15.2	23
ASIA	14.4	10.1	8.8	8.5	8.2	8.4	8.3	6.6
Central Asia	11	7.7	3	3	3	3	2.7	< 2.5
Eastern Asia	7.6	3.8	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
South-eastern Asia	17.3	11.7	10.5	10	9.8	9.8	9.8	8.7
Southern Asia	20.6	15.4	14.4	13.8	13.1	13.8	13.4	9.5
Western Asia	11.8	10.4	10.7	11.1	11.1	11.2	11.2	13.1
Western Asia and Northern Africa	10.9	9.7	8.6	8.9	9	8.9	9	*10.4*
LATIN AMERICA AND THE CARIBBEAN	8.7	6.7	6.2	6.7	6.8	7.3	7.4	9.5
Caribbean	21.3	17.5	17.3	17	16.6	17	16.6	14.4
Latin America	7.8	5.9	5.4	6	6.1	6.6	6.7	9.1
Central America	8.1	7.9	7.9	8.6	8.3	8.4	9.3	12.4
South America	7.6	5.1	4.4	4.9	5.2	5.8	5.6	7.7
OCEANIA	5.6	5.4	5.5	5.9	6	5.7	5.8	7
NORTHERN AMERICA AND EUROPE	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5

Notes: * Projected values. ** The projections up to 2030 do not reflect the potential impact of the COVID-19 pandemic. **For the 2030 projections: green = on track to achieve the 2030 target; yellow = some progress; red = no progress or worsening.**

Source: FAO et al. (2020).

Table 2: Number of undernourished people (millions) in the world, 2005-2019

	Number of undernourished people (millions)							
	2005	2010	2015	2016	2017	2018	2019*	2030**
WORLD	825.6	668.2	653.3	657.6	653.2	678.1	687.8	841.4
AFRICA	192.6	196.1	216.9	224.9	231.7	236.8	250.3	433.2
Northern Africa	18.3	17.8	13.8	14.4	15.5	15	15.6	21.4
Sub-Saharan Africa	174.3	178.3	203	210.5	216.3	221.8	234.7	411.8
Eastern Africa	95	98.1	104.9	108.4	110.4	112.9	117.9	191.6
Middle Africa	39.7	40	43.5	45.8	47.2	49.1	51.9	90.5
Southern Africa	2.7	3.2	4.4	5.1	4.5	5.2	5.6	11
Western Africa	36.9	37	50.3	51.2	54.2	54.7	59.4	118.8
ASIA	574.7	423.8	388.8	381.7	369.7	385.3	381.1	329.2
Central Asia	6.5	4.8	2.1	2.1	2.2	2.1	2	n.r.
Eastern Asia	118.6	60.6	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
South-eastern Asia	97.4	70.1	66.7	63.9	63.4	64.2	64.7	63
Southern Asia	328	264	263.1	256.2	245.7	261	257.3	203.6
Western Asia	24.3	24.2	27.6	29.2	29.5	30.4	30.8	42.1
Western Asia and Northern Africa	42.6	42	41.4	43.6	45	45.4	46.4	63.5
LATIN AMERICA AND THE CARIBBEAN	48.6	39.6	38.8	42.4	43.5	46.6	47.7	66.9
Caribbean	8.4	7.2	7.4	7.3	7.1	7.3	7.2	6.6
Latin America	40.1	32.4	31.4	35.1	36.3	39.3	40.5	60.3
Central America	11.8	12.4	13.4	14.7	14.4	14.7	16.6	24.5
South America	28.4	20	18	20.4	21.9	24.6	24	35.7
OCEANIA	1.9	2	2.2	2.4	2.4	2.4	2.4	3.4
NORTHERN AMERICA AND EUROPE	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.

Notes: * Projected values. ** The projections up to 2030 do not reflect the potential impact of the COVID-19 pandemic. **For the 2030 projections: green = on track to achieve the 2030 target; yellow = some progress; red = no progress or worsening. n.r. = not reported, as the prevalence is less than 2.5 percent. Regional totals may differ from the sum of regions, due to rounding**.

Source: FAO et al. (2020).

Without considering the potential impact of the COVID-19 pandemic, Eastern and Central Asia are on track to meet SDG Target 2.1 by 2030. Southern and South-eastern Asia are making progress, but nevertheless are not on track to achieve the target by 2030. The current increasing trend in Western Asia is the opposite of what is needed to achieve the target by 2030.

In **Latin America and the Caribbean** (LAC), the PoU was 7.4 percent in 2019, below the world prevalence of 8.9 percent, which still translates into almost 48 million undernourished people (Table 1 and 2). The region as a whole has seen a rise in hunger in the past few years, with the number of undernourished people increasing by 9 million between 2015 and 2019, but with important differences among the sub-regions. The Caribbean, the sub-region with the highest prevalence, showed some moderate progress in the recent past, while in Central and South America the situation has worsened. Progress and setbacks in reducing hunger are a result of economic conditions, extreme climate events, political instability and conflicts.

The Latin America and Caribbean region is not on track to achieve the SDG Target 2.1 of Zero Hunger by 2030 (Tables 1 and 2). The region as a whole is projected to have more than 19 million more hungry people in 2030 compared to 2019, even without considering the likely impact of the COVID-19 pandemic. A 3-percentage point increase in the PoU is projected for Central America. In South America, the PoU is projected to increase from 5.6 percent in 2019 to 7.7 percent in 2030, a total of almost 36 million people. The Caribbean sub-region, while making progress, is not on track to achieve the target by 2030.

In summary, despite having achieved the most progress in reducing undernourishment, Asia as a whole is currently home to more than 55 percent of the undernourished people in the world. Africa has the highest PoU and (after Southern Asia) the second highest number of undernourished people, about 250 million, accounting for 36.4 percent of the global total. A much smaller share of the world's undernourished people live in Latin America and the Caribbean (almost 7 percent). Even without considering the effects of COVID-19, projected trends in undernourishment would change the geographic distribution of world hunger dramatically (Table 2, far right column). While Asia would still be home to just over 329 million hungry people in 2030, its share of the world's hunger would shrink substantially (to 39 percent). Africa would overtake Asia to become the world region with the highest number of undernourished people, over 433 million people, accounting for 51.5 percent of the total. Comparing the sub-regions, Eastern Africa, predicted to have nearly 192 million hungry people in 2030, is forecast to be second only to Southern Asia, predicted to have almost 204 million hungry in 2030. Central America, South America and Western Asia are the three sub-regions outside of Africa which would host a much larger share of people suffering from hunger in 2030 than today.

Finally, the projections on undernourishment may be substantially altered by differential impacts of the COVID-19 pandemic, which are still being assessed. The potential impact of the COVID-19 pandemic on undernourishment is discussed in chapter 3.

2.2 Beyond Hunger: Progress Towards Access to Nutritious and Sufficient Food for All

Target 2.1 of Sustainable Development Goal 2 looks beyond hunger towards the goal of ensuring **access to nutritious and sufficient food for all**. The indicator to monitor its progress, prevalence of moderate or severe food insecurity, is assessed using the Food Insecurity Experience Scale (FIES). Considering the universal scope of the 2030 Sustainable Development agenda, this indicator is relevant for all countries in the world – "developed" as well as "developing" countries. It refers not only to severe conditions of food insecurity but also to situations at more moderate levels. People experiencing moderate food insecurity face uncertainties about their ability to obtain food and have been forced to reduce, at times during the year, the quality and/or quantity of food they consume due to lack of money or other resources. It thus refers to a lack of consistent access to food, which diminishes dietary quality, disrupts normal eating patterns, and can have negative consequences for nutrition, health and well-being.[10]

According to the latest estimates, 9.7 percent of the world population (or slightly less than 750 million people) were exposed to **severe** levels of food insecurity in 2019, defined using the FIES global reference scale. This implies reductions in the quantity of food consumed to the extent that they have possibly experienced hunger (Table 3).

Unsurprisingly, the prevalence of severe food insecurity in Africa (19.0 percent) is very close to the PoU in Africa (19.1 percent, see Table 1), and is the highest among all world regions. In Asia as a whole, the prevalence of severe food insecurity is 9.2 percent (though in Southern Asia it is 17.8 percent). In Latin America and the Caribbean it is 9.6 percent. In all regions of the world except Northern America and Europe (1.1 percent), the prevalence of severe food insecurity has increased from 2014 to 2019 (Table 3).

A broader look at the extent of hunger and food insecurity beyond severe levels reveals that **an additional 16.2 percent of the world population**, or 1.25 billion people, experienced food insecurity at **moderate** levels in 2019, meaning they did not have regular access to nutritious and sufficient food. The combination of moderate and severe levels of food insecurity brings the estimated **prevalence of moderate or severe food insecurity** (SDG Indicator 2.1.2) to 25.9 percent of the world population in 2019, amounting to a total of about **2 billion people**. Food insecurity (moderate or severe) at the global level has increased each year since 2014, mostly because of the increase in moderate food insecurity.

Prevalence of moderate or severe food insecurity is much higher in Africa than in any other part of the world. It is estimated that about half of the population (51.6 percent) of Africa experiences moderate or severe food insecurity. Latin America and the Caribbean is next, with a prevalence of more than 30 percent, followed by Asia at 22 percent. Northern America and Europe has an 8 percent prevalence.

The prevalence of food insecurity (moderate or severe) is on an upward trend in Africa (Table 3). This is explained by the increase in Sub-Saharan Africa. However, it is in Latin America and the Caribbean where food insecurity is rising the fastest: from 22.9 percent in 2014 to 31.7 percent in 2019, due to a sharp increase in South America (Table 3). In Asia, the percentage of people exposed to moderate or severe food insecurity remained stable from 2014 to 2016, then started increasing from 2017 onwards. The increase is concentrated in Southern Asia where the total prevalence of food insecurity increased from 29.4 percent in 2017 to 36.1 percent in 2019. The global crisis induced by the COVID-19 pandemic will certainly bring these figures to much higher levels, even in regions of the world like Northern America and Europe which have traditionally been more food secure.

10 The approach relies on data obtained by directly asking people, through an eight-question module inserted in surveys, about the occurrence of conditions and behaviours that are known to reflect constrained access to food. Based on their responses, the individuals surveyed are assigned a probability of being in one of three classes, as defined by two globally set thresholds: food secure or marginally insecure; moderately food insecure; and severely food insecure. See FAO, 2016; Cafiero, Viviani & Nord, 2018.

In terms of the distribution of food-insecure people in the world, from a total of 2 billion affected by moderate or severe food insecurity, 1.03 billion are in Asia, 675 million in Africa, 205 million in Latin America and the Caribbean, 88 million in Northern America and Europe and 5.9 million in Oceania. It is also important to highlight the differences across regions in the distribution of the population by food-insecurity severity level. For example, in addition to being the region with the highest overall prevalence of food insecurity, Africa is also the region where severe levels represent the largest share of the total. In Latin America, and even more so in Northern America and Europe, the proportion of food insecurity experienced at severe levels is much smaller.

2.3 Progress Towards Global Nutrition Targets

This section presents the latest assessment of progress towards the global nutrition targets, which constitute target 2.2 of the SDGs. These targets – to reduce child stunting, childhood overweight, child wasting, low birthweight and adult obesity, and to increase exclusive breastfeeding – were endorsed by the World Health Assembly (WHA) in 2012 to be achieved by 2025, and extended to 2030 to align with the 2030 SDG agenda (WHO, 2012; WHO & UNICEF, 2017). The assessment examines progress made since the baseline (2012) and projects trajectories towards the 2025 and 2030 targets, looking at sub-regional, regional and global levels.[11]

Globally, progress is being made towards the stunting and exclusive breastfeeding targets, but the pace must be increased to achieve them by 2025 and 2030. Currently the prevalence of child wasting is above the 5 percent target for 2025, putting the lives of tens of millions of children at risk in the immediate term. Progress is being made in reducing low birthweight, but not enough to achieve the target of a 30 percent reduction in low birthweight by 2025 and 2030. The increasing trend in childhood overweight is of great concern and must be urgently addressed, as must the trend in adult obesity which continues to rise.

11 The assessment of progress on nutrition outcomes is based on data generated and made available prior to the outbreak of the COVID-19 pandemic. The pandemic is likely to affect progress in the coming months and years.

Table 3: Prevalence of food insecurity at severe level only, and moderate or severe level, measured with the FIES, 2014-2019

	Prevalence of severe food insecurity in the total population (%)						Prevalence of moderate or severe food insecurity in the total population (%)					
	2014	2015	2016	2017	2018	2019	2014	2015	2016	2017	2018	2019
WORLD	8.3	7.9	8.1	8.6	9.4	9.7	22.4	22.4	23.2	24.8	25.8	25.9
AFRICA	16.7	16.8	18.2	18.5	18.3	19.0	46.3	46.5	49.4	51.4	50.6	51.6
Northern Africa	10.2	9.0	10.4	11.0	9.3	8.7	29.7	26.4	30.0	36.8	31.1	28.6
Sub-Saharan Africa	18.2	18.6	20.0	20.0	20.3	21.3	50.3	51.2	53.9	54.8	55.1	56.8
Eastern Africa	23.5	23.8	25.2	24.5	23.9	24.7	28.0	57.9	61.7	61.1	60.2	61.4
Middle Africa	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Southern Africa	19.4	19.5	19.7	19.9	19.7	19.8	44.1	44.4	44.6	44.8	44.8	44.7
Western Africa	11.7	12.5	13.8	14.9	15.8	17.2	42.1	44.3	46.4	48.6	50.5	53.2
ASIA	8.0	7.5	7.1	7.6	9.1	9.2	19.4	18.9	18.9	20.6	22.6	22.3
Central Asia	1.6	1.4	2.0	2.8	2.2	2.3	8.5	9.1	10.0	13.9	13.6	13.2
Eastern Asia	0.8	0.8	1.5	1.7	1.9	1.3	6.0	5.9	6.3	10.0	9.6	7.4
South-eastern Asia	4.4	3.8	4.0	5.6	5.4	4.8	16.9	15.3	17.0	19.6	19.6	18.6
Southern Asia	15.9	14.8	13.1	13.3	16.9	17.8	31.6	30.8	30.1	29.4	34.6	36.1
Western Asia	8.3	8.7	8.8	9.8	9.4	9.0	28.0	28.0	26.9	28.9	28.1	28.5
Western Asia and Northern Africa	9.2	8.9	9.6	10.4	9.3	8.8	28.8	27.3	28.4	32.6	29.5	28.5
LATIN AMERICA AND THE CARIBBEAN	7.1	6.4	8.1	9.3	9.2	9.6	22.9	25.1	29.4	32.0	31.6	31.7
Caribbean	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Latin America	6.9	6.2	7.9	9.2	9.1	9.5	22.6	24.9	29.4	32.0	31.6	31.7
Central America	10.4	10.2	10.0	11.8	13.6	14.1	31.8	32.0	31.4	34.7	38.3	39.3
South America	5.5	4.6	7.1	8.1	7.2	7.6	18.8	22.0	28.6	30.9	28.8	28.5
OCEANIA	2.5	2.6	3.3	4.1	3.7	4.2	11.1	9.5	11.5	14.2	12.9	13.9
NORTHERN AMERICA AND EUROPE	1.4	1.4	1.3	1.2	1.0	1.1	9.4	9.4	8.8	8.5	7.6	7.9

Notes: n.a. = not available, as data are available only for countries, representing less than 50 percent of the population in the region.

Source: FAO et al. (2020).

Progress towards the nutrition targets at the global level is summarised in Table 4 (excluding child wasting). Worldwide, 21.3 percent of children under 5 years of age were stunted in 2019, or 144 million. Although there has been some progress globally, rates of stunting reduction are far below what is needed, at 2.3 percent per year in recent years (defined as the period from 2008 to 2019). A rate of 3.9 percent per year is required to reach the targets of 40 percent reduction for 2025 and 50 percent reduction for 2030, starting from the baseline year (2012) (UNICEF, WHO & World Bank, 2020). If recent trends continue, these targets will only be achieved in 2035 and 2043, respectively.

The prevalence of stunting is unequally distributed across the world, and even within regions and sub-regions, with contrasting severity levels. More than nine out of ten stunted children lived in Africa or Asia in 2019, making up 40 percent and 54 percent of all stunted children in the world, respectively. Most regions have made some progress to reduce stunting between 2012 and 2019 but not at the rate needed to achieve the 2025 and 2030 targets. The prevalence of stunting in Sub-Saharan Africa is decreasing, but only at half the rate needed, and is still very high (31.1 percent in 2019). Moreover, Sub-Saharan Africa has actually seen an increase in the number of stunted children from 51.2 million in 2012 to 52.4 million in 2019. Central Asia, Eastern Asia and the Caribbean are on track to achieve the 2025 and 2030 targets (Table 4). If current progress continues, Asia and Latin America and the Caribbean will be very close to achieving the targets for 2025 and 2030 (missing them by only one year), while Africa will need to triple its progress rate if population growth continues to increase as projected.

The global prevalence of overweight among children under 5 years of age has not improved, increasing slightly from 5.3 percent in 2012 to 5.6 percent, a total of 38.3 million children, in 2019 (UNICEF, WHO & World Bank, 2020). Of the 38.3 million children who were overweight in 2019, 24 percent lived in Africa and 45 percent in Asia, despite these being the regions with the lowest prevalence of children who are overweight (4.7 percent in Africa and 4.8 percent in Asia). Australia and New Zealand has a very high prevalence rate (20.7 percent), Southern Africa (12.7 percent) and Northern Africa (11.3 percent) have prevalence rates considered high (de Onis et al., 2019), followed closely by Oceania (9.4 percent), Northern America (i.e. the US) (8.9 percent) and Western Asia (8.4 percent). Australia and New Zealand has experienced the largest increase in childhood overweight, as has Oceania (excluding Australia and New Zealand); both require concerted efforts to reverse their rapidly rising upward trends. There has been little or no progress to stem the rate of overweight for most of the sub-regions between 2012 and 2019 (Table 4). Africa as a whole has halted the increase in childhood overweight so far, but increased efforts are needed to achieve the target of 3 percent by 2030. All regions require urgent action to end the rise in childhood overweight by 2025 and achieve the target of no more than 3 percent by 2030.

Globally, 6.9 percent of children under 5 years (a total of 47 million) were affected by wasting in 2019 – significantly above both the 2025 target (5 percent) and the 2030 target (3 percent) (UNICEF, WHO & World Bank, 2020). The prevalence of wasting in Africa is 6.4 percent, with only the Southern Africa sub-region having a prevalence below 5 percent. Oceania excluding Australia and New Zealand has the highest prevalence of wasting of all regions (9.5 percent), followed by Asia (9.1 percent). Southern Asia, which is home to more than half of the world's wasted children under 5 years of age, is the only sub-region having a high prevalence of 14.3 percent (25 million) in 2019. By contrast, Latin America and the Caribbean is the only region with a prevalence of wasting (1.3 percent) already below the 2025 and 2030 targets.[12]

Worldwide, 14.6 percent of infants were born with low birthweight (less than 2,500 g) in 2015 (UNICEF & WHO, 2019). The Average Annual Rate of Reduction (AARR) for this indicator of 1 percent per year shows that some progress has been made in recent years, but not enough to achieve the target of a 30 percent reduction in low birthweight by 2025 (the 2030 target is the same). If progress continues at the current rate, the target will be achieved only in 2046. The estimates also indicate that none of the regions are on track to achieve the target of 30 percent relative reduction in the proportion of babies born with low birthweight, even by 2030. Notably, Southern Asia had the highest prevalence estimate (26.4 percent in 2015). Rates of reduction for this indicator are very low for all sub-regions, with a maximum AARR of 1.2 percent per year in Southern Asia. Moreover, recent trends indicate no reduction in South America, Eastern Asia and Northern America (i.e. the US), and a slight increase in Australia and New Zealand (Table 4).

As of 2019, it was estimated that globally, 44 percent of infants aged less than six months were exclusively breastfed (UNICEF, 2020a). The world is currently on track to achieve the 2025 target of at least 50 percent for this

12 Wasting is an acute condition that can change frequently and rapidly over the course of a calendar year. This makes it difficult to generate reliable trends over time with the input data available. As such, only the most recent global and regional estimates are reported. The assessment of child wasting is made based on the latest estimates (2019) through a straight comparison to the target levels of 5 percent and 3 percent for 2025 and 2030, respectively.

Table 4: Prevalence of child stunting, child overweight, low birthweight, exclusive breastfeeding (<6 months), adult obesity, 2012-2019

	Child stunting (%)				Child overweight (%)				Low birthweight (%)				Exclusive breastfeeding [b] (%)				Adult obesity [c] (%)		
	2012	2019	2025	2030	2012	2019	2025	2030	2012	2015	2025	2030	2012	2019	2025	2030	2012	2016	2025
WORLD	24.8	21.3			5.3	5.6			15	14.6			37	44.1			11.8	13.1	
AFRICA	32.3	29.1			4.8	4.7			14.1	13.7			35.5	43.7			11.5	12.8	
Northern Africa	19.8	17.6			10.1	11.3			12.4	12.2			40.7	42.1			23	25.2	
Sub-Saharan Africa	34.5	31.1			3.8	3.6			14.4	14			34.5	44			8	9.2	
Eastern Africa	38.5	34.5			4	3.7			13.8	13.4			48.6	61.1			5.3	6.4	
Middle Africa	34.4	31.5			4.8	5.1			12.8	12.5			28.5	n.a.			6.7	7.9	
Southern Africa	30.4	29			11.7	12.7			14.3	14.2			n.a.	33.5			25	27.1	
Western Africa	30.6	27.7			2.3	1.9			15.6	15.2			22.1	32.2			7.4	8.9	
ASIA [d]	27	21.8			4.4	4.8			17.8	17.3			39	45.3			6.1	7.3	
Central Asia	14.9	9.9			7.3	6.2			5.6	5.4			29.2	44.8			15.6	17.7	
Eastern Asia [d]	7.9	4.5			6.4	6.3			5.1	5.1			28.5	22			4.9	6	
South-eastern Asia	29.4	24.7			5.5	7.5			12.4	12.3			33.5	47.9			5.4	6.7	
Southern Asia	38	31.7			2.5	2.5			27.2	26.4			47.4	57.2			4.5	5.4	
Western Asia	15.9	12.7			7.7	8.4			10	9.9			32.3	33.1			27.2	29.8	
Western Asia and Northern Africa	17.8	15.2			8.9	9.9			11.2	11.1			37.4	38.7			25.3	27.2	
LATIN AMERICA AND THE CARIBBEAN	11.4	9			7.2	7.5			8.7	8.7			33.4	n.a.			22.2	24.2	
Caribbean	10.3	8.1			6.2	7			10.1	9.9			29.7	25.9			22	24.7	
Central America	16	12.6			6.5	6.9			8.8	8.7			21.6	33.2			25.1	27.3	
South America	9.2	7.3 [a]			7.6	7.9 [a]			8.6	8.6			41.9	n.a.			21.1	23	
OCEANIA [e]	37.9	38.4			7.3	9.4			10	9.9			56.9	61.3			21.3	23.6	
Australia and New Zealand [f]	n.a.	n.a.			16.2	20.7			6.2	6.4			n.a.	n.a.			27	29.3	
NORTHERN AMERICA AND EUROPE	n.a.	n.a.			n.a.	n.a.			7	7			n.a.	n.a.			25	26.9	
Northern America [g]	2.7	2.6			8	8.9			7.9	7.9			25.5	34.7			32.9	35.5	

Notes: a. Consecutive low population coverage; interpret with caution; b. Regional averages are population weighted using the most recent estimate for each country between 2005 to 2012 (2012 column) and 2014 to 2019 (2019 column), except for China where a 2013 estimate is used for 2019 aggregates; estimates in the 2012 and 2019 columns do not have the same subset of countries; c. There is no official target for adult obesity for 2030; d. Stunting and overweight under 5 years of age and low birthweight regional aggregates exclude Japan; e. Oceania excluding Australia and New Zealand; f. Overweight estimates for Australia and New Zealand are based only on data from Australia; g. Stunting estimates for Northern America are based only on data from the United States; n.a. shown where population coverage <50 percent. **For the 2025 and 2030 projections: green = on track to achieve the 2025 and 2030 target; yellow = off track - some progress; red = off track - no progress or worsening; grey = no data – unknown.**

Sources: UNICEF, WHO, & World Bank (2020); NCD-RisC (2017); UNICEF, & WHO (2019); UNICEF (2020a).

indicator. If additional efforts are not made, however, the global target for 2030 of at least 70 percent will not be achieved before 2038. Oceania, Eastern Africa and Southern Asia have, at current rates, already achieved the 2025 target. Most sub-regions are making at least some progress towards the 2025 and 2030 targets for exclusive breastfeeding, except Eastern Asia and the Caribbean, the only sub-regions experiencing a decline in prevalence. Central America is nearly on track to reach both the 2025 and the 2030 targets for exclusive breastfeeding, missing both targets by only one year if current trends continue. If the Eastern Africa, Central Asia and Southern Asia sub-regions maintain their current rates of progress, they will reach the targets set for both 2025 and 2030. The African and Asian regions present a sustained increasing trend in exclusive breastfeeding and are on track to achieve the target of at least 50 percent by 2025, but not the 2030 target of at least 70 percent (Table 4).

Adult obesity continues to rise, from 11.8 percent of the global population in 2012 to 13.1 percent in 2016. If this trend continues the target to halt the rise in adult obesity by 2025 (NCD-RisC, 2016) will not be met. If the prevalence continues to increase by 2.6 percent per year, adult obesity will increase 40 percent by 2025, compared to the 2012 level. All sub-regions show increasing trends in the prevalence of adult obesity between 2012 and 2016. Thus, they are all off track for the target of halting the rise in obesity by 2025. Northern America, Western Asia and Australia and New Zealand had the highest levels, 35.5 percent, 29.8 percent and 29.3 percent, respectively, in 2016. Latin America and the Caribbean as a whole and Oceania excluding Australia and New Zealand also had levels above 20 percent in 2016.

The projections for 2025 and 2030 described in this section do not take into consideration the likely impact of COVID-19 on the different forms of malnutrition. It is still too early to know the magnitude and duration of the pandemic and to predict its impact on the projected progress in reaching the global targets. Chapter 3 presents some of the ways COVID-19 might impact hunger and malnutrition.

2.4 Towards an Integrated Understanding of Food Security and Nutrition for Health and Well-being

This study's main focus is on how to end hunger, i.e. to reduce the prevalence of undernourishment, and therefore an integrated understanding of food and nutrition security is required. Poor access to food, and particularly nutritious food, contributes to undernutrition as well as overweight and obesity. It increases the risk of low birthweight, childhood stunting and anaemia in women of reproductive age. It is also linked to overweight in school-age girls and obesity among women, particularly in upper-middle- and high-income countries (FAO et al., 2018; Ishaq et al., 2018).

Food insecurity can both directly (through compromised diets) and indirectly (through the impact of stress on infant feeding) cause child wasting, stunting and micronutrient deficiencies. Although it may appear to be a paradox, food insecurity is often associated with overweight and obesity too. The higher cost of nutritious foods, the stress of living with food insecurity, and physiological adaptations to food restrictions help explain why food insecure families may have a higher risk of overweight and obesity. Poor access to food increases the risk of low birthweight and stunting in children, which are associated with a higher risk of overweight and obesity later in life (FAO et al., 2018).

Many countries have a high prevalence of more than one form of malnutrition. The multiple burden of malnutrition is more prevalent in low-, lower-middle- and middle-income countries and concentrated among the poor. Obesity in high-income countries is similarly concentrated among the poor. Access to safe, nutritious and sufficient food must be framed as a human right, with priority given to the most vulnerable. Policies must pay special attention to the food security and nutrition of children under five, school-age children, adolescent girls and women to halt the intergenerational cycle of malnutrition. The 1000 days between conception and a child's second birthday is a window of unsurpassed opportunity to both prevent child stunting and overweight and promote child nutrition, growth and development with lasting effects over the child's life.

The trends in food insecurity and malnutrition in all their forms pose a significant challenge to achieving SDG 2. It is imperative to continue addressing the urgent needs of those who are hungry, while at the same time going beyond hunger and ensuring access not only to sufficient food, but also to nutritious foods that constitute a healthy diet. Tackling hunger, food insecurity and all forms of malnutrition will require bold multisectoral action, involving the health, food, education, social protection, planning and economic policy sectors. Food environments must be transformed to make nutritious foods more available and affordable.

3 REVIEW OF OUTLOOKS TOWARDS 2030 AND IMPLICATIONS OF COVID-19

3.1 Review of Foresight Methods and Exercises to Achieving SDG 2 by 2030

After looking at the efforts and progress made towards achieving SDG 2, it is imperative to know if, continuing at the current pace and levels of commitment, the set goal and its targets will be achieved by 2030. In this regard, consideration of alternative future scenarios is crucial to understand how food and agricultural systems will evolve in an inherently uncertain future, including the current and ongoing consequences of COVID-19, and to identify policy options to deal with the challenges. While the previous chapter presented the prevalence of undernourishment and malnutrition projections for 2030 estimated using a simple version of Exponential Smoothing, the foresight exercises presented in this chapter provide alternative scenarios in which challenges are addressed to varying degrees, building on historical trends of factors that more broadly determine the performance of socio-economic and environmental systems. While scenarios are not a forecast or prediction of the future, they provide plausible means of assessing different possible futures with respect to political, economic, technological and other uncertainties.

This section reviews four major foresight exercises, "The Future of Food and Agriculture – Alternative Pathways to 2050" (FAO, 2018), "Agricultural Investments and Hunger in Africa Modeling Potential Contributions to SDG2 – Zero Hunger" (Mason-D'Croz et al., 2019), "Alternative Futures for Global Food and Agriculture" (OECD, 2016) and "An Outlook on Hunger" (IARAN, 2017), the results of which are presented in Table 5.

Most of the outlooks revealed by these foresight exercises suggest that demand for food will continue to grow driven by population growth and increased per capita incomes. With the growing demand, agricultural systems will struggle to cope with soil degradation, water shortages and climate change. All the studies agree that without a concerted effort to fight climate change with innovative energy policies and attention to land use change, and mitigate its negative consequences via increased spending and cooperation, the adverse effects of climate change and widening gaps of inequality will make it very hard to achieve the goal of zero hunger by 2030. The global hunger projection presented in section 2.1 is within the range of the estimates provided by scenarios discussed below.

3.1.1 The Future of Food and Agriculture – Alternative Pathways to 2050, by FAO

Relying as a reference framework on two recent foresight exercises aimed at informing global climate discussions, namely the Representative Concentration Pathways (van Vuuren et al., 2011) and the Shared Socioeconomic Pathways (O'Neill et al., 2017), the FAO (2018) designed a foresight exercise that specifically addresses global food and agriculture concerns. This exercise involves the selection of plausible scenarios of the future, and scrutinizes the selected scenarios against a range of uncertainties in a step-wise approach. Typically, these scenarios can be formed in a couple of ways, including the creation of different plausible narratives about current challenges using expert assessments on varying levels of the challenge; forming narratives by emphasizing and magnifying one or more "weak signals" of change noticed in the current situation; or simply by making plausible scenarios from historical trends.

Subsequently, and in cognizance of the fact that internal-consistency and interdependence among the different elements of a designed scenario are vital, the FAO established three scenarios postulating alternative futures in 2050 from the base year of 2012. The first, **Business As Usual (BAU) Scenario**, was designed to highlight how the world would be in 2050 if the outstanding challenges of food and agricultural systems remain unaddressed. The second, **Towards Sustainability Scenario (TSS)**, portrays how a timely implementation of proactive measures could help build sustainable food and agricultural systems. The third, **Stratified Societies Scenario (SSS)**, showcases a future with exacerbated levels of inequalities across countries and layers of societies (Table 5). These three scenarios use the same population estimate of 10 billion people in 2050 to present cross-scenario comparisons, showing the link between economic growth, equality, sustainability and the availability of natural resources.

Despite their specific peculiarities, each scenario serves to highlight the challenges that lie ahead for food systems and the poor. Two quantitative models – FAO Global Agriculture Perspectives System (GAPS) and Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) – were used to estimate the projections for these three scenarios. Generally, the three scenarios provide insights into the future of hunger, with the TSS scenario having the least PoU with fewer land requirements, reduced inequality and less global economic growth, and the SSS scenario having the largest PoU with high inequality despite its projected economic and agricultural output growth. This underscores the need for a more equitable distribution of income and access to basic needs in order to achieve the goals of the 2030 agenda. There are also tangible differences in scenario outcomes across regions and sub-regions, especially for countries in Sub-Saharan Africa.

3.1.2 Agricultural Investments and Hunger in Africa Modeling Potential Contributions to SDG2 – Zero Hunger, by IFPRI

The foresight exercise presented by Mason-D'Croz et al. (2019) uses IFPRI's IMPACT model, which has been extensively used to forecast global and regional agricultural production and demand, and food security. Relative to similar models, the IMPACT model is widely known for its representation of the global agricultural sector, including detailed geographical disaggregation and broad commodity coverage (Robinson et al., 2014), which makes it a good tool to analyse the potential of investing in agriculture across a range of commodities. At its core, the IMPACT system of models is a highly disaggregated, global partial-equilibrium multi-market model that simulates 62 agricultural commodity markets in 158 countries and regions. Furthermore, as a partial-equilibrium model, IMPACT endogenously models the feedback between the agricultural sector and the encompassing economy. For this reason, an interactive link to GLOBE, the global computable general-equilibrium model (Willenbockel et al., 2018), was incorporated into IMPACT to better assess the potential impact of investments in agriculture.

Using the IMPACT model, Mason-D'Croz et al. (2019) created three scenarios to explore the effects of further investments in agriculture on hunger and food security in Africa (Table 5). In the **No Climate Change (NoCC) scenario**, a baseline model of productivity is assumed, together with a constant 2005 climate. For the **Baseline Productivity (CC) scenario**, a baseline model of productivity is assumed with a strong impact of climate change. In the **Productivity Enhancement (COMP) scenario**, productivity gains as a result of comprehensive investments in agriculture and the rural sector were added to the CC scenario. This scenario is culled from similar studies (Rosegrant et al., 2017) evaluating the potential impact of various levels of investment by the CGIAR on agricultural development and sustainability.

The results from the IMPACT model under the three scenarios show that further investments in agriculture and the rural sector would help halve the number of people at risk of hunger, driving down the proportion from 12 percent in 2010 to about 5 percent in 2030. Finally, without the additional investments needed by 2030 in the COMP scenario, only 12 countries would be able to achieve a 5 percent target, while another five countries would reduce to below 10 percent the proportion of their population at risk of hunger.

3.1.3 Alternative Futures for Global Food and Agriculture, by OECD

To provide an outlook on the future of food and agriculture systems and identify robust policy options to the challenges that lie ahead, the OECD and ministries of non-member countries together developed three alternative views of the world for 2050. Each of these three alternative scenarios are loosely linked to one of the Shared Socioeconomic Pathways (O'Neill et al., 2017), while each of the storylines for climate change are directly linked to one of the Representative Concentration Pathways (van Vuuren et al., 2011). The **Individual, Fossil Fuel-Driven Growth (Individual scenario)** portrays a world of sovereignty and self-sufficiency ambitions with reduced global governance structures and less attention afforded to environmental and social issues beyond temporary responses to emerging problems (Table 5). The **Fast, Globally-Driven Growth (Fast scenario)** is driven by a revival of multilateralism, in which – despite international cooperation and a global commitment to increase carbon efficiencies – economic growth keeps on increasing GHG emissions. The **Citizen-Driven, Sustainable Growth (Sustainable scenario)** embodies a world in which individual countries fight to advance sustainable economic development, mainly due to the changing attitudes of citizens towards more cohesive societies and changing consumer preferences in favour of food from environmentally friendly food production systems.

To quantify the key aspects of these three scenarios and their implications, and to simulate some of the policy options to address the challenges in the food and agriculture sector, four global economic models were used: two computable general-equilibrium (CGE) models, namely ENVISAGE (van der Mensbrugghe, 2017) and MAGNET (Woltjer & Kuiper, 2014), and two partial-equilibrium

Table 5: Overview of selected foresight methods and exercises

Models and institutions	Methodology	Scenarios, assumptions and results		
GAPS and ENVISAGE models (FAO)	Partial-equilibrium model and General-equilibrium models	**Business As Usual Scenario (BAU)** **Assumptions:** Moderate economic growth; modest convergence in income equality and public investment; more bilateral trade agreements; modest tariff barriers; non-tariff barriers gain some importance; improved water efficiency without major technical change; more water stressed countries emerge; deforestation continues at current rates; moderate convergence towards the consumption of more nutritious food. **Results:** 7 percent of the world's population will still be undernourished in 2030; moderate to high challenges to food availability/stability and access/utilization.	**Towards Sustainability Scenario (TSS)** **Assumptions:** Moderate, but more equitable economic growth; SDG 10 (reduce inequality within and among countries) targets achieved; public investment in R&D; both tariff and non-tariff barriers are lower than in BAU; efficient water use; limited climate change reduces extreme droughts; no additional deforestation; reduced loss of biodiversity; higher foreign investment in low income countries than in BAU; global adoption of balanced, healthy and environmentally sustainable diets. **Results**: 3 percent of the world's population will still be undernourished in 2030; low challenges both for equity and sustainable production occur.	**Stratified Societies Scenario (SSS)** **Assumptions**: High economic growth with high income inequality; SDG 10 targets not achieved; limited public investment; unsustainable practices in energy use persists; both tariff and non-tariff barriers are higher than in BAU; more fragmented international trade; little investment in water efficiency; climate change exacerbates constraints; further deforestation; continued loss of biodiversity; higher foreign investment than BAU with little impact on low income countries; worse diets for most people due to lower purchasing power and consumer awareness, with elites consuming the high quality products. **Results:** 12 percent of the world's population will still be undernourished in 2030; high challenges to food availability/stability and access/utilization**.**
IMPACT (IFPRI)	Partial-equilibrium model linked to biophysical models and CGE model	**No Climate Change (NoCC)** **Assumptions:** No additional climate change; ''middle of the road" scenario (SSP2); current productivity level maintained; 7 percent reduction in yields due to changes in temperature and precipitation; varying population and economic growth for the regions. **Results:** About 12 percent of the world's population undernourished in 2030; average incomes increase by almost 78 percent globally and 131 percent in developing countries between 2010 and 2030; agricultural productivity increases by about 32 percent in the developing world between 2010 and 2030.	**Baseline Productivity (CC)** **Assumptions:** Adds strong climate change impacts to NoCC; + 8.5 W/m2 (representative concentration pathway) and increasing CO_2 concentration (1250 ppm by 2100); current baseline model productivity assumptions. **Results:** Increase in number of hungry by 16 million more people in 2030; average incomes increase by almost 76 percent globally and 130 percent in developing countries between 2010 and 2030; 4 percentage points reduction in agricultural productivity.	**Productivity Enhancement (COMP)** **Assumptions:** Productivity enhancement scenario under climate change; comprehensive investment scenario for agriculture and the rural sector; combined investments in agricultural R&D, resource management, and infrastructure in developing countries. **Results:** 5 percent of the world's population undernourished in 2030, while 10 percent remain undernourished in Africa; increases in average kilocalorie availability from 2700 to 3000 kcal per person per day between 2010 and 2030 for developing countries; average incomes increase by 80 percent globally and 140 percent in developing countries between 2010 and 2030; 40 percent increase in agricultural productivity between 2010 and 2030, 12 and 8 percentage points above the CC and NoCC scenarios; increasing incomes and lower food prices help to drive down food insecurity.

ENVISAGE, GLOBIOM, IMPACT, and MAGNET Models (OECD)	Computable General-equilibrium (CGE) and partial-equilibrium (PE) models	**Individual, Fossil Fuel-Driven Growth** **Assumptions:** Sovereignty and self-sufficiency focused; economic growth of individual regions with rising inequality; high agricultural productivity; significant investments in agricultural R&D and intensive farm input use; unsustainable consumption patterns; significant biodiversity losses and significant rise of GHG emissions; fragmented energy market segregated across fossil sources and for gas across regions. **Results**: About 15 percent reduction in the absolute number of malnourished children globally by 2030, but an increase in Sub-Saharan Africa until 2030 followed by a slight decline towards 2050; much lower per capita food availability growth regionally and globally compared to the other two scenarios.	**Fast, Globally-Driven Growth** **Assumptions:** Economic growth-focused; growth driven by a revival of multilateralism; increasing GHG emissions and climate despite a global commitment to increase carbon efficiencies; growing income and wealth inequality; unsustainable consumption growth that leads to water scarcity and land loss. **Results**: About 36 percent reduction in the absolute number of malnourished children globally by 2030; highest per capita food availability gains with the global average reaching 3000 kcal per day by 2030.	**Citizen-Driven, Sustainable Growth** **Assumptions:** Sustainable development of economies driven by changing attitudes of consumers and citizens in favour of sustainable consumption and development; development of technologies that are natural resource saving and preserve the environment; slow climate change with a substantial reduction of GHG emissions; higher agricultural productivity with reduced input use; similar assumptions with SSP1 and RCP2.6 (representative concentration pathway) on world population, urbanization, temperature increases, and effective energy consumption. **Results**: About 44 percent reduction in the absolute number of malnourished children globally by 2030; per capita food availability grows almost at a similar rate to the Fast scenario particularly in developing countries.		
MICMAC and Linear Regression (IARAN)	MICMAC and linear regression analysis	**Strong and Equitable Growth** Assumptions: Reduction in conflict; rapid increase in women's empowerment; strong action on climate change; better food policies in MDC & LDCs; high energy diversification; higher consumers purchasing power; declining commodity prices; fair trade replaces free trade and no financial crisis. **Results:** Closer to achieving the SDG 2 target, but not met due to growing populations, economic inequality, social exclusion, climate change and natural disasters.	**Rise of the Rest** Assumptions: Rapid reduction in conflict; culture clash concerning women's empowerment; limited action on climate change, and some level of energy diversification; grassroots movements in LDCs shaping food policy; increase in rural dwellers' purchasing power; decline in food prices, no financial crisis and protectionism lead to LDC growth. **Results:** Closer to achieving the SDG 2 target, but not met due to growing populations, economic inequality, social exclusion, climate change and natural disasters.	**Slow and Fragile Growth** Assumptions: No change in conflict; gradual rise in women's empowerment; limited action on climate change; more dependence on fossil fuels for energy; weaker food policies in LDCs than in MDCs; regional financial crises in southeast Asia, rising food prices and reduction of purchasing power of rural dwellers; free trade is still common. **Results**: Small progress with over 650 million people remaining undernourished by 2030.	**Deepening Divide** Assumptions: Rising global conflict; no change in women's empowerment; weak climate change adaptation in LDCs; energy use shifts to biofuels; regional financial crises in southeast Asia; rising food prices; high inequality in cities; protectionism in MDCs and none in LDCs. **Results**: SDG 2 target not met.	**System Shock** Assumptions: Rising global conflict; reduction in women's empowerment; no meaningful action on climate change; energy dependence on fossil fuels; very weak food policies in LDCs and strong policies in MDCs; decline in consumers' purchasing power; higher food prices, trade wars due to protectionism and global financial crisis. **Results**: SDG 2 target not met.

Source: Authors' own construction based on cited papers.

(PE) models, namely GLOBIOM (Havlík et al., 2014) and IMPACT (Rosegrant & IMPACT Development Team, 2012).

The projected results under the three scenarios varies substantially. The projected gain in per capita food availability is highest under the Fast scenario due to strong income growth and significant agricultural productivity growth. On the contrary, under the Individual scenario the growth in per capita food availability significantly slows down. The per capita food availability estimated for the Sustainable scenario falls in between the Fast and Individual scenarios. However, under this scenario total food availability increases and average dietary composition in developing counties improves to levels similar to those in the Fast growth scenario. The prevalence of malnutrition also declines as a consequence of higher food availability although unequal distribution within the population is masked by regional totals. According to the IMPACT estimates, the number of malnourished children in Sub-Saharan Africa could increase up to 2030 under the Individual scenario. However, the number of malnourished children will decrease globally by 15 percent, 36 percent and 44 percent under the Individual, Fast and Sustainable scenarios respectively, indicating that progress is possible while the context matters significantly. Income growth, which is embedded in all of the scenarios, is the main driver of the reduction in malnourishment.

3.1.4 An Outlook on Hunger: A Scenario Analysis on the Drivers of Hunger Through 2030, by IARAN

To assess the drivers of global hunger, and to develop scenarios of global hunger in 2030, IARAN (2017) used Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) and linear regression analyses. The drivers – obtained using the Impact Uncertainty Matrix technique as reported in the report – include conflict, food policy, women's empowerment, energy policy, financial crisis, commodity prices and trade. These drivers are critical uncertainties in the global hunger conundrum making it important to understand the structure of their system of interactions and to identify the key influences at their core.

Based on the interaction and influence of the critical uncertainty drivers, five scenarios were developed to represent a range of plausible courses for the future. The scenarios – **Strong and Equitable Growth, Rise of the Rest, Slow and Fragile Growth**, **Deepening Divide,** and **System Shock** – are intended to present insights into the future of hunger, with each scenario presenting a particular and different outlook of the future (Table 5). None of the scenarios predict the attainment of the Sustainable Development Goal no. 2 of ending hunger by 2030. Scenario 3, the 'business as usual' case, shows that only small progress can be made, in tandem with the FAO's projection that about 650 million people will likely be undernourished by 2030. Scenarios 1 and 2 (optimistic) project a positive outlook, with the world getting close to achieving the SDG 2 target. However, results from the IARAN study show that heavy trends such as growing populations, natural disasters, social exclusion, and economic inequality would prevent the target from being reached in the expected time-frame. Hence, a focused and committed effort to long-term approaches and the targeting of the key drivers of hunger will be necessary to achieve the goal of ending hunger.[13]

3.2 How the COVID-19 Pandemic May Affect Hunger and Malnutrition in the World

3.2.1 Potential Impact of the COVID-19 Pandemic on Hunger

The COVID-19 pandemic is spreading across the world, posing a serious threat to food security. Unless immediate actions are taken, there is little doubt that the pandemic will expose more people to food insecurity and accelerate the projected increase in the number of hungry people. Both the scope and severity of the COVID-19 pandemic are as yet unknown, so the projections provided here must be seen as preliminary (FAO et al., 2020).

There are multiple ways in which the pandemic may affect food systems and food security (Schmidhuber, Pound, & Qiao, 2020; Torero, 2020; Savastano, 2020). The COVID-19 pandemic is already delivering shocks to the supply side and demand side of food systems throughout the world. On the supply side, COVID-19 itself may not necessarily create food shortages, as the production of the major food crops (wheat, rice, maize and soybean) is expected to remain above average in 2020 (AMIS, 2020). But the pandemic has already created disruptions along the food supply chain.[14] COVID-19 containment measures are limiting labour mobility in areas dependent on seasonal or migrant labour, making it difficult to access markets and transport food both within and across countries. Further interruptions of logistics could disrupt new planting seasons too (FAO et al., 2020).

13 The scenario analysis did not estimate the number people at risk of hunger by 2030.

14 **PARI Policy Brief No. 26**: Emerging Impacts of COVID–19 on the Kenyan Food and Beverage Manufacturing Sector
PARI Policy Brief No. 25: Emerging Impacts of COVID–19 on the Nigerian Food and Beverage Manufacturing Sector
PARI Policy Brief No. 24: Emerging Impacts of COVID–19 on the South African Food and Beverage Manufacturing Sector. https://research4agrinnovation.org/pari-policy-briefs/

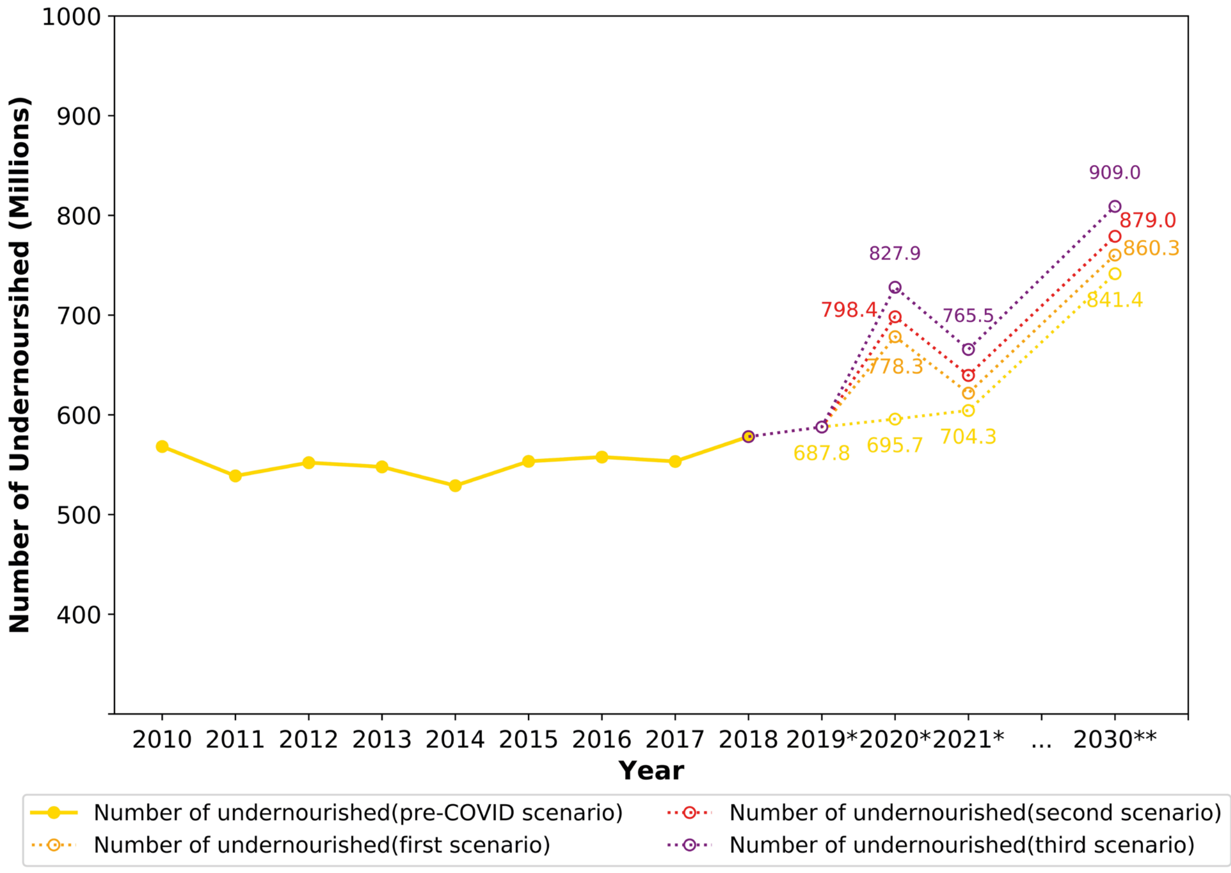
On the demand side, lockdowns across the world are expected to hamper people's ability to access food and create serious economic downturns. This will make it difficult for many people, particularly the poor and vulnerable, to afford food. Low- and middle-income countries will likely be the most affected, as they do not have the contingency mechanisms and funds to stimulate their economies and protect the most vulnerable. As a consequence, a pandemic-induced global economic crisis is likely to generate new pockets of food insecurity even in countries that previously did not require interventions (FAO et al., 2020).

Estimating COVID-19's effect on food security comes with a high degree of uncertainty due to a lack of data and clarity about what the future of the world economy will look like. Potential scenarios take different shapes, depending on the kind of policies that will be put in place and the time they will take to show their impact. At the time of writing, a so-called "U-shaped" recovery appeared to be more likely, which could mean a recession in 2020 followed by a recovery starting in 2021, but whose length is uncertain. Such a recovery is conditional on second waves of infections not materializing or being easily contained. Although it is still too early to quantify the full impact of the pandemic, this section presents the results of a quantitative analysis of the potential consequences in terms of the PoU, as driven by the global economic prospects. The analysis aims to show how the scenario described in Figure 2 might change once some of the potential effects of COVID-19 are factored in (FAO et al., 2020).

COVID-19 is triggering shocks on both the supply and demand side of the global economy, therefore the simplest way to gauge its potential effect on the PoU is through its impact on world economic growth. This is done by combining data from the International Monetary Fund's World Economic Outlook (WEO) released in April and updated in June 2020 (IMF, 2020), with a statistical analysis of the relationship between economic growth and food availability. It follows the methodology and country samples of an earlier exercise conducted by FAO using previously available data (FAO, 2020b; Conti, Cafiero, & Sánchez, 2020; FAO et al., 2020).

Based on time series of total food supplies and GDP growth over 1995–2017 for most countries in the world, the statistical analysis shows that GDP growth reduction significantly affects the net food supply in net food-importing countries, and especially in low-income food-deficit countries (LIFDCs). On average, 1 percentage point of GDP growth reduction is estimated to reduce the food supply by 0.06 percent in net food-importing countries

Figure 2: How the COVID-19 pandemic may affect hunger in the world: three scenarios, 2010-2030



Notes: The dotted lines represent the projections for the longer period from 2019 to the 2030 target year.

Source: FAO et al. (2020).

that are not low-income, and by 0.306 percent in LIFDCs (FAO et al., 2020).

The IMF's WEO forecasts a contraction of 4.9 percent in world GDP in 2020, followed by a recovery of 5.4 percent in 2021. It provides country-specific estimates of GDP change in 2020 and 2021. The aforementioned elasticities estimated by FAO were applied using the GDP growth forecasts for 2020 and 2021 to all net food-importing countries (distinguishing between LIFDCs and non-LIFDCs) in order to estimate the likely shift in the series of total Dietary Energy Supply. This is used to compute the PoU under three scenarios, illustrated by three different lines in Figure 2 below, which contrast with the projection of a world without COVID-19 (the yellow line) (FAO et al., 2020).

The first scenario (orange line) builds on the WEO, which forecasts world economic growth of -4.9 percent in 2020 and +5.4 percent in 2021. These figures closely approximate an earlier forecast by IFPRI (Laborde, Martin, & Vos, 2020). This scenario would imply an increase of about 83 million undernourished in 2020 (from 695.7 to 778.3 million) attributable to the COVID-19 pandemic (FAO et al., 2020).

The second, less optimistic scenario (red line) foresees 2.1 percentage points lower GDP growth both in 2020 and 2021 compared with the baseline scenario, i.e. average world economic growth of -7 percent in 2020 and +3.3 percent in 2021. In such a scenario, the increase in the number of undernourished in 2020 would be approximately 103 million (from 695.7 to 798.4 million) (FAO et al., 2020).

The third, more pessimistic scenario (purple line) implies a reduction of 5.1 percentage points in the GDP growth rates compared to the first scenario, thus assuming a world economic growth of -10 percent in 2020 and +0.3 percent in 2021. This scenario would bring the number of undernourished up to almost 828 million in 2020, of which more than 132 million would be attributable to the impact of COVID-19. The expected recovery in 2021 would bring the number of undernourished down to 766 million, which is 62 million more than the already worrisome projection in the absence of the pandemic (indicated by the yellow line). In all the above cases, the world economy would not fully recover in 2021 (FAO et al., 2020).

The analysis is limited to the potential impact of the pandemic on net food supplies, as the pre-COVID-19 projections for population size and composition and for food consumption inequality are kept the same. The analysis does not, therefore, capture the full impact of the economic recession and may underestimate the total potential impact of COVID-19 on food insecurity should the simulated economic growth scenarios materialize. It is also important to highlight that the analysis assumes that recovery, as presented in the IMF's WEO, will take place in two years. Considering the high degree of uncertainty about the duration of the recovery, this represents an important limitation of this assessment (FAO et al., 2020).

While it cannot be considered precise or detailed, the analysis demonstrates that if no action is taken to prevent foreseeable disruptions in world food systems, especially in food-deficit countries, COVID-19 will further complicate the already daunting challenge of reaching SDG target 2.1 of Zero Hunger (FAO et al., 2020).

3.2.2 Potential Impact of the COVID-19 Pandemic on Malnutrition

It is too early to provide evidence on the impact of COVID-19 on the nutritional status of populations. However, the pandemic is expected to increase levels of all forms of malnutrition in vulnerable households. This may occur due to:

- An increase in food insecurity due to, for example, disruptions along food supply chains that complicate the transportation of food to markets, restrictions of movement that impact consumers' access to markets, price increases especially in import-dependent countries, loss of jobs and incomes resulting from the economic recession, and interruption or lack of social protection mechanisms. Higher food prices, especially for nutritious foods, and reduced affordability of healthy diets can all negatively affect nutrient intake and diet quality, and consequently increase the risk of malnutrition (FAO et al., 2020).
- The overwhelming of health systems' capacities to deliver curative and preventive services, including child care and antenatal care, due to factors such as cessation of services, health worker illness and fatigue, scarcity of essential medicines, and diminished access to health services, including the loss of health insurance coverage as well as precautionary behaviour of families (WHO, 2020). In children, this can hamper the management of wasting, which affects their nutritional status and health, leading to higher risk of mortality (Roberton et al., 2020). At the same time many people living with non-communicable diseases (NCDs) may no longer be able to access the medicines that they need (FAO et al., 2020).
- A possible increase in infant and young child morbidity due to diminished healthcare resources to

prevent and treat malaria, diarrhoea and other infectious diseases (Roberton et al., 2020) and increased malnutrition (FAO et al., 2020).

- The discontinuation or suspension of community-level activities including community worker visits to households to provide counselling and deliver interventions, as well as cancellation of vitamin A and vaccination campaigns and growth monitoring and promotion events (FAO et al., 2020).
- School closures leading to missed meals and nutrition education normally provided through school food and nutrition programmes (WFP, 2020; FAO et al., 2020).
- Deterioration of childcare practices. This could happen because of separation of mothers and caregivers from children due to quarantine, self-isolation, illness or death. Diminished or suspended breastfeeding promotion and nutrition counselling activities, together with mothers' fears around COVID-19 infection may result in increased utilization of breastmilk substitutes. It could also spur opportunistic marketing, making the adoption and enforcement of the International Code of Marketing of Breast-Milk Substitutes even more important (UNICEF, 2020b; FAO et al., 2020).
- Altered purchasing patterns favouring products with longer shelf life and often poorer nutrition profiles (IFIC, 2020), which could lead to higher levels of undernutrition, as well as overweight and obesity (UNSCN, 2020; Haddad et al., 2020; FAO et al., 2020).
- Fragility of, or failure to scale up health, food and social protection programmes (FAO et al., 2020). Social safety nets and efforts to provide accurate information on virus transmission are key to mitigating potential negative effects of COVID-19.

The Standing Together for Nutrition consortium, a multidisciplinary consortium of nutrition, economics, food, and health systems researchers, recently estimated the impact of COVID-19 on child malnutrition and nutrition-related mortality. To do so they linked three approaches to modelling combined economic and health systems impacts: MIRAGRODEP's macroeconomic projections of impacts on per capita gross national income (GNI); microeconomic estimates of how predicted GNI shocks impact child wasting using DHS data on 1.26 million children from 52 LMICs for the period 1990 to 2018; and the Lives Saved Tool (LiST) which predicts the impact of country-specific health system disruptions on child wasting and child mortality (Headey et al., 2020). Their estimates suggest an average 7.9 percent decline in GNI per capita projections in LMICs. Applied to 118 LMICs, this could increase the prevalence of moderate and severe wasting by about 14.3 percent among children younger than five years of age. This translates to an additional estimated 6.7 million children with wasting in 2020 as compared to pre-COVID-19 projections. An estimated 57.6 percent of these children are in South Asia and 21.8 percent in Sub-Saharan Africa. Estimates show that the combined effect of the increase in wasting and a 25 percent reduction in the coverage of nutrition and health services, cause an additional 128,605 deaths in children younger than five years in 2020, with an estimated 52 percent of these deaths in Sub-Saharan Africa. While these projections are an early estimate and may not fully capture the impact of COVID-19 on child nutritional status, they emphasize the urgent need for actions to protect and improve child nutrition (Headey et al., 2020).

4 THE CHANGING FINANCIAL COMMITMENTS OF G7 COUNTRIES TO FOOD AND NUTRITION SECURITY AND RURAL DEVELOPMENT

This chapter presents an assessment of development assistance and in particular the G7's Elmau commitment to increase bilateral and multilateral assistance to achieve SDG 2. The Organization for Economic Cooperation and Development's (OECD) database on Official Development Assistance (ODA) for the period 2000 to 2019[15] is used, with ODA disaggregated by recipient countries and by sectoral distribution over time,[16] with special emphasis on food and agriculture related ODA.

4.1 Global Flow of Development Assistance and the Contribution of G7 Countries

The volume of global development assistance has been on the rise since 2000, putting the total volume contributed by members of the OECD Development Assistance Committee (DAC) between 2000 and 2019 at US$ 2.39 trillion. In 2019 alone, ODA from DAC member countries was US$ 150.2 billion, which is an increase of about 8.5 percent from 2015 and about 98.2 percent from 2000 (Figure 3). While it has doubled since 2000, the growth in ODA since 2010 has mainly been due to humanitarian aid and in-donor refugee costs, increasing from about 3 percent in 2010 to about 11 percent in 2017. In 2019, net ODA was up in 18 DAC member countries and down in another 11 countries.

The G7 countries contribute 75 percent of the total global ODA, and their contribution has risen from US$ 51.6 billion in 2000 to US$ 111 billion in 2019. However, only three countries in the G7 have significantly increased their ODA allocation since 2000 – the United States, Germany and the United Kingdom, by 137 percent, 203 percent and 251 percent respectively. Focusing on the period after the G7's Elmau commitment in 2015, with the exception of France, Germany and the United Kingdom, ODA from G7 countries has not significantly increased.

15 The ODA figures reported for 2019 are based on preliminary data released in April 2020.

16 The assessment of the sectoral allocation of ODA is based on ODA data for the period between 2000 and 2018, as the latest available sectoral distribution of ODA is available only up until 2018.

Figure 4 shows the sectoral allocation of ODA from the G7 countries in 2019. Government and civil society sector received the highest allocation of US$ 11.4 billion, followed by the transport and storage sector with US$ 10.4 billion. We emphasize that a narrow definition of aid allocations by sector is not very meaningful as there are cross-cutting effects.

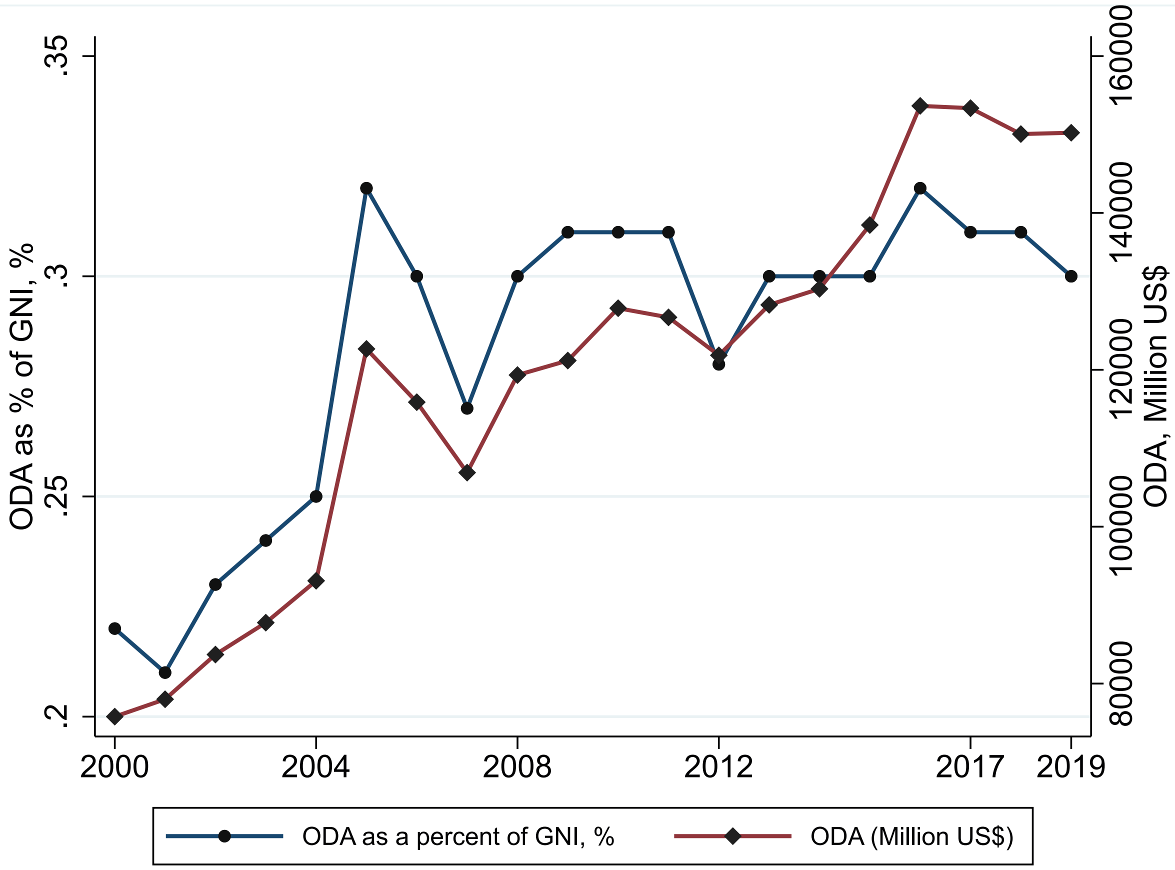
4.2 Allocation of ODA to Food Security, Nutrition and Rural Development by G7 Countries

It is difficult to directly connect ODA allocations to food and nutrition security initiatives and agriculture. Development cooperation projects always have wider effects beyond those related to their core and singular objectives, although such projects can rarely include in their budget the resources and activities for purposes other their core objectives. For instance, development projects such as road and bridge construction, electrification, water supply and sanitation, health and education, all indirectly and positively impact food security and small-farm agriculture.

This study employs a definition for food security, nutrition and rural development ODA developed by Schwegmann and Wedemark (2014). The OECD purpose codes are used to identify the amount of ODA allocated to food security, nutrition and rural development and for measuring the donor countries' spending in an internationally comparable way. We identify the following categories, with minor adaptation, as pertinent for estimating ODA contributions to food security and rural development.

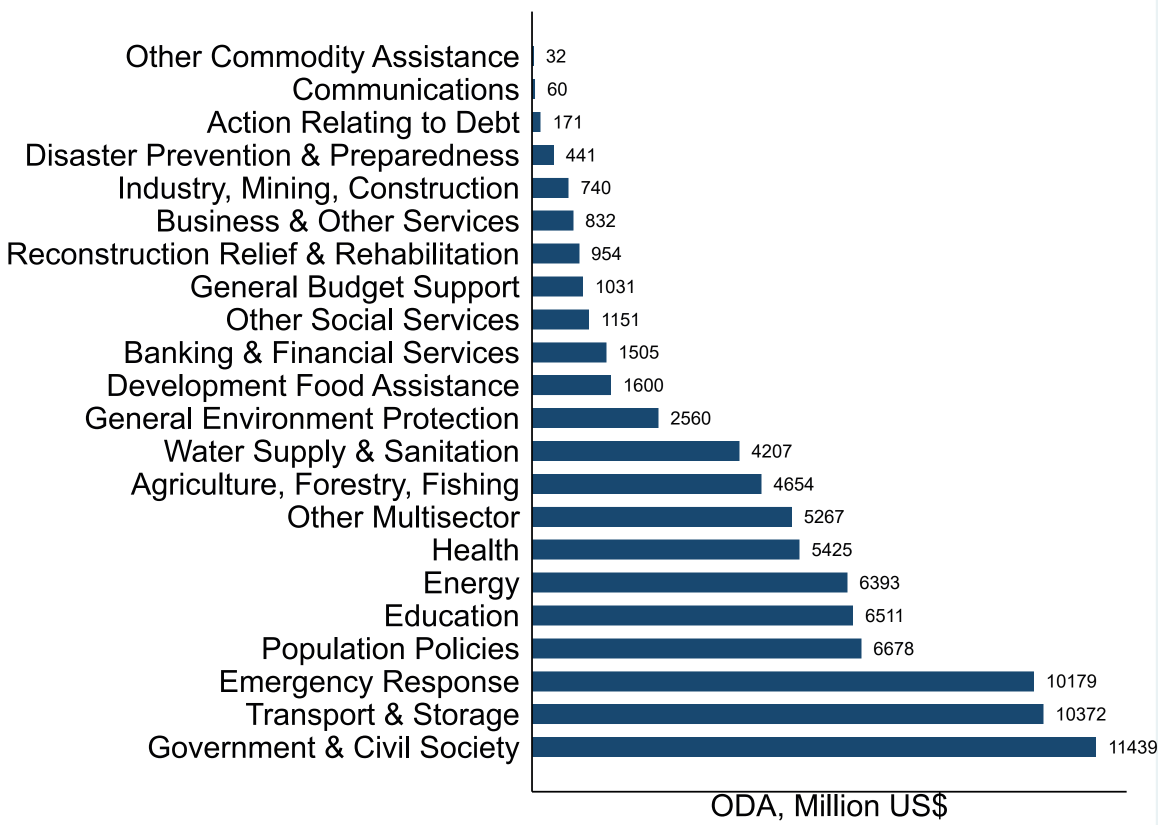
1. Agricultural – OECD sector code 311
2. (Industrial Crops / Export Crops – OECD sector code 31162) – included in Agriculture
3. Fishing – OECD sector code 313
4. Forestry – OECD sector code 312
5. Food Aid (Food Assistance and Emergency Food Assistance) – OECD purpose codes 52010 and 72040

Figure 3: Net ODA and ODA as percent of GNI of DAC countries, 2000-2019 (millions of US$)



Source: Authors' own elaboration based on OECD (2019)

Figure 4: Sectoral allocation of total G7 ODA, 2018 (millions of US$)



Source: Authors' own elaboration based on OECD (2019)

6. Environmental Protection (including Removal of Land Mines and Explosive Remnants of War) – OECD sector code 410 and purpose code 15250
7. Rural Development – OECD purpose code 43040
8. Water Supply and Sanitation – OECD purpose code 140

This study adds the water and sanitation project categories to food security and rural development ODA due to the growing body of evidence that indicates the important positive impact that access to safe drinking-water, sanitation, and hygiene services have on nutrition. Observational studies, conducted in low income settings, have shown that increasing access to and use of improved sanitation and water sources reduce the risk of stunting (WHO, UNICEF, & USAID, 2015).

Going by the above categorization and the consequent sector-wise allocation of ODA, Figure 5 highlights the absolute value of ODA allocations by G7 countries, between 2000 and 2018, to food security and rural development. The total ODA commitments from G7 countries going to food security and rural development in 2018, at US$ 17 billion, is 109 percent higher than the US$ 8.1 billion allocated to the same in 2000. Over the 18-year period, the total ODA allocated to food security and rural development amounted to US$ 247.7 billion, comprising 14.6 percent of the entire ODA from G7 countries.

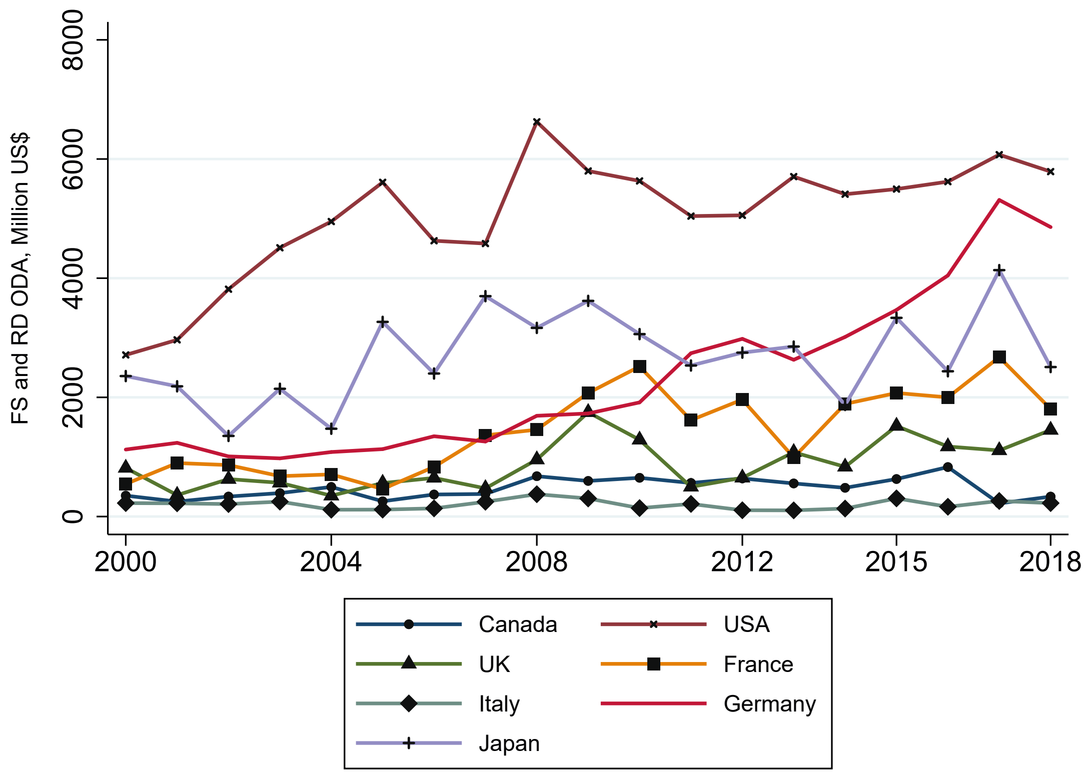
Breaking down the 2018 ODA allocation for food security and rural development into the eight sub-categories as listed above, Figure 6 reveals the categorical allotment of each G7 member country in real terms.

4.3 G7 Commitments and Actions

At the G7's 2009 meeting in L'Aquila, Italy, member countries had committed to focus specifically on food security, forming the L'Aquila Food Security Initiative (AFSI). This new commitment was to include some qualitative aspects and the mobilization of over US$ 22.24 billion by 2012. As reported by the AFSI Pledge Tracking Table, AFSI donors collectively honoured their commitments, in aggregate fulfilling 106 percent of the total pledges. While actual disbursement was slow for some of the G7 member countries, their commitments to enhance spending on food security and ending hunger were broadly fulfilled (US Department of State, 2012). Subsequent G7 meetings were avenues for reaffirming the commitments of member countries to support and focus development cooperation towards agricultural development and food security.

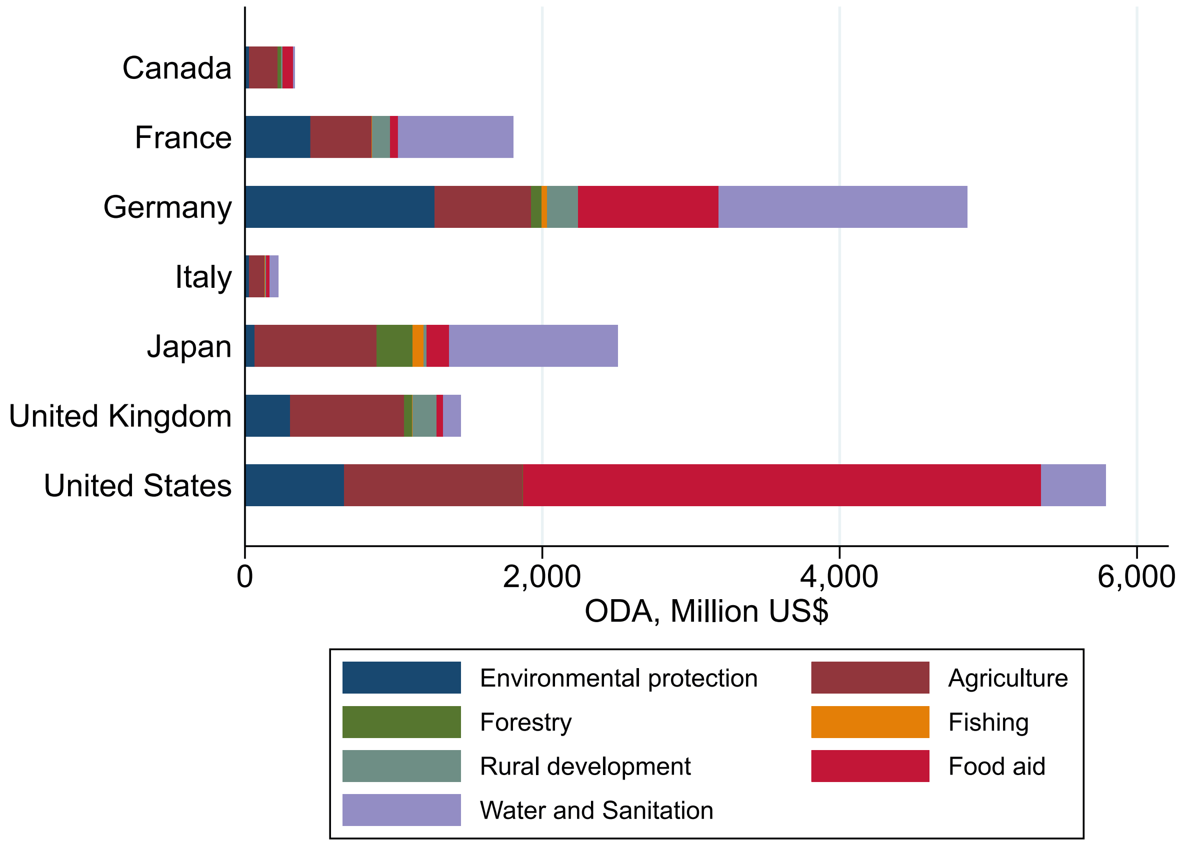
The **G7 commitment made at Schloss Elmau in 2015** was novel because it was a commitment to people – the promise to lift 500 million people in developing countries out of hunger and malnutrition by 2030 – regardless of financial needs. The mobilization of resources to increase ODA to agriculture, rural development, and food security and nutrition, was one of several specific targets (Leaders' Declaration, 2015).

Figure 5: Trend of food security (FS) and rural development (RD) ODA by G7 countries, 2000-2018 (millions of US$)



Source: Authors' own elaboration based on OECD (2019)

Figure 6: Sub-sectoral allocation of G7 food security and rural development ODA, 2018 (millions of US$)



Source: Authors' own elaboration based on OECD (2019)

Since the 2015 Elmau commitment, Germany has substantially increased ODA investments and projects focused on agriculture and food security, especially in the framework of the initiative of "One World No Hunger" of BMZ. With the exception of Germany and more recently Japan, however, G7 countries have not significantly increased the ODA allocated to agriculture, rural development, food security and nutrition, and have therefore fell short on their commitments.

4.4 The Relevance of ODA for Reducing Hunger and Malnutrition

Public and private investment are pivotal to the fight against poverty and hunger. Agricultural investments provide interrelated societal benefits in the form of economic growth, increased agricultural productivity, and environmental sustainability. Infrastructural investments reduce transaction costs and connect smallholders to local and global markets (FAO, 2012). Public spending and social protection expenditures also indirectly contribute to improved food security by raising rural and urban incomes, and thus, purchasing power, which improves access to more nutritious diets and food utilization. Poverty reduction and a growing economy also have the potential to create multiplier effects on sustained growth in incomes and food security.

The literature on the effectiveness of official development assistance (ODA) is vast and controversial. The majority of quantitative analytical studies suggest that aid has a positive effect on economic growth through its positive effects on investments in physical capital (see Hansen and Tarp, 2000; Dalgaard, Hansen, & Tarp, 2004). Studies looking at the long-term effects of aid on growth (Arndt et al., 2015) find that aid impacts growth only in the very long-term (i.e. 40 years) but not over shorter periods (Arndt et al., 2010). The main impact pathways are through positive effects of aid on investment, public spending (consumption and investment), as well as education. Yet, there is also criticism of ODA. Aid can distort relative prices and set wrong incentives (Easterly et al., 2003), and can further increase developing countries' dependence on Western donor countries, foster autocratic regimes, and promote corruption (Moyo, 2009). Easterly et al. (2003) and Rajan and Subramanian (2008) find no significant effect of aid on economic growth.

Taking a closer look at the nature of growth, it becomes apparent that certain sectors are key to improving food and nutrition security. About three-quarters of the economically active rural population in most low-income countries are engaged in agriculture (Lowder et al., 2014). Given these numbers, agricultural growth is more likely to be pro-poor and two to three times more effective than overall growth in reducing poverty in low-income countries (Christiaensen, Demery, & Kuhl, 2010). Agricultural growth is directly linked to food and nutrition security because it increases food supply and generates income for the poor. An increase in domestic food production contributes to higher per capita caloric intake and lower poverty levels (Majid, 2004; Kaya et al., 2013). In this context, agricultural policies that support agricultural productivity gains and profitability play a crucial role in pro-poor growth and the reduction of hunger (Webb & Block, 2012; Mangrini et al., 2017; Mary et al., 2019; Adjaye-Gbewonyo et al., 2019).

Aid attributed specifically to the agricultural sector could have a stronger and more immediate impact than overall ODA (Kaya et al., 2013).[17] Ssozi et al. (2019) find that higher aid per agricultural worker is associated with increased output per worker in industrial food production but also a decreased output in crop production;

Recent empirical studies looking at the relationship between nutrition-sensitive aid and PoU (Mary et al., 2018) as well as child stunting (Mary et al., 2020) suggest that agricultural aid improves food and nutrition security. Mary et al. (2018) estimate that a 10 percent increase in overall nutrition-sensitive aid decreased PoU by 1.1 percent after two years during the period between 2002 and 2015. Similarly, a 10 percent increase in agricultural aid per capita reduced child stunting by 0.5 percent (Mary et al., 2020).[18]

4.5 Testing the Association Between ODA and Food and Nutrition Security

When attempting to identify a relationship between ODA and food and nutrition security, different econometric approaches should be pursued. As countries with a high prevalence of poverty and hunger would attract more aid because of their low level of development (Addison et al., 2017), the simultaneity between ODA and food security needs to be addressed, preferably by a sound instrumental variable approach.

After 2000, during the period of a significant reduction in global hunger, ODA flows steadily increased. Flows to Asia and Africa quadrupled, while aid flows to Latin America doubled over the past 15 years (Figure 7). For individual countries, the picture might be quite different, since ODA is also used as a political instrument.

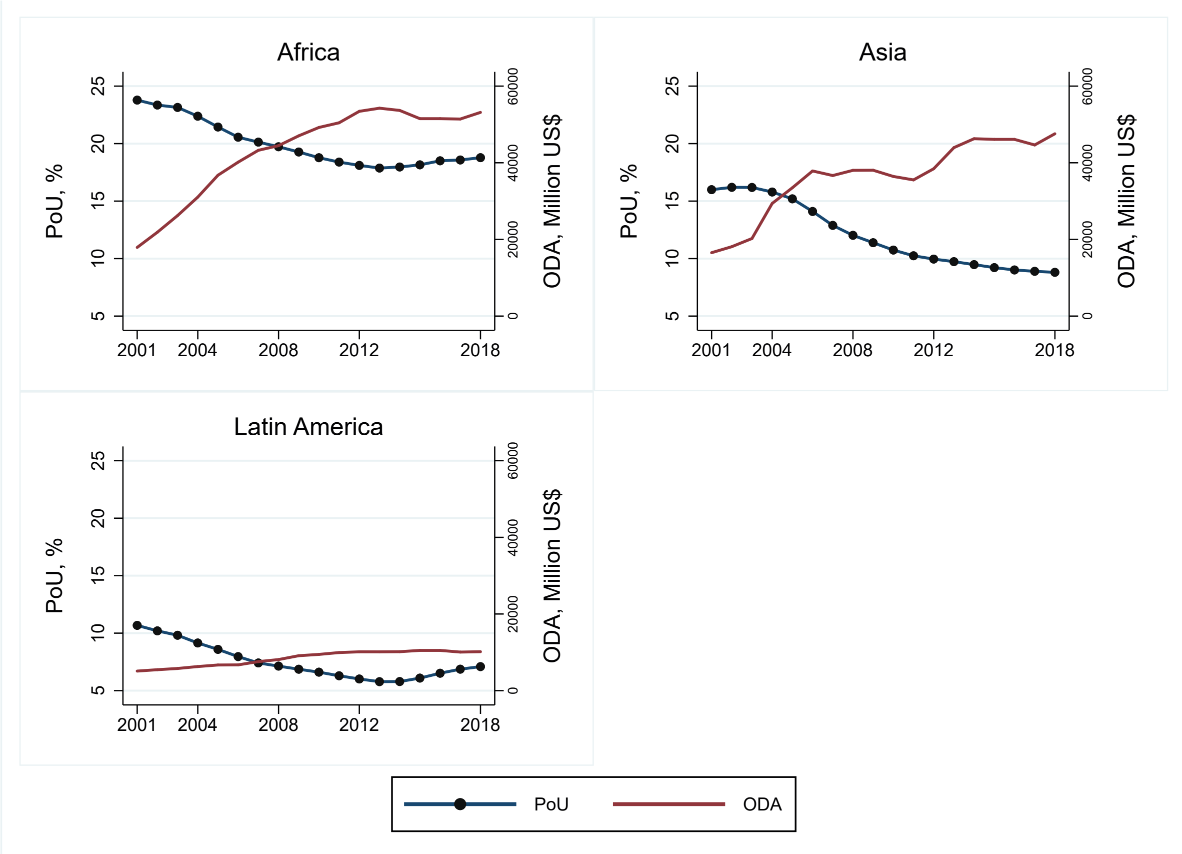
Like agricultural R&D spending and foreign direct investment (FDI), ODA is likely to have a cumulative and longer-term effect on food insecurity. Many examples could be given to illustrate this argument, one of them being investment in education which generates returns only after the entry of beneficiaries to the labour market. Focusing on the immediate short-term impacts of aid would neglect the impact it has on all the sectors that affect food insecurity in the medium or long-term (Arndt et al., 2015). It is therefore difficult to associate yearly ODA flows to year-to-year changes in undernourishment and child malnutrition. Instead, we focus on the cumulative effects of foreign aid on food insecurity over longer periods.

The econometric assessment is complicated due to two empirical elements. First, the effect of aid on hunger or other outcomes variables is not immediate but there are potential lags related to the impact of aid, and second, the high prevalence of hunger and poverty is associated with higher aids flows, and thus, there is a reverse causality between aid and the outcome variables (Addison et al., 2017). The existing studies focus on the relative immediate impact of aid on hunger and malnutrition, and thus, neglect the long-term effects aid has on all the sectors which contribute to reducing food insecurity. In addition to this, the identification strategy applied in these earlier studies fails to convincingly address reverse causality. In this study we specifically focus on the effectiveness of sectoral aid by providing evidence on the effects of food and agriculture related aid, and secondly, we address the weak instrumentation concern with the existing literature by offering an instrumental variable regression in the spirit of Arndt et al. (2015).

17 The relevance of ODA for improving food security and ending hunger is extremely complex because entire food systems play a role in the prevalence of undernourishment and the pathways towards food and nutrition security. A more detailed discussion on food systems frameworks, which put into perspective the interconnections between agriculture, income and employment, food security, and markets, was part of the intermediate report of this study (ZEF & FAO, 2020).

18 The two studies are subject to two methodological concerns. First, the instrumentation of agricultural ODA is weak, and second, the model specifications assume an immediate effect of agricultural ODA. The contribution to the literature of this study is twofold. First, it adds to the small but growing literature on the effectiveness of sectoral aid by providing evidence on the effects of agricultural aid. Second, it addresses the weak instrumentation concern by offering an instrumental variable regression in the spirit of Arndt et al. (2015).

Figure 7: Progress in PoU and ODA development since 2001



Source: Authors' own elaboration based on FAO (2020) and OECD (2019)

As discussed above, the correlation between agricultural ODA and PoU might give a wrong signal since low levels of development and a high prevalence of hunger might attract more ODA. Therefore, examining whether a causal impact of ODA to hunger reduction can be found requires a strong econometric approach. To see if this assertion might hold, an econometric analysis was conducted as described below. Data on PoU from the latest The State of Food Security and Nutrition in the World report (FAO et al., 2020) and on the prevalence of stunting, wasting, and underweight of under 5 children from the Joint Malnutrition Estimates (JME) collected by WHO (UNICEF, WHO & World Bank, 2020) were matched with ODA data from the OECD's Creditor Reporting System (CRS). All ODA values were used in US$ at constant prices. The variable of interest was the change in PoU and child malnutrition between 2000 and 2017. We tested for the effects of overall ODA as well as agricultural ODA, as defined in section 4.2.

To account for endogeneity, we use the instrumental variable approach proposed by Rajan and Subramanian (2008) and refined by Arndt et al. (2010) and Arndt et al. (2015). This approach requires proceeding in two steps. First, we estimate the supply of aid, both overall ODA and agricultural ODA, of each donor country to each recipient country, which we then aggregate at the level of recipient country. The approach is described in detail in Annex 2.

The results of the instrumental variable regression for the long-term drivers of PoU are given in Table 6. Column (1) presents the results for average per capita agricultural ODA. In line with expectations agricultural aid reduces PoU, and it is statistically significant at 10 percent.[19] The point coefficient of 0.210 implies that an increase of average per capita agricultural ODA by US$ 1 was associated with a reduction in PoU by 0.21 percentage points. Given that the per capita agricultural ODA between 2000 and 2017 among the sample countries was, on average, US$ 10.2, and increased by about 20 percent (in constant US$ 2010), agricultural ODA has significantly contributed to the reduction of PoU since 2000, specifically by about 2.1 percentage points. About half of the recipient countries received between US$ 2-13 per capita (pc), including Ghana (US$ 11 pc), Uganda (US$ 10 pc), and Ethiopia (US$ 10 pc). Some countries with significant progress in

19 We also run the estimation of the model using different estimators, namely a simple OLS estimator and the inverse probability weighted least squares (IPWLS) estimator dividing the sample in treated countries (with larger ODA inflows) and control countries (with smaller ODA inflows). We do not find a significant effect using the OLS estimation pointing at the need to use an instrumental variable approach. The results of the IPWLS estimation confirm the results of the instrumental variable approach.

the reduction of hunger, such as Myanmar and Angola, on the other hand, received only US$ 2.6 pc and US$ 5.8 pc, respectively. Increasing agricultural aid in these countries could reduce hunger more significantly due to the diminishing returns of aid.[20]

The results for the second indicator, average agricultural ODA relative to the GDP, in column (2), confirm the results in column (1) although the coefficient estimate is only significant at the 15 percent level of significance. Column (3) presents the results for the total ODA (per capita) countries received. The point estimate is also negative but not statistically significant at conventional levels. In all three specifications, in columns (1)-(3), the change in per capita GDP is strongly correlated with a reduction in PoU.

20 To account for the possibility of diminishing returns to aid, we also estimate a linear-log model, which is presented in Table A5 in the Annex 3. The corresponding coefficients of 1.78 (column (1)) implies that additional 10 percent of agricultural aid (which corresponds to US$ 1) was associated with a reduction in PoU by 0.18 percentage points.

The results for stunting, wasting, and underweight of under 5 children are presented in Table 7. Columns (1), (3), and (5) show the results for per capita agricultural ODA and columns (2), (4), and (6) give the results for agricultural ODA relative to GDP. For both agricultural ODA variables, we find that agricultural ODA reduces all malnutrition indicators. However, we find that the coefficients are significantly different from zero only at 15 percent for stunting and underweight and 5 percent for wasting. GDP per capita was found to be mildly statistically significant for stunting and significant at the 5 percent level for wasting. For stunting and underweight, this supports findings from Vollmer et al. (2014) who found no statistically significant effect of per capita growth rate on malnutrition in children and confirms the study by Headey and Ruel (2020) who found a significant effect of GDP reduction on child wasting.

Overall, we found a statistically significant and economically meaningful contribution of agricultural ODA to hunger and malnutrition reduction since 2000.

Table 6: Instrumental variable regression for change in PoU between 2000-2017

	Change in PoU between 2000-2017		
Variables	**(1)**	**(2)**	**(3)**
Per capita agricultural ODA 2000-2017[1]	-0.210* (0.117)		
Agricultural ODA/GDP 2000-2017		-437.1 (274.9)	
Per capita overall ODA 2000-2017			-0.0358 (0.0243)
Change in GDP per capita 2000-2017	-0.00154*** (0.000449)	-0.00220*** (0.000758)	-0.00149*** (0.000455)
PoU 2000	-0.567*** (0.0663)	-0.497*** (0.0758)	-0.574*** (0.0672)
Constant	8.043*** (2.765)	10.18*** (3.841)	7.747** (2.631)
Observations	70	70	70
R-squared	0.53	0.40	0.52

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. We included a dummy variable for countries in Sub-Saharan African and Latin American countries but omitted the coefficient estimates for the sake of space. We excluded small states and countries that were classified as fragile and conflict-affected states by the World Bank.

Source: Authors' elaboration.

1 We always use a 3-year moving average of the ODA data to smooth out discrepancies between aid commitments and actual aid flows.

Table 7: Instrumental variable regression for change in child malnutrition between 2000-2017

	Change between 2000-2017					
	Stunting		Wasting		Underweight	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
per capita agricultural ODA 2000-2017	-0.174+ (0.117)		-0.169*** (0.0594)		-0.108+ (0.0678)	
Agricultural ODA/GDP 2000-2017		-288.3 (204.9)		-360.9** (159.0)		-187.4+ (115.5)
Change in GDP per capita 2000-2017	-0.000159 (0.000532)	-0.000381 (0.000647)	-0.000418+ (0.000255)	-0.000973*** (0.000470)	-0.000340 (0.000299)	-0.000499 (0.000470)
Prevalence of stunting 2000	-0.361*** (0.0772)	-0.286*** (0.0829)				
Prevalence of wasting 2000			-0.432*** (0.108)	-0.374*** (0.137)		
Prevalence of underweight 2000					-0.234*** (0.0582)	-0.185*** (0.0538)
Constant	0.746 (3.833)	-0.859 (3.393)	4.282*** (1.619)	5.259*** (2.316)	1.182 (1.904)	0.765 (1.692)
Observations	59	59	59	59	59	59
R-squared	0.39	0.405	0.28	0.28	0.56	0.58

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, +p<.015. We included a dummy variable for countries in Sub-Saharan Africa and Latin American as well as fragile and conflict-affected states but omitted the coefficient estimates for the sake of space. We also controlled for the change in the level of improved access to water and sanitation in the regression but do not show the coefficients. We excluded small states and countries that were classified as fragile and conflict-affected states by the World Bank.

Source: Authors' elaboration.

5 PROGRESS IN HUNGER REDUCTION: ANALYSIS OF BEST PERFORMING COUNTRIES

5.1 Introduction

The Sustainable Development Goal 2 (SDG 2) of ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture, calls for a radical change in how countries shape their food systems and operationalize their fight against hunger and poverty. Concerted actions of various actors and stakeholders, both local and international, are needed in order to prioritize interventions that are proven to be effective in sustainably lifting people out of hunger. The multidimensional nature of food security also requires that efforts to achieve SDG 2 are broad-based, and that synergies with other SDGs, like eradication of poverty, gender equality, reduced inequality, and responsible consumption and production are safeguarded.

Countries with high levels of hunger are often exposed to financing constraints, making it difficult for them to address certain needs, e.g. food security of the poor, while simultaneously addressing a whole range of development challenges. It is equally difficult for policymakers to accommodate the trade-offs between short-term emergency and long-run nutrition and sustainability objectives. In many cases, this leads to an erratic policy environment relying on discretionary interventions (Pernechele, Balié, and Ghins 2018).

This chapter adds to the discussion on strategies that should be prioritized by low and lower-middle income countries in the fight against hunger. It looks in detail at the countries that have achieved remarkable progress in hunger reduction over the period 2001-2018. By comparing successful countries to those that have performed poorly, we highlight what successful countries have done differently in order to reduce hunger.

This analysis complements the work of the Monitoring and Analysing Food and Agricultural Policies (MAFAP) programme at the Food and Agriculture Organization of the United Nations (FAO) and a study by Laborde, Mamun, and Vos (2019). However, the scope and methods employed here differ significantly. With a particular focus on public expenditure towards food security, we also draw on agricultural public expenditure reviews performed by selected countries under the auspices of the World Bank (WB).

5.2 Data and Method

The analysis in this chapter focuses on countries that achieved the greatest reduction of hunger, as measured by the prevalence of undernourishment (PoU) over the period 2001-2018.[21] It covers selected low and lower-middle income countries. On average, and in particular in the baseline year, these groups of countries exhibit high levels of PoU. Low income countries reported an average of 29 percent PoU over the reference period (34 percent in 2001), and lower-middle income countries, an average of 16 percent (20 percent in 2001). For comparison, upper-middle income countries reported an average of 8 percent PoU (10 percent in 2001). We presume that countries with higher initial levels of hunger also have the largest scope for hunger reduction.

We excluded from the analysis countries with a PoU of 5 percent or lower at the beginning of the reference period. We assume that PoU at this level is a matter of transitory economic and political crises, including conflict, rather than underlying structural factors; and therefore, addressing undernourishment in these contexts would require different measures than the ones discussed in this chapter. As we are interested in countries that reported the highest PoU reduction in terms of percentage points (p.p.), this exclusion does not affect the sample of best performing countries.[22]

Out of the low and lower-middle income countries we selected the top quartile in terms of PoU reduction performance and refer to these countries as best performers. There are a total of 19 such countries and they constitute the principal focus of this analysis.[23] In addition we selec-

21 The limitation of the analysis in this chapter is that it does not include nutritional outcomes.

22 Ukraine, however, is excluded as a worst performing country because its initial PoU level was lower than 5 percent.

23 Note that we include in the analysis all the countries for which the data is available. However, we check the robustness of our results by excluding small states and other outliers. The classification of small states follows that of the World Bank.

ted the bottom quartile of PoU reduction performance and refer to these countries as worst performers. These countries serve as the comparison group. Due to missing data however, we dropped from the analysis two of the worst performing countries – Somalia and Democratic People's Republic of Korea.

There are two ways of measuring changes in PoU: in percentage points (p.p.) or percentage change. We chose the first option as it is more straightforward than the latter, and thus selected for the analysis countries that reported, in percentage point terms, the highest PoU reduction (or increase in the case of the worst performers). This relative measure does not allow the distinguishing of large and small countries.

The objective of this analysis is to find out if the best performers differ systematically from the worst performers with respect to a range of factors that are expected to play a role, directly or indirectly, in hunger reduction. To this end, we employed several statistical tests to test hypotheses on the differences in means, medians, and distributions among the two samples.[24]

The set of factors were selected based on the literature review and in line with the food system approach. Food system is a holistic framework well adapted to address the complex nature of food security and to enunciate relationships between a range of components that go beyond food production and consumption, while also considering broader processes, including socio-economic and environmental constraints and their impact on food security (IAP, 2018). The scope of this chapter, and data limitations, do not allow us to analyse a comprehensive set of food system elements. Instead, we focus on a subset of factors. Specifically, our analysis covers the following structural and policy factors:

1. **Economic structure and performance**, which includes variables such as GDP, GDP growth, and source of value added (VA) in the economy, i.e. manufacturing and agriculture. These factors represent the income and employment channels of food security, and are particularly relevant for its food access dimension.
2. **Agricultural production,** which influences food availability and constitutes the core of the food system framework. We account for agricultural VA and employment, and agricultural productivity, i.e. cereal yields, and food import dependence.
3. **Demographic structure,** which relates to hunger reduction in both negative, e.g. increased food demand, pressure on available resources, etc. and positive ways, e.g. as a resource in income generation, especially when its qualitative aspects are considered. We include population size, growth and density, and also urbanization level.
4. **Human development,** which, in a narrow sense, defines the quality of human resources available in the economy, but in a wider sense, is an important development outcome itself. In the food security context, it can have a broad range of impacts, affecting, amongst all, food access and utilization. We capture poverty headcount ratio, inequality (Gini index), Human Development Index (HDI), literacy rate, and primary and secondary school enrolment.
5. **Public interventions,** which are expected to deliver services and investments that are conducive to hunger reduction. We look at total government expenditure and its components along the functional classification, i.e. spending on agriculture and health, and the economic classification, i.e. capital investment. We also include Official Development Assistance (ODA) to capture the role that foreign governments can play in supporting hunger reduction in recipient countries.
6. **Institutional capacity,** based on the World Bank's Worldwide Governance Indicators (WGI). We are interested in factors relevant for delivery and democratic quality, which might affect governments' spending efficiency and commitment to fight against hunger.
7. **Capital investment** which, apart from investments aimed at hunger reduction, encompasses a broad range of investments in non-financial assets and as such, can have long-term implications for economic growth.

The data used in the analysis comes from various sources. PoU data, covering the period 2001-2018, is obtained from the FAO's latest dataset.[25] Some degree of uncertainty with respect to the data remains, as PoU is not directly observable but relies on estimates. This is particularly important for our analysis, which draws on data points for individual countries.

The data for the remaining variables cover the period 2001-2017, as for most of them 2018 observations are

24 We proceeded in three ways. First, we relaxed the assumption of equal variance in the two groups, and rather than using the standard Student's t-test, we applied the Welch t-test. Second, we relaxed the assumption of normal distribution in both groups, and employed a non-parametric k-sample test on the equality of medians, based on chi-squared test statistic. Third, we applied the Wilcoxon rank sum test (or the Mann – Whitney U-test), which is another non-parametric alternative to the unpaired two-sample t-test. The advantage of the Wilcoxon rank sum test, and non-parametric tests in general, is that it does not rely on any distributional assumptions, is less sensitive to outliers than the t-test, and since it is not based on the Central Limit Theorem, it performs well even if the sample size is small. In comparison to the simple equality of medians test, the advantage of the Wilcoxon rank sum test is that it considers the rank of each observation relative to the full distribution rather than relative to the median.

25 Re-estimated and updated by the FAO in 2020. Important differences between old and new versions are noted.

unavailable. The data on government expenditure and its components is compiled from several sources: IMF Government Finance Statistics (GFS) dataset, IMF World Economic Outlook (WEO) dataset, IFPRI Statistics on Public Expenditures for Economic Development (SPEED) dataset, FAOSTAT, and the WB's World Development Indicators (WDI). Cross-country government expenditure data is flawed with many problems. First, there are many missing data points for our sample countries, and as a result, it is impossible to use a single source of data. Second, we observe inconsistencies, sometimes large, between data from different sources, which often arise due to different definitions employed by the different data collection authorities. In order to address these data issues while keeping the highest number of observations in our analysis, we compiled the series from the abovementioned data sources and performed interpolations and extrapolations in a systematic manner following the approach by Bingxin, Magalhaes, and Benin (2015). All government expenditure data were compiled at the general government level and expressed in real terms, in 2010 US$. We were unable to distinguish between budgeted and executed government expenditure.

The data on ODA comes from the OECD.[26] The remaining variables used in the analysis were compiled from the WB's WDI and from FAOSTAT, with the governance indicators sourced from the WB's WGI.

The exploratory analysis is purely descriptive. Therefore, our findings do not convey causality between the explored factors and hunger reduction. Also, statistical inference of the results and observations based on a comparison of the best performers to other countries is not possible. Nevertheless, a detailed analysis of the countries which have been successful in reducing PoU can allow us to draw some lessons with respect to the enabling factors that might be conducive towards hunger reduction.

5.3 Best Performers

The list of the best performers in hunger reduction among the low and lower-middle income countries over the period 2001-2018 is presented in Table 8. As explained above, we define performance in hunger reduction in terms of percentage points (p.p.) change in PoU. Defining performance in terms of percent change in PoU would produce a somewhat different list (see Table A5 in Annex 3). Additionally, we check which countries performed best in absolute terms, i.e. number of people lifted out of hunger between 2001 and 2018 (Table A6 in Annex 3).[27] 12 countries qualify as the best performers according to all three measures.

The best performers achieved remarkable hunger reduction between 2001 and 2018, ranging from 49 p.p. reduction by Angola, to 10 p.p. reduction by Nicaragua, Tajikistan and Indonesia (Table 8). In the case of four countries (Ethiopia, Myanmar, Vietnam, Indonesia), this has translated into lifting around 10 or more million people out of hunger in each country. The PoU change ranges from 86 percent in the case of Uzbekistan (a change in PoU from 18 percent in 2001 to 3 percent in 2018) to 26 per cent for Timor Leste (a change in PoU from 42 percent in 2001 to 31 percent in 2018). The aggregate levels (Table 9) show that on average, the best performers managed to reduce PoU by 17 p.p., i.e. by half, which is around three times higher than the PoU reduction in the full sample of low and lower-middle income countries.

The difference in hunger reduction is even more striking when the best performers are compared to the worst (see the complete list of countries in Table A7 in Annex 3). The worst performers reported a 3 p.p. increase in PoU despite starting from a lower base. Indeed, the best and worst performers experienced very different trajectories in PoU over time (Figure 8). While the best performers experienced a steady reduction of PoU over the years, somewhat slowing down after 2015, hunger levels in the worst performing countries stagnated in the 2000s and increased rapidly after 2012. Surprisingly, the food price crisis of 2008/09 does not seem to (contemporaneously) have affected the prevalence of hunger in either of the two groups.

The aggregate figures hide an important heterogeneity among the best performers. More specifically, we observe that best performing countries can be split into roughly three distinct groups: countries that started at high levels of PoU, i.e. top quartile in the PoU distribution (we call them high flyers), countries that ended at low levels of PoU, i.e. bottom quartile in the PoU distribution (we call them last mile), and countries that fit neither of these two categories over the reference period (Table 8). This distinction might be important as we expect that the process of hunger reduction at relatively high and relatively low levels of PoU can be different and require different measures. Despite different starting points, both

26 Only foreign aid flows between the OECD Development Assistance Committee (DAC) donor and recipient countries are included in the dataset. Foreign aid flows outside of the DAC framework are excluded from the analysis in this chapter.

27 This measure, while straightforward, is nevertheless not very meaningful if we do not account for population growth in respective countries. For example, in Afghanistan, where PoU decreased by close to 40 percent over the reference period, the absolute number of undernourished people increased by 0.8 million.

Table 8: Best performers in PoU reduction over 2001-2018

Best performers Top 25 percent of low and lower-middle income countries that recorded highest p.p. reduction in PoU 2001-2018								
				PoU change		Change in the number of undernourished people (million)	High flyers	Last mile
Country	Income group	PoU (2001)	PoU (2018)	p.p.	%			
Angola	Lower-middle	67	19	**-49**	-72	-5.7	+	
Ethiopia	Low	47	20	**-27**	-58	-10.6	+	
Sierra Leone	Low	51	26	**-25**	-49	-0.4	+	
Myanmar	Lower-middle	38	14	**-24**	-63	-10.2	+	
Afghanistan	Low	48	30	**-18**	-37	0.8	+	
Nepal	Low	24	6	**-18**	-74	-4.0		+
Cameroon	Lower-middle	23	6	**-17**	-73	-2.1		+
Uzbekistan	Lower-middle	18	3	**-15**	-86	-3.7		+
Senegal	Lower-middle	24	9	**-15**	-61	-0.9		+
Vietnam	Lower-middle	20	6	**-13**	-68	-9.9		+
Bolivia	Lower-middle	28	16	**-12**	-44	-0.6		
Mali	Low	16	5	**-11**	-69	-0.9		+
Zambia	Lower-middle	38	27	**-11**	-29	0.6	+	
Uganda	Low	38	27	**-11**	-29	2.3	+	
Timor Leste	Lower-middle	42	31	**-11**	-26	0.0	+	
Togo	Low	31	21	**-11**	-34	0.0		
Nicaragua	Lower-middle	28	17	**-10**	-38	-0.3		
Tajikistan	Low	13	3	**-10**	-78	-0.6		+
Indonesia	Lower-middle	19	9	**-10**	-53	-17.3		+

Note: PoU reported in 3-year moving averages. Numbers do not add up because of rounding. Change in the number of undernourished people not adjusted for population growth. Last mile: bottom quartile of PoU distribution among low and lower-middle income countries in 2018.

Source: Authors' own elaboration based on FAO et al. (2020).

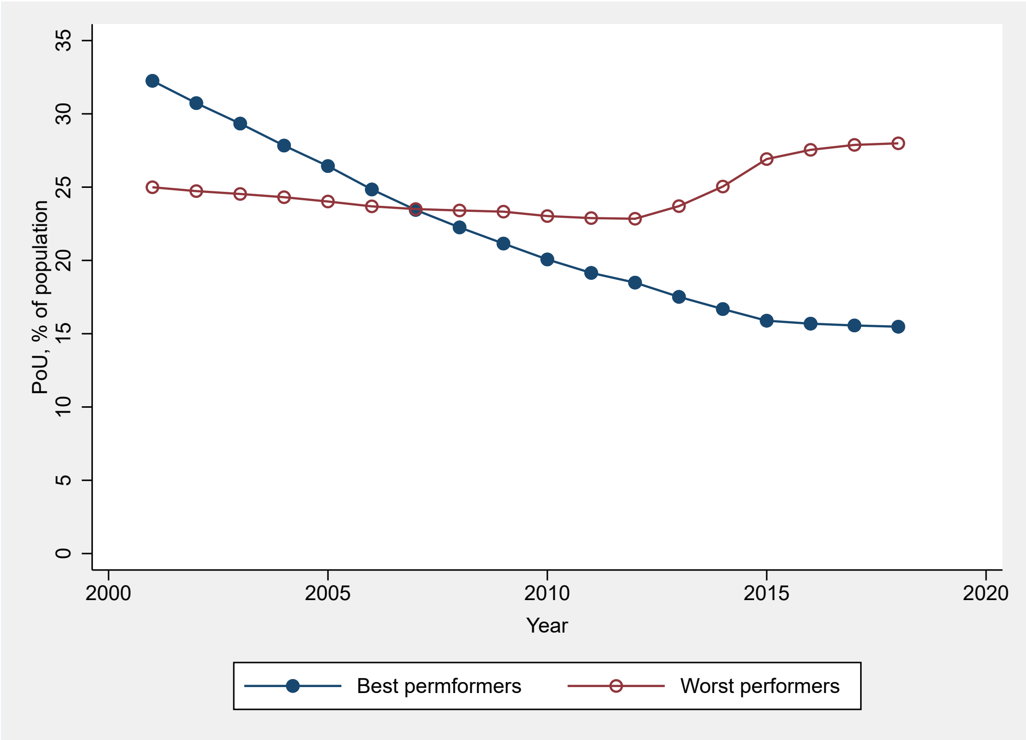
Table 9: PoU levels and changes over 2001-2018 in low and lower-middle income countries

	PoU (%)		Change in PoU 2001 - 2018	
	2001	2018	p.p.	%
Best performers (n=19)	**32.3**	**15.5**	**-16.8**	**-54.8**
Worst performers (n=19)	25.0	28.0	3.0	18.4
Low income countries (n=31)	33.8	28.5	-5.3	-18.8
Lower-middle income countries (n=47)	20.5	14.7	-5.8	-22.6
excluding countries with PoU ≤ 5% in 2000 (n=42)	22.5	16.1	-6.4	-21.6
Low and lower-middle income countries (n=78)	25.8	20.2	-5.6	-21.1
excluding countries with PoU ≤ 5% in 2000 (n=73)	27.3	21.4	-5.9	-20.4

Note: PoU reported in 3-year moving averages. Best and worst performers exclude countries with PoU ≤ 5% in 2001.

Source: Authors' own elaboration based on FAO et al. (2020).

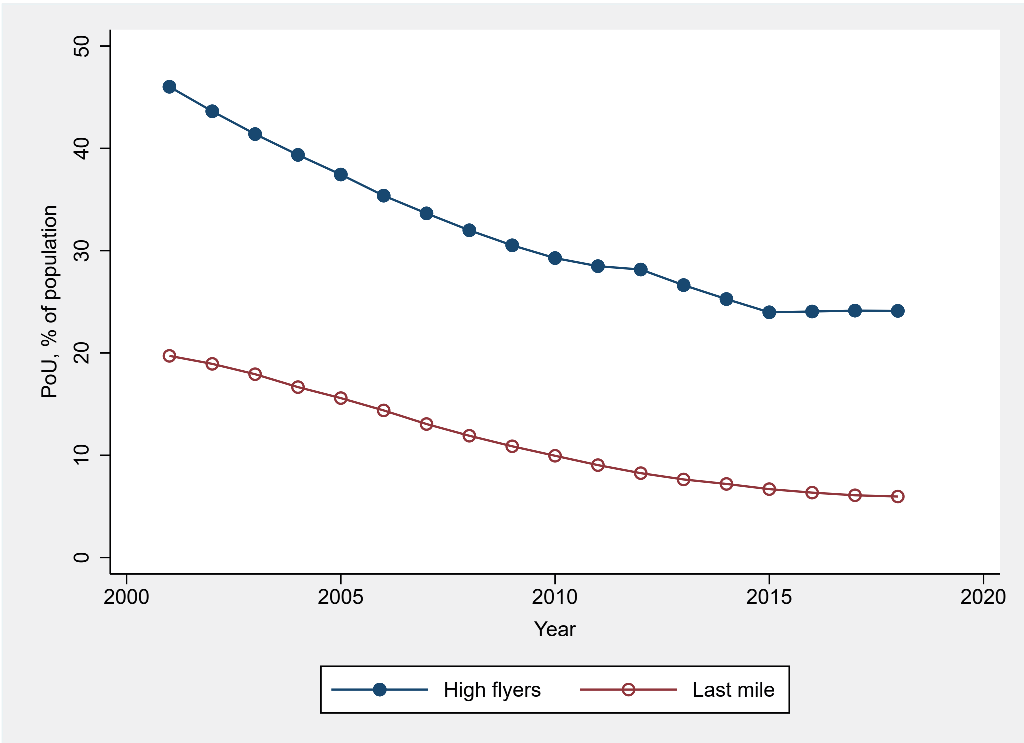
Figure 8: Change in PoU over 2001-2018: Best and worst performers



Notes: The line figures are based on averages for best and worst performers.

Source: Authors' own elaboration based on FAO et al. (2020). PoU reported in 3-year moving averages.

Figure 9: Change in PoU over 2001-2018: High fliers and last mile



Notes: The line figures are based on average levels for high flyers and last mile countries.

Source: Authors' own elaboration based on FAO et al. (2020). PoU reported in 3-year moving averages.

high fliers and last mile groups followed a parallel trajectory in hunger reduction over time (Figure 9).

5.4 Economic Structure and Performance

In what follows, we present the results for the differences in selected factors which we expect to play a role in hunger reduction. We present the results of the three tests listed above, i.e. Welch t-test, non-parametric equality of medians test (Chi-square test), and Wilcoxon test (Mann – Whitney U test).

For clarity of exposition, we show the means of the selected variables for the best and worst performers; but not the medians. For the three tests, we show the statistical significance of the differences at the usual significance levels, but do not report the actual magnitude of underlying differences and respective p-values. These details can be found in Kubik (2020).

The analysis begins by a look at the economic structure and performance of the best performers to capture the economic processes that might have accompanied hunger reduction. We also look at the factors related to agricultural production that might directly affect food security. Several important differences between the best and worst performers are highlighted in Table 10.

The best performers have almost 2.5 times higher GDP, on average, but this does not hold in per capita terms as they also have, on average, much larger population sizes (see section 5.5). The best performers registered higher annual GDP growth, over 6 percent on average against close to 4 percent for the worst performers. When looking at the structure of the economy, i.e. manufacturing and agriculture value added (VA), there are no important differences in relative terms, i.e. both sectors' shares in total VA are similar among the best and worst performers[28], but there are differences in absolute terms, i.e. the best performers have much higher manufacturing and agriculture VA. These differences are particularly striking in the case of manufacturing VA, which for the best performers was 4.5 times higher than for the worst performers. The average annual growth rate of manufacturing VA was for the best performers over double that of the worst performers. Similar observations can be made with respect to agriculture VA, but the magnitude of the differences is lower than for manufacturing. These results are corroborated by the differences in average cereal yields. The degree of food import dependence is lower (15 percent) for the best performers as against the worst performers (19 percent).

We tested the consistency of our results by excluding small states.[29] The results (not reported here) remain similar, only the magnitude of differences changes. In addition, some of the results might be driven by outliers. The detailed analysis is presented in Kubik (2020).

5.5 Demographic Structure and Human Development

The differences between the best and worst performers in hunger reduction in terms of demographic structure and human development are presented in Table 11. Best performers have population sizes that are twice that of the worst performers, and this holds even if we exclude two of the ten most populous countries in the world, Indonesia from the best performers and Nigeria from the worst performers. This result is important in that it shows that large population size is not necessarily a constraint in hunger reduction. The best performers tend to be more urbanized and densely populated, although the differences are small. Again, this might point to the existence of larger and more dynamic markets, and economies of scale in policy interventions that reduce hunger.

Differences are also evident in respect to the selected aspects of human development. The poverty headcount ratio is on average 10 p.p. lower among the best performers, and inequality is less pronounced, although the differences between both groups are small. The Human Development Index, which is a comprehensive measure of development, including such aspects as a long and healthy life, decent standard of living, and education, is only slightly higher for the best performers. This observation is corroborated by the education indicators, where the best performers clearly outperform the worst performers, i.e. they report a higher average literacy rate (72 percent vs. 66 percent), higher primary school enrolment (90 percent vs. 75 percent) as well as secondary enrolment (52 percent vs. 34 percent).

5.6 Public Interventions

Along with the importance of structural factors presented in sections 5.4 and 5.5, we hypothesize that the hunger reduction process is also a matter of policies and public interventions. In this section, we look at total general go-

28 Note that in the case of manufacturing share in total VA, both non-parametric tests report evidence of statistically significant differences between the two groups, however, the magnitude of this difference is relatively small. For example, the median is 9.8 percent for the best performers and 7.7 percent for the worst performers.

29 Following the World Bank, we excluded the Pacific Islands small states only.

vernment expenditure and its selected components, i.e. expenditure on agriculture and expenditure on health, which we expect to have the most immediate effect on hunger reduction. Ideally, we would also look at other types of expenditure, such as education, social protection, or environment; however, the lack of consistent yearly data for the countries in our sample makes it impossible. It should be reemphasised that public expenditure data is flawed and therefore the results need to be interpreted with caution.

The average differences in government expenditure between the best and worst performers in hunger reduction are highlighted in Table 12. While it is 2 p.p. lower as a share of GDP, total government expenditure is around three times higher among the best performers in absolute terms, i.e. on average more than US$ 13 billion per year for the best performers against an average of US$ 4.5 billion for the worst performers. Nevertheless, it is 25 percent lower in per capita terms, but this difference disappears when we exclude small states. The results are not driven by the two large countries, i.e. Indonesia and Nigeria. However, total government expenditure might not be meaningful if we do not control for how resources were spent.

In the two components of government expenditure that we expect to potentially affect hunger reduction, i.e. agriculture and health, we observe a similar pattern to that found above. Differences in agricultural expenditure are particularly pronounced, as the best performers spend roughly 4.5 times more on agriculture than the worst performers. There are no significant differences in per capita terms. The share of agriculture in total spending

Table 10: Differences between best and worst performers: Economic structure and performance

	Differences in selected indicators				
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Economic structure					
GDP					
GDP (constant US$, million)	26415.50	63043.30	***	***	***
GDP annual growth (%)	4.00	6.11	***	***	***
GDP pc (constant US$)	1561.60	1290.50	**	-	-
GDP pc annual growth (%)	1.64	3.89	***	***	***
Manufacturing [a]					
Manufacturing share in total VA (%)	10.25	10.61	-	**	**
Change between 2001-2017 (%)	-20.66	7.42	***	-	***
Manufacturing VA (constant US$, million)	2775.80	12152.50	***	***	***
Manufacturing VA annual growth (%)	2.80	6.18	*	***	***
Agriculture [b]					
Agriculture share in total VA (%)	25.13	23.50	-	-	-
Change between 2001-2017 (%)	-17.22	-18.14	-	**	-
Agriculture VA (constant US$, million)	6471.60	10342.50	*	***	***
Agriculture VA annual growth (%)	2.63	4.50	-	***	***
Employment in agriculture (% of total employment)	52.57	52.34	-	**	-
Change between 2000-2017 (%)	-16.71	-18.59	-	***	***
Cereal yield (kg per ha)	1343.70	2284.40	***	***	***
Food import dependence (%) [c]	19.00	15.00	***	***	***
No. of observations	289	323			
No. of countries	17	19			

Note: ***p<0.01, **p<0.05, *p<0.1. a. Data not available for Madagascar and Solomon Islands (worst performers). b. Data not available for Solomon Islands (worst performer). c. Percentage of available calories that are imported for human consumption.

Source: Authors' own elaboration based on WDI and FAOSTAT (data retrieved in June 2020).

is also higher among the best performers (5.5 percent) as against the worst performers (3.8 percent). For the African countries in both samples, it is 6 percent against 4 percent, still much below the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) objective of 10 percent.

We were unable to distinguish between public expenditure financed by domestic sources and that financed by Official Development Assistance (ODA), due to the lack of consistent data, mainly as a result of disparities between donors and recipients in how foreign sources should be accounted for in national accounts; and because of the apparent aid fungibility. Such a distinction might be important because in many low and lower-middle income countries, foreign aid contributes a substantial proportion of national and regional budgets, especially in the context of typically lower tax bases and a large degree of informality in local economies. Foreign aid might therefore be an important ingredient of hunger reduction processes. On the other hand, the more volatile nature of ODA in comparison to domestic funding via taxes might challenge the sustainability of public interventions which rely too heavily on ODA funds. Accordingly, while we cannot go much into detail, we nevertheless compare aid flows between the best and worst performers (Table 13). Because of our focus on hunger reduction, we also look at agricultural aid, which we define in a broad sense, i.e. the aggregate of (1) Agriculture, Forestry & Fishing; (2) Development Food Assistance; (3) Emergency Food Assistance; (4) General Environment Protection; (5) Rural Development; (6) Water Supply & Sanitation; (7) Removal of Land Mines; based on the OECD classifications (see also section 4.2).

The comparison of ODA inflows between the best and worst performers (Table 13) shows that, in absolute terms, the best performers received over US$ 1.4 billion per year on average, twice as much as the worst performers. However, in per capita terms, the best performers

Table 11: Differences between best and worst performers: Demographic structure and human development

	Differences in selected indicators				
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Demographic structure					
Population (million)	18.04	36.75	***	***	***
Population growth (%)	2.36	2.23	-	*	**
Population density (people per sq. km)	76.19	82.66	-	***	***
Urban population (% of total population)	34.52	37.53	*	-	***
Human development					
Poverty headcount ratio (% of total population, last available data) *[a]	38.22	28.21	***	**	***
Gini index (last available data) [a]	41.68	39.42	***	**	*
Human Development Index (HDI)	0.48	0.52	***	***	***
Literacy rate (% of adult population, last available data)	66.43	72.24	***	-	***
Net enrolment rate, primary (%, last available data) [a]	75.40	89.78	***	***	***
Net enrolment rate, secondary (%, last available data) [b]	34.22	51.61	***	***	***
No. of observations	289	323			
No. of countries	17	19			

Notes: ***p<0.01, **p<0.05, *p<0.1. * Poverty headcount ratio at US$ 1.90 a day (2011 PPP). a. Data not available for Afghanistan. b. Data not available for the Democratic Republic of the Congo (DRC), Republic of the Congo, Nigeria (worst performers), Vietnam, and Zambia (best performers).

Source: Authors' own elaboration based on WDI and FAOSTAT (data retrieved in June 2020).

received only half of what the worst performers did. In relative terms, i.e. measured as the share in total government expenditure, ODA is much less important for the best performers than the worst performers, i.e. 41 percent against 60 percent. For the reasons explained above, however, these figures cannot be directly interpreted as a contribution of ODA to public expenditure; especially because ODA flows are not budgeted into domestic budgets, and some flows are disbursed independently by donors. However, these results suggest that the best performers are less dependent on ODA funds and have a higher capacity of domestic resource mobilization. The pattern is similar for agricultural ODA, but the magnitude of the difference is higher, i.e. agricultural ODA, at US$ 280 million per year on average, is close to three times higher for the best performers. The share of agricultural ODA in total ODA is slightly higher for the best performers, 19 percent against 17 percent.

5.7 Capital Investment

In this section, we hypothesize that capital investment can play an essential role in hunger reduction, mainly through the income channel, i.e. by boosting economic growth and putting low-income countries on a conver-

Table 12: Differences between best and worst performers: Government expenditure

	Differences in selected indicators				
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Government expenditure*					
Total expenditure					
Total expenditure (% of GDP)	26.26	23.81	**	***	***
Total expenditure (constant US$, million)	4495.50	13276.20	***	***	***
Total expenditure annual growth (%)	5.28	7.31	-	***	**
Total expenditure pc (constant US$)	439.70	337.40	***	***	**
Total expenditure pc annual growth (%)	2.92	5.08	-	**	**
Agriculture expenditure [a]					
Agriculture expenditure (% of total expenditure)	3.78	5.51	***	***	***
Agriculture expenditure (constant US$, million)	125.30	558.50	***	***	***
Agriculture expenditure annual growth (%)	4.04	7.94		*	*
Agriculture expenditure pc (constant US$)	15.47	13.49	-	-	-
Agriculture expenditure pc annual growth (%)	1.79	5.71	-	-	*
Health expenditure					
Health expenditure (constant US$, million)	252.70	792.60	***	***	***
Health expenditure annual growth (%)	5.00	8.23	-	**	**
Health expenditure pc (constant US$)	23.05	20.50	-	-	***
Health expenditure pc annual growth (%)	3.82	5.77	-	-	**
No. of observations	289	323			
No. of countries	17	19			

Notes: ***p<0.01, **p<0.05, *p<0.1. * General government. a. Data not available for Mali, Nicaragua, Tajikistan (best performers), Chad, and Mauritania (worst performers).

Source: Authors' own elaboration based on data compiled from IMF GFCF, WEO, IFPRI SPEED, FAOSTAT, WDI (data retrieved in June 2020).

Table 13: Differences between best and worst performers: ODA

			Differences in selected indicators		
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Official Development Assistance (ODA)					
Total ODA					
Total ODA (constant US$, million)	692.7	1430.4	***	***	***
Total ODA pc (constant US$, million)	137.2	72.54	***	**	***
Total ODA share in government expenditure (%)	60	41	**	***	***
Agriculture ODA *					
Agriculture ODA (constant US$, million)	98.62	280	***	***	***
Agriculture ODA (% of total ODA)	17	19	**	***	***
Agriculture ODA pc (constant US$, million)	18.21	12.67	***	-	-
No. of observations	289	323			
No. of countries	17	19			

Notes: ***p<0.01, **p<0.05, *p<0.1. * Agriculture ODA: (1) Agriculture, Forestry & Fishing; (2) Development Food Assistance; (3) Emergency Food Assistance; (4) General Environment Protection; (5) Rural Development; (6) Water Supply & Sanitation; (7) Removal of Land Mines

Source: Authors' own elaboration based on OECD (data retrieved in October 2019).

gence path, in line with traditional growth models, i.e. Harrod-Domar and Solow-Swan. We acknowledge that some investments might have a more direct impact on hunger reduction, especially investments in agriculture and related infrastructures; however, we are not able to distinguish these in a cross-country analysis because of a lack of data. While the data is globally available for all the countries in our sample, for a number of countries only the most recent data points are available. The results, therefore, need to be treated with caution.

The main results in terms of public capital investment, total (public and private) gross fixed capital formation (GFCF), and foreign direct investment (FDI) are presented in Table 14. We observe clear patterns across all investment categories. No differences can be seen in relative public investment, i.e. measured in relation to GDP. However, there are large differences in absolute terms, with the best performers reporting annual public investment close to three times higher than the worst performers, i.e. on average over US$ 3 billion against over US$ 1 billion per year.

Second, this pattern is reflected in aggregate, public and private capital investment, as measured by gross fixed capital formation (GFCF). GFCF amounts to close to a quarter of GDP in both samples, but in absolute terms, GFCF is three times higher in best performing countries, i.e. over US$ 18 billion per year against almost US$ 6 billion. Best performers also reported twice higher average annual growth of capital investment, 10 percent against 5 percent. These relative differences are even more pronounced when we exclude the two large countries, Indonesia and Nigeria, even though the averages fall. It does not seem that public investment crowded out private investment; on the contrary, they appear to have gone hand in hand among the best performers; with the exception of Ethiopia, where private investment increased substantially once public capital investment started declining.

Note that the best performers did not have to compromise on aggregate consumption in order to achieve high levels of capital investment. Their average consumption per year was twice as high as that of the worst performers. Finally, higher domestic investment in the best performing countries seems to have attracted higher foreign investment. With close to US$ 1.5 billion per year on average, FDI inflows to the best performers were twice that of the worst performers.

Table 14: Differences between best and worst performers: Capital investment

			Differences in selected indicators		
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Capital investment					
Gross Fixed Capital Formation (GFCF) (public and private) [a]					
GFCF (% of GDP)	23.07	24.14	-	***	***
GFCF (constant US$)	5699	18805.9	***	***	***
GFCF annual growth (%)	5.22	9.95	*	***	***
Public capital investment [b]					
Government capital investment (% of GDP) *	6.715	6.178	-	-	-
Change between 2000 and 2017 (%)	6.626	75.29	***	***	***
Government capital investment (constant US$, million)	1089.2	3129	***	***	***
Government capital investment annual growth (%)	5.93	8.60	-	-	-
Foreign Direct Investment (FDI) [c]					
FDI net inflows (constant US$, million)	671.3	1454.2	***	***	***
FDI net inflows annual growth (%)	6.76	9.18	-	**	-
Final consumption expenditure [d]					
Final consumption expenditure (constant US$, million)	23.31	51.12	***	***	***
Final consumption expenditure annual growth (%)	3.97	4.76	-	***	***
No. of observations	289	323			
No. of countries	17	19			

Notes: ***p<0.01, **p<0.05, *p<0.1. * General government. a. Data only partially available for Cabo Verde, Solomon Islands (worst performers) and Zambia (best performer). b. Data of low quality. Data partially available for Burundi, Cabo Verde, Guinea-Bissau, Liberia, Papua New Guinea, Solomon Islands, Vanuatu (worst performers), Cameroon, Nepal, Sierra Leone and Timor Leste (best performers). Data not available for Mauritania, Niger, Chad (worst performers) and Tajikistan (bets performer). c. Data only partially available for Timor Leste (best performer). d. Data not available for Ethiopia (best performer), Papua New Guinea and Solomon Islands (worst performers); and only partially available for Afghanistan, Myanmar, Tajikistan, Zambia (best performers), Cabo Verde, Chad, and Vanuatu (worst performers).

Source: Authors' own elaboration based on IMF GFCF and WDI (data retrieved in June 2020).

5.8 Governance

This discussion on the potential covariates of hunger reduction among best performing countries, and in particular the analysis of public expenditure and capital investment, would not be complete without considering governance. To address this issue, we look at the World Bank's Worldwide Governance Indicators (WGI) and compare them between the best and worst performers. For ease of comparison, we aggregate the WGI indicators into two indicators: democratic quality and delivery quality. The former is an average of (1) voice and accountability, (2) political stability, and (3) rule of law; and the latter an average of (1) government effectiveness, (2) regulatory quality, (3) control of corruption (Table 15).

It is observed that, on average, both groups of countries performed badly in terms of both democratic quality and delivery quality, with means well below zero. For reference, note that the indices usually range between -2.5 and 2.5. Over the reference period, the average governance outcomes for the best performers were worse than those of the worst performers. However, over the same period, the governance outcomes have improved significantly among the best performers, and slightly declined among the worst performers. Of course, there is large heterogeneity amongst countries. Those that reported the largest improvements are Indonesia, Myanmar and Sierra Leone.

Table 15: Differences between best and worst performers: Governance

	Differences in selected indicators				
	Worst performers (Mean, 2001-2017)	Best performers (Mean, 2001-2017)	Welch t-test (Difference in means)	Non-parametric equality of medians test (Chi-square test) (Difference in medians)	Wilcoxon rank sum test (Mann - Whitney U test) (Difference in distributions)
Governance *[a]					
Aggregate measures					
Democratic quality (mean 2000-2017) **	-0.54	-0.80	***	-	***
Change between 2000 and 2017 (difference)	-0.03	0.20	***	***	***
Delivery quality (mean 2000-2017) ***	-0.72	-0.84	**	-	**
Change between 2000 and 2017 (difference)	-0.08	0.10	***	***	***
No. of observations	289	323			
No. of countries	17	19			

Notes: ***p<0.01, **p<0.05, *p<0.1. * Governance is assessed based on the set of Kaufmann indices from the WGI; the indicators are measured in their standard normal units, ranging from approximately -2.5 to 2.5. ** Average of (1) voice and accountability, (2) political stability, (3) rule of law. *** Average of (1) government effectiveness, (2) regulatory quality, (3) control of corruption. a. Data not available for the Democratic Republic of the Congo (DRC) (worst performer) and Timor Leste (best performer).

Source: Authors' own elaboration based on WGI (data retrieved in June 2020).

5.9 Discussion and Conclusion

In this chapter we have looked at low and lower-middle income countries that achieved a remarkable progress in hunger reduction over the period 2001-2018 in an attempt to understand which factors have contributed to their success. To this end, we compared the best performers with the worst performers in hunger reduction along a range of selected indicators. By doing so, we have shed some light on the strategies that should be prioritized by low and lower-middle income countries in their fight against hunger. Two limitations have to be acknowledged. First, due to its descriptive character, the analysis does not allow conclusions to be drawn about causalities between the indicators and hunger reduction. Second, a large degree of heterogeneity across countries suggests that there is no one-size-fits-all solution to hunger. Nevertheless, the analysis has produced several clear patterns.

First, the best performers are larger economies, with higher GDP and population size. Importantly, these are countries that have managed to set themselves on a rapid economic growth trajectory over the reference period. We can assume that their economic growth must have been, at least partially, pro-poor and inclusive. This clearly points to the importance of income channels in a sustained hunger reduction process – which necessitates accounting for interlinkages between various SDGs, i.e. SDG 1 and 2. In line with this, we observe the importance of scale in setting forth the hunger reduction process.

Second, the best performers in hunger reduction present some of the characteristics of countries in the early stages of structural transformation. While the role of agriculture, both in terms of value added and employment, is still very important in these countries, the weight of manufacturing in total GDP is rapidly gaining importance. Labour also seems to be gradually moving out of agriculture, and also out of rural areas, amplifying the effects of urbanization. Importantly, these processes are accompanied by relatively high growth in agricultural value added and agricultural productivity. This pattern is particularly visible in the case of high flyers in our sample of best performers, as these countries started from a low base but are quickly catching up with last mile countries.

Third, the hunger reduction process requires significant financial resources, either domestic or foreign, private or public. Our analysis points to the importance of the private sector and market processes. Indeed, the relative weight of public expenditure is slightly lower for the best performers, even though the absolute levels are much higher. Our findings suggest that it is relevant not only to consider how much is spent, but also how the money is spent. In this respect, we make two observations. First, agriculture receives more public resources in the best performing countries which seems to have direct implications for food security. Second, the example of best performers clearly shows that capital investment should be prioritized. Importantly, public investment did not seem, on average, to crowd out private investment among the best performers. Note, however, that efficiency of public expenditure, including capital investment, is certainly a factor to be weighed in; even though we were unable to capture it in our analysis.

6 INVESTMENT NEEDS TO END HUNGER AND THE G7 COMMITMENTS

The different scenarios provided in chapter 3 highlight the worryingly large proportion of the world population that will remain undernourished in 2030 under business-as-usual scenarios, emphasizing that at the current pace of progress and commitments, achieving zero hunger by 2030 is highly unlikely. This chapter, on the other hand, shows that achieving zero hunger is in principle possible and that achieving targets 2.1 and 2.2 of SDG 2 need not be prohibitively expensive, provided that cost effective measures with the potential to yield the greatest reduction in hunger and child malnutrition are prioritized. This chapter enunciates a mix of cost-effective interventions that could be implemented to achieve zero hunger and reduce malnutrition by 2030.

6.1 Review of Selected Existing Cost-Estimation Models

Here we review several estimates of the cost of achieving SDG 2, in particular, ending hunger and improving nutrition. We focus on the five most up-to-date estimates, i.e. "Achieving Zero Hunger", IMPACT, "Toward a Zero-Hunger by 2030", MIRAGRODEP, and "Investment Framework for Nutrition". Some of them, for example "Achieving Zero Hunger" and "Toward a Zero-Hunger by 2030", use the same methodology as earlier works, i.e. Schmidhuber and Bruinsma (2011) and Hoddinott, Rosegrant and Torero (2013); these earlier works are therefore not included in our review. In the case of others, for example the MIRAGRODEP "Ending Hunger: What Would It Cost", the applied methodology is similar to another ongoing work, i.e. Ceres2030; we therefore present only the studies for which the final results are readily available (see also Fan et al. 2018).

The **"Achieving Zero Hunger"** model by the Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agricultural Development (IFAD), and the World Food Programme (WFP) (2015) offers the most extensive, but also most costly framework of all the models reviewed here, including extensive social protection programmes and targeted pro-poor investments. The basic premise of the Achieving Zero Hunger model is that hunger is a result of lack of purchasing power which translates into a lack of access to sufficient and nutritious food, and therefore the target of eradicating hunger (SDG 2) can be achieved only by eliminating poverty (SDG 1). Unlike other models, it aims for absolute-zero levels of hunger globally by 2030. Note that hunger is measured here by the prevalence of undernourishment (PoU), defined as chronically inadequate dietary energy intake, in line with the methodology adopted in the FAO's The State of Food Security and Nutrition in the World 2019 report (FAO et al., 2019). The Achieving Zero Hunger model draws upon a methodology previously used by Schmidhuber and Bruinsma (2011) and employs the partial-equilibrium GAPS model. The twin-track approach of social protection and pro-poor development is expected to bring relatively fast but also sustainable eradication of poverty and hunger. In the short-term, public investment in social protection is expected to close the poverty gap and increase incomes, both directly and through increased productivity. In the long-run, the effects of social protection will be reinforced and sustained by targeted private and public pro-poor investments, especially in rural areas, and particularly so in agriculture (see Table 16). The average cost of achieving zero hunger would be **US$ 265 billion** annually, out of which US$ 67 billion will cover social protection and US$ 198 billion pro-poor investments.

The International Food Policy Research Institute's (IFPRI) **IMPACT** model analyses the potential contribution of agricultural investments to achieving SDG 2, and proposes a comprehensive investment package that can reduce hunger to 5 percent of the global population. These investments focus on agriculture and include agricultural research and development (R&D); resource management, especially water and irrigation; and infrastructure, mainly transportation and energy. Note that this is the only framework explicitly modelling the impact of R&D on agricultural productivity; it is also the only one to account for climate change impacts. The IMPACT model is a highly disaggregated, global partial-equilibrium multi-market model. To overcome the limitations of a partial-equilibrium model, it is linked to GLOBE, a global computable general-equilibrium (CGE) model which estimates the impacts of investment in agriculture on the broader economy. Hunger is not measured directly based on the expected consumption, as in other models, but is proxied by the risk of hunger based on the estimated calorie availability per day per capita only. The cost of the agricultural investment package is estimated at **US$ 52 billion** annually for the developing world. These investments are expected to result in a reduction of the share of the population at risk of hunger to 5 percent, except for Eastern and Central Africa where hunger will remain at 10 percent level.

"Toward a Zero-Hunger by 2030" by Torero and von Braun (2015) provides global cost estimates for the investments necessary to reduce hunger to near zero by 2030, with the assumption that transitory undernourishment at around the 3 percent level, related to conflict and crises, would require different measures. The estimates are to a great extent extrapolated from Hoddinott, Rosegrant and Torero (2013), where three main investment strategies towards a reduction in hunger are considered: accelerating yield enhancements, i.e. investment in agricultural R&D; market innovations, i.e. information and communication technologies (ICTs) and improving the functioning of fertilizer markets; and interventions that reduce micronutrient deficiencies (vitamin A, iodine, iron, zinc) and reduce stunting. This framework is somewhat similar to the IMPACT model presented above, as it uses the same IFPRI baseline model. However, the conceptual framework and the underlying assumptions vary to some extent; hunger is measured as in "Achieving Zero Hunger". Agricultural R&D is expected to increase productivity, and the elasticity of yields to R&D expenditure is estimated based on a literature review; this yield growth entails both income and price effects, which will then affect the incidence of hunger. The original cost estimates for agricultural R&D in the underlying Hoddinott, Rosegrant and Torero (2013) paper show that it would cost US$ 733 per person to reduce the number of undernourished by 210 million by 2050 (the original time frame of the baseline paper), which translates into a prevalence of hunger reduced to 5.9 percent. Torero and von Braun (2015) suggest to accelerate these investments up to 2030, and couple them with the remaining investment strategies, i.e. food markets and ICTs, as well as with programmes to reduce micronutrient deficiencies and stunting, which would lift 500 million people out of hunger and attain the objective of near-zero hunger. The total cost of all measures addressing hunger and malnutrition would be **US$ 30 billion** annually; out of which the cost of ending hunger would be **US$ 15 billion** annually.

The "**Ending Hunger: What Would It Cost"** model by IFPRI and the International Institute for Sustainable Development (IISD) combines micro-, meso- and macro-level inputs. Note that the same modelling approach is used by Ceres2030, a partnership between IFPRI, IISD and Cornell University. This modelling framework is based on the **MIRAGRODEP** dynamic multi-country multi-sector CGE model combined with household surveys, which allows for more precise targeting of interventions based on the identification of hungry households. This household-level targeting is expected to result in spending efficiency in comparison to the other models which are based on national averages. As noted by Fan et al. (2018), the MIRAGRODEP model's targeting approach, together with the narrow focus on reducing hunger in isolation of other SDGs, produces one of the lowest cost estimates, **US$ 11 billion** annually. Hunger is measured by the PoU, as defined in the FAO model "Achieving Zero Hunger" described above. Rather than eradicating hunger to absolute-zero level, it aims at reducing its prevalence to 5 percent or less. Two other sub-goals of SDG 2, i.e. raising agricultural productivity and doubling smallholders' income (target 2.3) and ensuring sustainable agricultural systems (target 2.4) are also accounted for in the design of interventions. Three types of interventions are included in the MIRAGRODEP model: social safety nets, directly targeting consumers through food subsidies; farm support to increase farmers' productivity and incomes; and rural development, mainly through infrastructure investments (see Table 16). These interventions are expected to affect calorie consumption by increasing poor households' incomes, as in Achieving Zero Hunger, or by decreasing food prices. The importance of interventions addressing nutrition are also acknowledged, however because of household data limitations, they are not accounted for in the modelling framework.

Finally, the **"Investment Framework for Nutrition"** by the World Bank (WB). This model has a narrow scope in comparison to the other models presented here, because its adopted methodological framework is very simple and transparent. Rather than aim to reduce hunger, as in the other models, the WB framework estimates the financing needs for improved nutrition targets. More specifically it aims to (1) reduce the number of stunted children under five by 40 percent; (2) reduce the number of reproductive-age women with anaemia by 50 percent; (3) increase the rate of exclusive breastfeeding in the first six months up to at least 50 percent; and (4) reduce and maintain childhood wasting to less than 5 percent. These targets correspond to the World Health Assembly's Targets for Nutrition, but also contribute to SDG 2 (Shekar et al., 2017). The case for investing in nutrition is very strong: ending malnutrition is critical for long-term human capital, labour productivity and broad economic development (Fink et al., 2016; Horton &

Steckel, 2013; Hoddinott et al., 2008). At the same time, nutrition interventions are considered to be among the most cost-effective (Horton & Hoddinott, 2014). The interventions included in the model are identified based on two criteria: (1) strong evidence of their impact; (2) relevance for low- and middle-income countries. The selected interventions range from staple-food fortification and micronutrient supplementation to public provision of supplementary food and behaviour promotion campaigns. To estimate the total cost of scaling up the selected nutrition interventions, financing needs are first analysed for the highest-burden countries based on the unit-cost data obtained from a literature review; these results are then extrapolated to all low- and middle-income countries. The estimates suggest that to reach the nutrition targets it will cost around **US$ 7 billion** annually between 2015 and 2025; more than half of this amount targeted at reducing stunting.The five models presented above provide a very wide range of estimates for the total investment necessary to achieve SDG 2, i.e. ending hunger and improving nutrition. These differences are largely attributable to the different objectives and policy questions asked, interventions and investment strategies considered, as well as definitions, methods and assumptions used (Mason-D'Croz et al., 2019; Fan et al., 2018). The differences in the approaches adopted by the costing frameworks make it difficult to directly compare the resulting estimates. We calculated the estimated cost per person[30] of hunger eradication for all the modelling frameworks except the WB's Investment Framework for Nutrition that only provides estimates of nutrition-specific interventions (Table 16). These estimated costs per person vary widely, from more than US$ 4,000 in Achieving Zero Hunger to just above US$ 300 in Torero and von Braun (2015). The number of people lifted out of hunger also differs substantially, from 650 million in Achieving Zero Hunger, 580 million in the IMPACT model, 500 million in Torero and von Braun, to only 290 million in the MIRAGRODEP model. These differences are accounted for by differences in modelling assumptions, and the scope of each framework in terms of suggested investments and interventions. Rather than providing clear-cut answers, the studies suggest that a variety of diverse investment strategies can contribute to ending hunger.

Although all five models address the issue of financing needs for the achievement of SDG 2, the scope of each framework is narrower than the scope of SDG 2 itself. SDG 2 has five targets, the first two concerned with ending hunger and ending all forms of malnutrition by 2030. The remaining three targets concern doubling agricultural productivity and the income of small-scale food producers by 2030, ensuring sustainable food production systems by 2030, and maintaining the genetic diversity of seeds, plants and animals, including wild species by 2020. Three of the models focus on either eradicating or substantially reducing hunger. However, the definitions of hunger vary between the studies, and are based either on food access, as in the Achieving Zero Hunger and the MIRAGRODEP model, or food availability, as in the IMPACT model; none consider all four dimensions of food security. Only two frameworks, the WB's Investment Framework for Nutrition and the estimates by Torero and von Braun (2015), explicitly model the nutrition outcomes; with the latter being the only one to address both objectives of hunger eradication and improved nutrition in one framework. The other four models only assume that investment to reduce hunger will also help to reduce malnutrition. Finally, only one model, MIRAGRODEP "Ending Hunger: What Would It Cost", factors in the question of sustainability in agriculture.

There are important trade-offs between the scope of a modelling framework and the complexity and feasibility of the methodology used. Looking at the five frameworks reviewed here, it seems that the narrower the scope of the study, the more transparent the model and the more precise the estimates, as in the case of the Investment Framework for Nutrition and the MIRAGRODEP model. Regarding the latter, the combination of macro-level and household-level data is an interesting methodological development in comparison to studies based on national averages, as it allows not only for more efficient targeting of interventions but could also better capture the distributional and inequality effects of investments, which are largely omitted in most analyses. Finally, only a few models explicitly include the investments necessary to create enabling environments for achieving SDG 2; admittedly, these are relatively difficult to present in monetary terms.

Last but not least, the financing strategy with respect to the pacing of investments, allocation of financial resources between competing objectives, distribution of

30 Total cost per person is calculated as the total cost of investment over 2015-2013 divided by the estimated number of people lifted out of hunger. The total cost of investment is calculated as total net discounted cost over the 15 years period (only for Achieving Zero Hunger, the time frame is 14 years, i.e. 2016-2030). The discount rate is assumed to be 5 percent, following Rosegrant, Hoddinott and Torero (2013). For each modelling framework, the absolute number of people lifted out of hunger due to the proposed investments is calculated as the difference between the projected number of hungry people in the business as usual 2030 scenario and the projected number of hungry people in the 2030 investment scenario. These figures are retrieved from each model. The total cost per person of hunger eradication is then calculated as the total net discounted cost divided by the number of people lifted out of hunger. We calculate only the cost per person for the investments towards hunger reduction, but not for the investments towards improvement in nutrition due to the very specific nature and outcomes of each intervention.

Table 16: Overview of selected costing models

Model/ framework and institu-tion(s)	Research question/ time frame	Target	Investments/ interventions	Methodology	Financing sources	Total annual cost (billion US$)	Total cost per person of hunger eradication (US$) over 2015-2030 *
Achieving Zero Hunger (FAO, IFAD, WFP)	What are the additional investments needed to end poverty and hunger in all countries by 2030?	Zero hunger; eradicating extreme poverty	Pro-poor investments: primary agriculture and natural resources, agro-processing operations, infrastructure, institutional framework, R&D, extension (the estimate also considers a social protection component of US$ 183 bill. which is not included here to make it comparative with the other initiatives)	Partial-equilibrium model	Public and private	**82**	**1242**
IMPACT (IFPRI)	How much would hunger decrease given investments to achieve target yield increases by 2030?	5 percent hunger	Agricultural R&D; irrigation expansion; water use efficiency; soil management; transport and energy infrastructure	Partial-equilibrium model linked to bio-physical models and CGE model; impacts of climate change included	Public	**52**	**929**
Toward a Zero-Hunger by 2030 (Torero and von Braun, 2015)	What is the global cost to accelerate undernourishment reduction to a level that would almost eliminate hunger by 2030?	3 percent hunger; improved nutrition	Accelerating yield enhancements (agricultural R&D); market innovations (information and communication technologies, increasing competition in the fertilizer market); interventions that reduce micronutrient deficiencies (vitamin A, iodine, iron, zinc) and reduce stunting	Partial-equilibrium model (IMPACT)	Public, including ODA	**30,** out of which **15** for ending hunger	**312**
MIRAGRODEP (IFPRI, IISD)	What is the minimum cost to end hunger for vulnerable households by 2030?	5 percent hunger	Social safety nets: food subsidies; farm support: production subsidies, fertilizer subsidies, investment grants, R&D, extension; rural development and infrastructure: reduction of post-harvest losses, irrigation, roads	CGE model combined with household surveys for targeted interventions	Public, including ODA	**11**	**393**
Investment Framework for Nutrition (WB)	What is the minimum cost to meet the World Health Assembly targets on nutrition by 2025?	40 percent reduction in child stunting; 50 percent reduction in anaemia in women; 50 percent increase in exclusive breastfeeding rates; 5 percent child wasting	Targeted nutrition interventions (micronutrient and protein supplementation, public provision of complementary food, promoting good health and hygiene) and selected nutrition-sensitive interventions (staple food fortification and pro-breastfeeding policies)	Benefit-cost analysis	Public, including ODA, and private, including household contributions and innovative financing mechanisms	**7**	**Not applicable**

* Total cost per person calculated as total net discounted cost over the 15 years period (only for the Achieving Zero Hunger, the time frame is 14 years, i.e. 2016-2030). The discount rate is assumed to be 5 percent, following Hoddinott, Rosegrant and Torero (2013). For each modelling framework, the absolute number of people lifted out of hunger by the proposed investments is calculated as the difference between the projected number of hungry people in the business as usual 2030 scenario and the projected number of hungry people in the 2030 investment scenario. These figures are retrieved from each model. The total cost per person of hunger eradication is then calculated as the total net discounted cost divided by the number of people lifted out of hunger. We calculate only the cost per person for the investments towards hunger reduction, but not for the investments towards improvement in nutrition due to the very specific nature and outcomes of each intervention.

Source: Adapted from Mason-D'Croz et al. (2019)

the burden of investment between various financing sources, and the sustainability of results beyond 2030, especially in the context of large economic, climatic or political shocks, is rarely considered in detail in the reviewed frameworks. In particular, the issue of how to spread investments over time is not discussed in much detail in any of the models; instead, the costing estimates are presented in terms of annual averages. However, this has serious implications not only for the resource mobilization strategy and therefore the feasibility of timely investments, but can also affect the economy-wide outcomes of the intervention.

Another question is how to allocate limited financial resources between the various SDGs and the development targets specific to SDG 2. Of course, the case for investing in hunger eradication is evident, as the right to food is considered to be among the most basic of human rights. However, in the context of scarce financial resources, the potential synergies between different objectives, as in the case of eradicating hunger (SDG 2) and poverty (SDG 1), need to be found; and on the other hand, potential conflicts, for example between doubling agricultural productivity (SDG 2.3) while preserving the natural environment (Sachs et al., 2019), e.g. ensuring sustainable food production systems (SDG 2.4), need to be addressed to make the proposed investment strategies efficient. Additionally, the long-term sustainability of the proposed investment frameworks are rarely explicitly addressed. The time horizon of the models ends in 2030, aside from the Investment Framework for Nutrition which ends in 2025. The latter is the only one to include a 5-year maintenance period (2021-2025); in general, however, the question of how to sustain the results beyond 2030 is not discussed. In the broader frameworks, like the Achieving Zero Hunger or MIRAGRODEP frameworks, the implicit assumption is that pro-poor investments in agriculture and their expected long-term economy-wide growth effects will be sufficient to maintain zero or 5 percent hunger levels worldwide. While this might hold if the proposed frameworks' scenarios hold, the reduction in hunger might be reversed in the case of major economic, climate or political shocks, as the last decade has proven (FAO, 2018). Only the IMPACT model includes the effects of climate change in its modelling framework; and none of the models discuss the challenges of achieving zero hunger in fragile states, i.e. conflict and post-conflict states.

The question of where to find the financial resources for the proposed investments and to which extent such investments can be sustained over several decades is only broadly discussed in the models reviewed here. The emphasis is mainly on public finance, and for a reason: a big proportion of investments relate to the domain of public goods that would be heavily under-invested if financed from private sources (Mason-D'Croz, 2019); also, social protection programmes fall within the range of government responsibilities. For example, the Achieving Zero Hunger model suggests that on average, 60 percent of investments should be financed by the public sector; in the IMPACT, MIRAGRODEP, and the framework by Torero and von Braun (2015), the full amount of investment should be provided by the public sector. Only the MIRAGRODEP, as a CGE model, explicitly models domestic taxation: in light of insufficient domestic public resources, it makes a case for donor support with the ODA share varying based on the recipient countries' income. Torero and von Braun (2015) suggest that G7 countries should consider sharing the estimated costs in proportion to their GDP, i.e. 50 percent.

Last but not least, the potential of the private sector is insufficiently accounted for. Only the Achieving Zero Hunger and the Investment Framework for Nutrition include investment financing by the private sector in their frameworks, but this form of finance is not always directly modelled. A significant methodological improvement is the consideration of domestic private financing: the Achieving Zero Hunger framework discusses investments by farmers and the Investment Framework for Nutrition mentions contributions by households. In particular, in the former, the potential effects of social protection programmes and pro-poor investments on asset accumulation and the future investment potential of the poor are discussed. On the other hand, none of the models explicitly accounts for the potential of Foreign Direct Investment (FDI) as a potential source of financing towards hunger eradication. Indeed, as noted in FAO, IFAD and WFP (2015), while some of the estimated financing needs might be too high in comparison to public sector financing capacity, they constitute a very small proportion of the global GDP: for example, the US$ 265 billion per year is only 0.3 percent of the projected world GDP.

6.2 A Food Systems Approach to Reducing Hunger and Child Malnutrition

Despite continued global agricultural output growth since the 1960s, food insecurity still persists, albeit with huge differences between countries, within countries and even households (FAO, IFAD, & WFP, 2015). Agriculture-focused interventions alone will not be enough to achieve the goal of sustainable food security. Developing a sustainable food system would mean a shift from an agriculture-centred approach to a multi-sectoral approach hinged on sustainability. A sustainable future largely depends on a sustainable food system that provides food security and nutrition without compromising the social, economic and environmental futures for the generations to come (HLPE, 2014).

Performing food systems analysis using a multi-sectoral approach entails a simultaneous assessment of the relevant processes that influence food availability, access, utilization and stability, along with the roles and interactions of stakeholders. This exercise poses significant ramifications, as it requires the consideration of multiple and sometimes conflicting objectives in addition to some external factors influencing the dynamics of food systems, such as demography, urbanization, economic growth and climate change. Otherwise, changes or improvements targeted at one part of the system might have detrimental effects on one or more parts of the entire food system. Consequently, it is important when using a multi-sectoral or cross-disciplinary approach to also estimate the potential synergies and trade-offs between all the factors – both internal and external – that pertain to the food system (Ruben, Verhagen & Plaisier, 2019).

This study pursues a multi-sectoral approach to food systems analysis to identify the intervention options and investments needed to alleviate hunger or undernourishment and child malnutrition. In addition to adequate food access, additional nutrition-specific interventions such as disease prevention, micronutrient supplementation, and staple food fortification are important for enhancing child growth (Bhutta et al., 2013; Shekar et al., 2017). The prevalence of undernourishment (or hunger) (PoU) is defined as the proportion of the population whose habitual, daily, per capita Dietary Energy Consumption (DEC) level is lower than their dietary energy requirement (Cafiero & Gennari, 2011). A lognormal distribution function of the dietary energy intake is used to calculate the PoU. The lognormal function is constructed considering the average level of DEC and a measure of inequality on this level of consumption (the coefficient of variation or CV). The average DEC is measured as a ratio of total food available for consumption – derived from the country's Food Balance Sheets – by the number of people in the population. The CV is estimated from food consumption data collected in nationally representative population surveys, when available, and interpolated for the years between surveys. Taking the lognormal distribution function of the dietary energy intake and minimum dietary energy requirement (MDER) into consideration, it is possible to calculate the percentage of the population at risk of hunger (the area below the lognormal functional curve and less than the MDER line) (FAO et al., 2019).

Following the above definition of hunger, it can be seen that improved access to food for consumers is key for hunger eradication. Yet, food access depends on multiple factors along the food supply chain and governance measures for the proper functioning of the chain. The four dimensions or components of food security are food availability, food access, food affordability, and food stability. In economic terms, food availability matches with food supply, and food access and affordability with food demand. Food stability reflects the dynamics in food demand and supply systems and reminds us of the importance of taking into consideration seasonal or temporary food prices and scarcity shocks in hunger prevention policies. Market platforms and infrastructure (roads, storage, etc.) to connect the supply (production) system with the consumption (access) system is also important for food security. Overall, infrastructural and institutional platforms (energy access, water access) are essential for the proper functioning of the entire food supply chain (supply, distribution, and access). Hunger and child malnutrition reduction measures can thus be grouped into:

1. Food supply management measures,
2. Market platform and infrastructure improvement measures,
3. Food demand management measures,
4. Interventions with nutrition-specific and nutrition-sensitive measures.

Each of the four domains include several sub-measures or options. Food supply can be enhanced by multiple options that can enhance crop and livestock yields. For instance, high yield crop varieties and livestock breeds relevant to a particular environment can enhance food supply. Agricultural research activities play an important role in inventing the new varieties and breeds and for improving production management. Proper management of soil, water, chemicals (fertilizer, pesticides, etc.), machinery, and labour are essential for preventing potential crop yield losses at the farm level because of soil nutrition depletion, drought, diseases, and pests.

Market platform and infrastructure improvements help in reducing post-harvest losses. Improved storage systems, better roads, availability of food processing, and proper food distribution systems (supermarkets, food markets) can greatly improve access to food by consumers. Trade rules at the international and intra-national level also greatly impact on food access. Some infrastructural improvements such as electricity access and information and communication technologies (ICTs) can improve food supply, distribution and access systems. For example, using mobile phones, farmers can access information about the weather and market conditions, allowing them to better manage water resources and fetch higher prices for their produce. ICT and storage systems are also important to plan and predict food supplies and hence, stabilize food market prices.

Demand-side measures to improving food access relate to reducing household food waste and improving the consumers' ability to get adequate food. Education campaigns may work to change food consumption and waste behaviour. Improved incomes and purchasing capacity of the population can improve food affordability. For some marginalized groups with inadequate income and informal jobs, social security programmes such as food vouchers and financial assistance can be considered. Severe cases of child malnutrition, caused by nutrient insufficiency and certain diseases, require nutrition-specific interventions. Normal child growth can be maintained with iron supplements to cure anaemia, and various vitamin supplements to decrease nutritional deficiencies. The specific intervention options considered in this study are described in detail in the next section.

6.3 Marginal Abatement Cost Curve Approach and Investment Scenario Assumptions

Policymakers need to prioritize the allocation of resources to competing hunger-reduction measures by identifying the sets of least cost investment options that have the potential to yield the greatest reduction in hunger and malnutrition in a defined time horizon. It is therefore essential that policymakers and practitioners can compare the different hunger and malnutrition reduction measures and make economically efficient investment decisions. In this regard, Marginal Abatement Cost Curves (MACC) can be helpful as a policy tool in ranking investments options. Applications are common in the economic assessment of climate change mitigation options or for water policies. Marginal Cost Curves (MaCC) provide an effective way of visualizing action against hunger that can initiate economic discussion of cost-effectiveness and hunger reduction potential. This section aims at developing a realistic and policy-relevant global marginal cost curve (MaCC) of different hunger and malnutrition reduction measures to assess their cost-effectiveness and contribute to the evaluation of which actions should be prioritized and implemented to achieve targets 2.1 and 2.2 of SDG 2 by 2030. This section starts with a literature review dedicated to explaining the main elements of the MaCC and the key steps followed in developing the MaCC, including a detailed discussion on the reference and investment scenario assumptions used to build the MaCC.

6.3.1 The Marginal Cost Curve and Key Steps of the Process

The MaCC represents the relationship between the cost-effectiveness of different hunger reduction interventions and the hunger reduction potential of each intervention. It reflects the additional costs of lifting people out of hunger and malnutrition by each intervention. In this study, the global hunger reduction MaCC is developed by first identifying the variety of intervention options that can effectively reduce hunger and malnutrition, and then by determining the cost and hunger reduction potential of the interventions based on a systematic review and integrated evaluation of model-based or intervention studies. Through the systematic review, two key parameters are compiled from existing studies to compute the hunger and malnutrition reduction potential of each intervention: (1) food security enhancement potential in terms of additional food supply, income, or prevented levels of undernourishment (reduction in the population at risk of hunger and the number of undernourished children (stunted children below the age of 5) due to the interventions); and (2) the cost of implementing the interventions. While these parameters were readily found in the literature for some of the interventions, additional calculations or assumptions based on expert assessments were considered for others.[31] Finally, the interventions are ranked from the cheapest to most expensive, based on their marginal costs (the per-unit cost of lifting an individual out of hunger or malnutrition) to represent the cost of achieving incremental levels of hunger and malnutrition reduction.

6.3.2 Reference Scenario

In a MaCC based economic assessment of investment options, reference scenarios are built either based on a "no change" scenario, using historical trends to forecast the future, or based on models that provide a forecast of the future. The cost and hunger reduction potential of the various investment options considered in this study are also analysed relative to a "business as usual" scenario, employing a reference scenario of investments, hence marginal, wherein the costs of investments are assumed to remain frozen or grow following historical trends. The costs in the reference scenario include all investments required to achieve the projected level of implementation of the intervention options by 2030, including the capital, operational, and programme costs where applicable.

Model-based foresight exercises, as reviewed in the previous section, highlight how food and agricultural

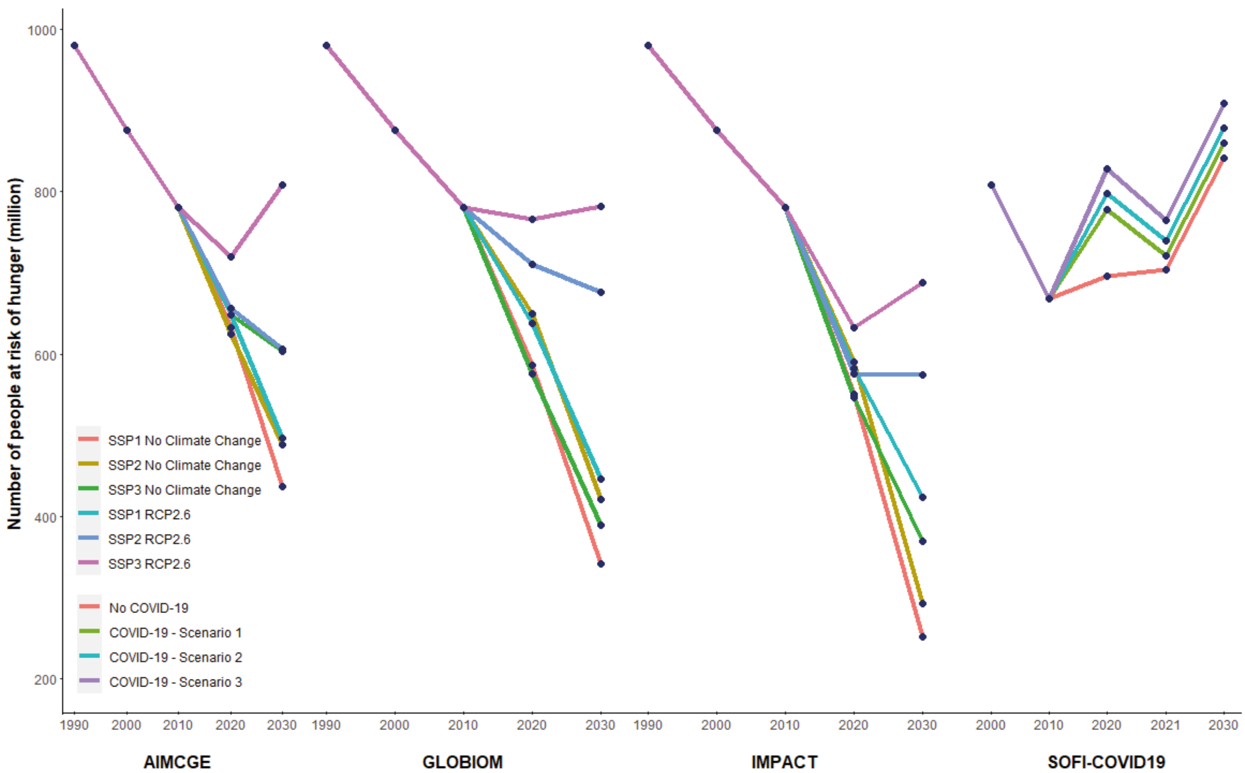
31 As a result, the assumptions behind the potential reduction in hunger and malnutrition and cost-effectiveness differs across the individual interventions.

systems could evolve in an inherently uncertain future. These foresight exercises provide alternative scenarios on food security in which challenges are addressed to varying degrees, building on historical trends of factors that determine the performance of socio-economic and environmental systems. According to the bio-economic model-based assessments of AIM/CGE, GLOBIOM and IMPACT, under various climatic and socio-economic development scenarios the world will be home to between 250 to 810 million undernourished people in 2030 (Figure 10). If population growth were to be largely controlled, high economic growth rates (SSP1) maintained and climate change effects neglected (black lines), the number of undernourished people would be reduced to between 251 to 437 million. Yet, when climate change (RCP2.6) is considered in the modelling assessments the number of undernourished people is expected to be between 293 and 497 million (grey lines). Under the worst scenario, with high population growth, economic stagnation, high-income inequality (SSP3), and a climate change impact (RCP2.6), the number of undernourished people is expected to be between 680 and 808 million (Hasegawa et al., 2018). All three modelling assessments indicate similar trends of hunger reduction under various socio-economic and environmental changes. Yet, the magnitude of the reduction differs across the modelling assessments and under none of them is the target of Zero Hunger achieved.

Finally, the worst scenarios of the projected number of undernourished people in 2030 lie close to those presented in chapter 2, i.e. about 840 million. The projected situation in 2030 presented in section 2 reflects the trends in recent years, without considering the impact of the COVID-19 pandemic. The pandemic is expected to further accelerate the projected increase in the number of hungry people, at least in the immediate future as discussed in section 3.2.1. These projections reinforce the need for urgent action to get back on track towards achieving the Zero Hunger goal.

In our analysis presented in this chapter, three IMPACT model-based projections, from the study by Rosegrant et al. (2017), are used as a reference scenario for the population at risk of hunger in 2030. The IMPACT model indicates the most optimistic food security outlook in 2030. Its scenarios were selected because of the availability of detailed descriptions of the model, the assumptions and the cost of intervention options. Rosegrant et al. (2017) used IFPRI's IMPACT model together with a global computable general-equilibrium model (GLOBE) and several linked post-solution models to evaluate investment requirements, land-use changes, greenhouse gas (GHG) emissions, biodiversity, water quality, and micronutrient availability and dietary diversity. In addition to the climate change assumptions, Rosegrant et al. (2017) consider investment in agricultural research and development (agricultural R&D), water resource management,

Figure 10: Hunger levels expected under various socio-economic and climate change scenarios



Source: Authors' own elaboration based on Hasegawa et al. (2018).

and infrastructure in all three reference scenarios. The projections of these investments in the baseline scenarios are based on historical trends and expert opinions of long-term developments in the agricultural sector. Investments in water resource management are modelled endogenously combining the IMPACT model with a suite of water models. The climate change reference scenario estimated using the HADGEM2-ES model serves as the main reference point for this analysis.

6.3.3 Opportunities of Investments in Policies and Programs for Hunger and Malnutrition Reduction

In this section, the inputs and details used in computing the parameters for the development of the MaCC of global hunger and malnutrition are presented briefly to make all of the assumptions transparent and avoid the common critique, inherent in MaCC, of a lack of transparency. Table 17 provides an overview on each intervention and the related calculations. Given that the cost and hunger reduction potential of each intervention is compiled from existing studies, the discussion of the assumptions closely follows those given in the original studies. The details are presented in Annex 4.

Table 17: Investment options for hunger and child malnutrition reduction and investment scenarios assumptions

	Interventions	Sources	Calculations and assumptions
1	Agricultural R&D	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of increased investments in the CGIAR plus increased complementary investments in national agricultural research systems (NARS), where US$ 1.97 billion and 0.99 billion per year is invested by the CGIAR and NARS respectively.
2	Agricultural R&D efficiency enhancement	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of higher CGIAR research efficiency so that the yield impact of investments is 30 percent higher. Agricultural R&D efficiency enhancement scenario is assumed to cost 30 percent of the annual average incremental investment in agricultural R&D with a total of 0.89 billion.
3	Agricultural extension services	FAO et al. 2019; Ragasa & Mazunda, 2018; Ecker & Qaim, 2011; Blum & Szonyi, 2014; World Bank, 2020a	Hunger-reduction potential of increased investment in extension service is estimated for 38 low and lower-middle-income countries using the methodological note for calculating PoU and the impact of extension services on DES estimated based on Ragasa and Mazunda's (2018) estimate of 36 percent increase in value of farm production and Ecker and Qaim (2011) estimate of the elasticity of dietary energy supply (calories) to income of 0.66. Based on Blum and Szonyi, (2014), the implementation cost is assumed to be 1 percent of the 38 low and lower-middle-income countries GDP in 2019 (based on WDI in 2019 (World Bank, 2020a)).
4	Irrigation expansion - Large-scale irrigation expansion	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of large-scale irrigation expansion in developing countries by 2030, with projected irrigated expansion of 20 million hectares roughly offset by a reduction of 22 million hectares of rainfed agriculture.
5	Irrigation efficiency enhancement	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of a 15-percentage point increase in basin efficiency by 2030 based on water infrastructure investment and water management improvement in food production units.
6	Irrigation expansion - Small scale irrigation expansion in Africa	FAO, 2020a; You et al., 2011; Passarelli et al., 2018; Ecker & Qaim, 2011	Hunger-reduction potential of increased investment in small-scale irrigation expansion in Africa is estimated using the methodological note for calculating PoU and the impact of the expansion on DES estimated based on estimates in Passarelli et al. (2018) of 2.5 times increase in agricultural income and in Ecker and Qaim (2011) of the elasticity of dietary energy supply (calories) to income of 0.66. The total annual cost of the expansion is assumed to be US$ 3.8 billion per year based on the estimate by You et al. (2011).
7	Soil-water management	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of technologies such as no-till agriculture and water harvesting that increase the water holding capacity of soil or make precipitation more readily available to plants.
8	Crop protection - insects	Rosegrant et al., 2014	Using DSSAT and IMPACT models, simulates hunger-reduction potential of investments to reach 50 percent adoption rate of crop protection from insects. To calculate the cost, we assume the technology is implemented on 175 Mha with US$ 50 per ha cost.
9	Crop protection - diseases	Rosegrant et al., 2014	Using DSSAT and IMPACT models, simulates hunger-reduction potential of investments to reach 50 percent adoption rate of crop protection from diseases. To calculate the cost, we assume the technology is implemented on 175 Mha with US$ 40 per ha cost.
10	Crop protection - weeds	Rosegrant et al., 2014	Using DSSAT and IMPACT models, simulates hunger-reduction potential of investments to reach 50 percent adoption rate of crop protection from weeds. To calculate the cost, we assume the technology is implemented on 175 Mha with US$ 60 per ha cost.

11	Nitrogen-use efficiency	Rosegrant et al., 2014	Using DSSAT and IMPACT models, simulates hunger-reduction potential of investments to reach 75 percent adoption rate of nitrogen-use efficiency. To calculate the cost, we assume the technology is implemented on 175 Mha with US$ 500 per ha cost.
12	Integrated soil fertility management	Rosegrant et al., 2014	Using DSSAT and IMPACT models, simulates hunger-reduction potential of investments to reach 40 percent adoption rate of integrated soil fertility management. To calculate the cost, we assume the technology is implemented on 175 Mha with US$ 100 per ha cost.
13	Optimal crop planting and varieties (Climate change adaptation)	Hasegawa et al., 2014	Using the AIMCGE model, simulates the hunger-reduction potential of investment in climate smart agriculture adaptation (optimal crop planting pattern and improved crop varieties). The implementation cost is assumed to be 10 percent of the value of the additional food supply gained from adopting climate smart agriculture.
14	Soil Carbon Sequestration (Climate change mitigation)	Lal, 2011	Simulates the hunger-reduction potential of investment in soil carbon sequestration to reduce 2.1 billion tons C per year with US$ 50 per ton per annum SOC sequestration cost.
15	ICT - Agricultural information services	Hoddinott, Rosegrant, & Torero, 2013; FAO et al., 2019	Hunger reduction potential of improved access to market information through ICT is estimated by extending Hoddinott, Rosegrant & Torero's (2013) poverty reduction estimates in six countries to cover 69 low and lower-middle income countries and then converting the poverty reduction estimates to hunger-reduction using an estimated correlation coefficient of 0.68 (FAO et al., 2019).
16	Infrastructure (Road, Rail, Electricity)	Rosegrant et al., 2017	Using the IMPACT model, simulates the hunger-reduction potential of a mix of infrastructure improvements in developing countries, focusing primarily on improvements to transportation infrastructure (road building, road maintenance, and railroads) and increased rural electrification.
17	Food loss reduction along the value chain	Rosegrant et al., 2015	Using the IMPACT model, simulates the hunger-reduction potential of increased investments in post-harvest reduction assuming a scenario of 10 percent reduction in the post-harvest loss is maintained globally by 2030 through increased investments in infrastructure.
18	International trade - Completing the Doha Development Agenda (DDA)	Anderson, 2018; FAO et al., 2019	Hunger-reduction potential of enhancing international trade is estimated converting Andersons's (2018) poverty reduction estimate of about 160 million using a correlation coefficient of 0.68 (FAO et al., 2019). Following Anderson (2018), 5 percent of the estimated annual comparative static benefit of 2025 is assumed to be the adjustment cost of the trade reform for the period of ten years, amounting to an annual total investment of US$ 30 billion.
19	Intra-African trade - African continental Free Trade Area (AfCFTA) agreement	World Bank, 2020b; FAO et al., 2019; Anderson, 2018	Hunger reduction potential of AfCFTA is estimated converting World Bank's (2020b) poverty reduction estimate of 30 million by 2035. The poverty reduction by 2030 is first calculated using linear interpolation and converted into hunger reduction using a correlation coefficient of 0.68 (FAO et al., 2019). To estimate the implementation cost of AfCFTA, we follow Anderson (2018) in assuming 5 percent of the economic gains from the continental free trade agreement estimated to be US$ 450 billion by 2035 in the study by World Bank (2020b) over ten years period. Then, the adjustment cost of the trade reform is then assumed to be US$ 2.25 billion per year.
20	Social protection - Scaling up existing programmes	FAO et a., 2020; Hidrobo et al., 2018; reviewed papers in Table A8	Based on systematic reviews of cost-effectiveness studies of social protection programmes across different countries, the minimum per dollar cash transfer cost of per capita is identified at US$ 35.7 and used to calculate the annual per capita cost of scaling existing programmes. Based on the review of the current coverage of social protection programmes, we estimated that about 103.1 million people could be targeted.
21	Social protection - Establishing new programmes	FAO et al., 2020; Hidrobo et al., 2018; reviewed papers in Table A8	Based on systematic reviews of cost-effectiveness studies of social protection programmes across different countries, the maximum per dollar cash transfer cost per capita is identified at US$ 88.9 and used to calculate the annual per capita cost of scaling existing programmes. Based on the review of the current coverage of social protection programmes, we estimated that about 103.1 million people could be targeted.
22	COVID-19 - Social protection	FAO et a., 2020; Hidrobo et al., 2018; reviewed papers in Table A8	Following the less pessimistic COVID-19 impact scenario estimated by FAO et al. (2020) and on the systematic reviews of cost-effectiveness studies of social protection programmes across different countries, the maximum per dollar cash transfer cost per capita is identified at US$ 88.9 and used to calculate the annual per capita cost of scaling existing programmes. Based on the less pessimistic scenario of COVID-19 impact on hunger estimated by FAO et al. (2020), we estimated that about 137.9 million people could be targeted.

23	Nutrition program	Shekar et al., 2017	Using the LiST tool, simulates increased investment in scaling up 7 nutrition specific interventions to 90 percent coverage in 37 countries that account for 90 percent of the stunted children globally to reduce stunting among children below 5 years of age. Stunting reduction is converted into hunger reduction using an estimated correlation coefficient of 0.997.
24	Female literacy improvement	Smith & Haddad, 2015; Shekar et al., 2017; World Bank, 2020a	Stunting reduction potential of investment in women's education is estimated using Smith and Haddad's (2015) elasticity of stunting to female secondary school enrolment (-0.166) for 37 countries that account for 90 percent of the stunted children globally with an assumption that the female secondary enrolment rate between 2011 and 2015 is maintained over the next ten years, which is about 6.66 million additional female students enrolled at a per capita cost of US$ 130. Stunting reduction is then converted into hunger reduction using an estimated correlation coefficient of 0.997.

Source: Authors' own elaboration.

6.3.4 Investments to Reduce Hunger and Malnutrition: Marginal Cost Curve Results

The MaCC consisting of various hunger and malnutrition reduction measures is presented in Figure 11. Overall, the measures included in the MaCC have the potential to lift over a billion people out of hunger and malnutrition over ten years between 2020 and 2030. To meet the G7 commitment of lifting 500 million people out of hunger and malnutrition by 2030, an average annual investment ranging between about US$ 11 to 14 billion will be required for a mix of least-cost intervention options –agricultural R&D efficiency enhancement, agricultural extension services, agricultural R&D, ICT - agricultural information services, small-scale irrigation expansion in Africa, female literacy improvements, and scaling up existing social protection (Table 18).

Following the 2030 hunger projection by FAO et al. (2020) and taking the preliminary estimates on the impact of COVID-19 on hunger (based on the second scenario) into consideration, the global goal of ending hunger by 2030 may require an investment of about US$ 39 to 50 billion to lift about 840 to 909 million people out of hunger. Table 18 presents the combined or cumulative hunger reduction potential and the costs of the different investment options considered in this analysis.

As illustrated in Figure 11, investing in agricultural R&D efficiency enhancement, agricultural extension services, 'ICT - Agricultural information systems', are low cost options that have a relatively large hunger-reduction potential. Scaling up existing social protection programmes and establishing new programmes to serve food insecure households can reduce the number of people at risk of hunger by about 206.2 million at an annual per capita cost of about US$ 35.7 and US$ 88.9 per undernourished. To address the potential increase in the number of people at risk of hunger estimated in 2020 and 2021 of about 137.9 million, an additional US$ 12.3 billion will need to be spent in social protection.

Investments in 'African Continental Free Trade Area (AfCFTA) agreement', 'Food loss and waste reduction', 'Irrigation efficiency enhancement', improvements in international trade (completion of the DDA), 'Infrastructure', 'Soil-water management', and 'Large-scale irrigation expansion' can considerably decrease undernourishment by about 232.2 million. These hunger-reduction measures are relatively expensive investment options that require a longer time for implementation and hence would need to be frontloaded earlier in the decade to have a large effect soon before 2030. They also have much broader development impacts beyond reduction of hunger. The same applies to interventions related to climate adaptation such as optimal crop planting practices and adoption of improved crop varieties, and improving soil nutrient content by soil carbon sequestration measures that improve food supply and consequently reduce the number of people facing the risk of undernourishment

With regards to investments to reduce child malnutrition (stunting among children below the age of 5 years), while investment in women's education provides the least cost option, investment in nutrition-specific investments can significantly reduce the number of stunted children by about 30 million at a total incremental average cost of about US$ 5 billion per year. Taking all of the other hunger-reduction measures together (see Table 18), the number of stunted children could be reduced by about 40 million.

As the cost of each intervention is assumed to be fixed per undernourished person lifted out of hunger, the marginal cost curve appears like a step function. In reality it can be assumed that each intervention has a decreasing impact with increasing investments in terms of hunger reduction. Due to these scaling effects, it is not surprising that the additional cost of reducing the number of undernourished people increases with the number of undernourished people lifted out of hunger. Lifting the first group of people out of hunger requires less investment, than the last group of hungry.

Table 18: Hunger reduction potential of interventions and cost of implementation from 2020 to 2030

Least-cost Rank	Interventions	Reduction in number of people at risk of hunger (Million)	Reduction in number of people at risk of hunger (Cumulative, Million)	Average annual incremental investment cost (US$ Million)	Average annual incremental investment cost (Cumulative, US$ Million)	Average annual incremental investment costs per individual rescued from risk of hunger (US$)
1	Agricultural R&D efficiency enhancement	69.9	69.9	888	888	12.7
2	Agricultural extension services	81.5	151.4	2096	2984	25.7
3	ICT - Agricultural information services	26.6	178.0	698	3682	26.2
4	Small-scale irrigation expansion in Africa	142.3	320.3	3790	7472	26.6
5	Agricultural R&D	92.0	412.3	2960	10432	32.2
6	Female literacy improvement	2.6	414.9	87	10518	33.1
7	Social protection - Scaling up existing programmes	103.1	518.0	3676.8	14195	35.7
8	Crop protection - Insects	10.1	528.0	700	14895	69.7
9	Social protection - Establishing new programmes	103.1	631.1	9158	24053	88.9
10	COVID-19 - Social protection	137.9	769.0	12255	36308	88.9
11	Crop protection - Diseases	8.8	777.8	875	37183	99.4
12	Integrated soil fertility management	16.6	794.4	1750	38933	105.1
13	Crop protection - Weeds	9.4	803.8	1050	39983	111.7
14	Trade - African Continental Free Trade Area (AfCFTA)	15.3	819.1	2250	42233	147.1
15	Nitrogen-use efficiency	56.5	875.6	8750	50983	154.9
16	Nutrition-specific interventions	30.9	906.6	4950	55933	160.0
17	Food loss reduction	36.0	942.6	8580	64513	241.7
18	Irrigation efficiency enhancement	18.6	961.2	4590	69103	246.3
19	Trade - Doha Development Agenda	108.8	1070.0	30000	99103	275.7
20	Infrastructure (Road, Rail, Electricity)	33.8	1103.8	10810	109913	320.0
21	Soil-water management	12.2	1116.0	4580	114493	374.5
22	Irrigation expansion - Global large-scale irrigation expansion	7.6	1123.6	3520	118013	473.4
23	Optimal crop planting and varieties (Adaptation)	9.7	1133.3	13300	131313	1371.1
24	Soil Carbon Sequestration (Mitigation)	36.4	1169.7	64000	195313	1758.2

Source: Authors' own elaboration.

6.3.5 Strength and Limitations of the Marginal Cost Curve Approach

MaCC can be used to identify promising policies and programmes for investment. This facilitates priority setting by governments and investment stakeholders from the private sector and civil society. An advantage of MaCC analysis is also its transparency. However, the concept has some limitations. These limitations have been highlighted in the climate change mitigation literature (Kesicki & Ekins, 2012; Bockel et al., 2012; Eory et al., 2018).

One of the limitations relates to the fact that the MaCC presents the incremental cost of reducing hunger and malnutrition for a single point in time. Hence, it cannot capture intertemporal dynamics, synergies, and interactions among interventions. Another aspect is that the MaCC concentrates on hunger and malnutrition reduction and thus attributes the entire cost of the interventions to hunger and malnutrition reduction. This is an overestimation in terms of economic cost-benefit considerations, as most of the interventions considered in this analysis generate various ancillary benefits, including reducing poverty and enhancing health, environmental sustainability, and education. Nevertheless, the MaCC can be considered useful for an assessment of various potential interventions to reduce hunger based on a synthesis of studies from different fields based on multiple methodologies.

6.3.6 Future Research Needs

The global hunger and malnutrition MaCC presented in this chapter provides a straight forward way of identifying options for action against hunger compared with more complex economic model-based analysis. Additionally, this type of analysis can be adapted to national and regional level to help policymakers prioritize cost-effective and least-cost hunger reduction measures for specific developing countries or regions.

Additional analysis – for example at continental or perhaps nation state levels – is warranted for prioritizing the measures for implementation and setting policies to promote them. Additional studies could focus on extending the analysis by identifying additional cost-effective measures in specific country contexts which can further contribute to hunger and malnutrition reduction. Technical and behavioural challenges to implementing the identified least-cost measures need to be considered in the prioritization process, despite their economic attractiveness.

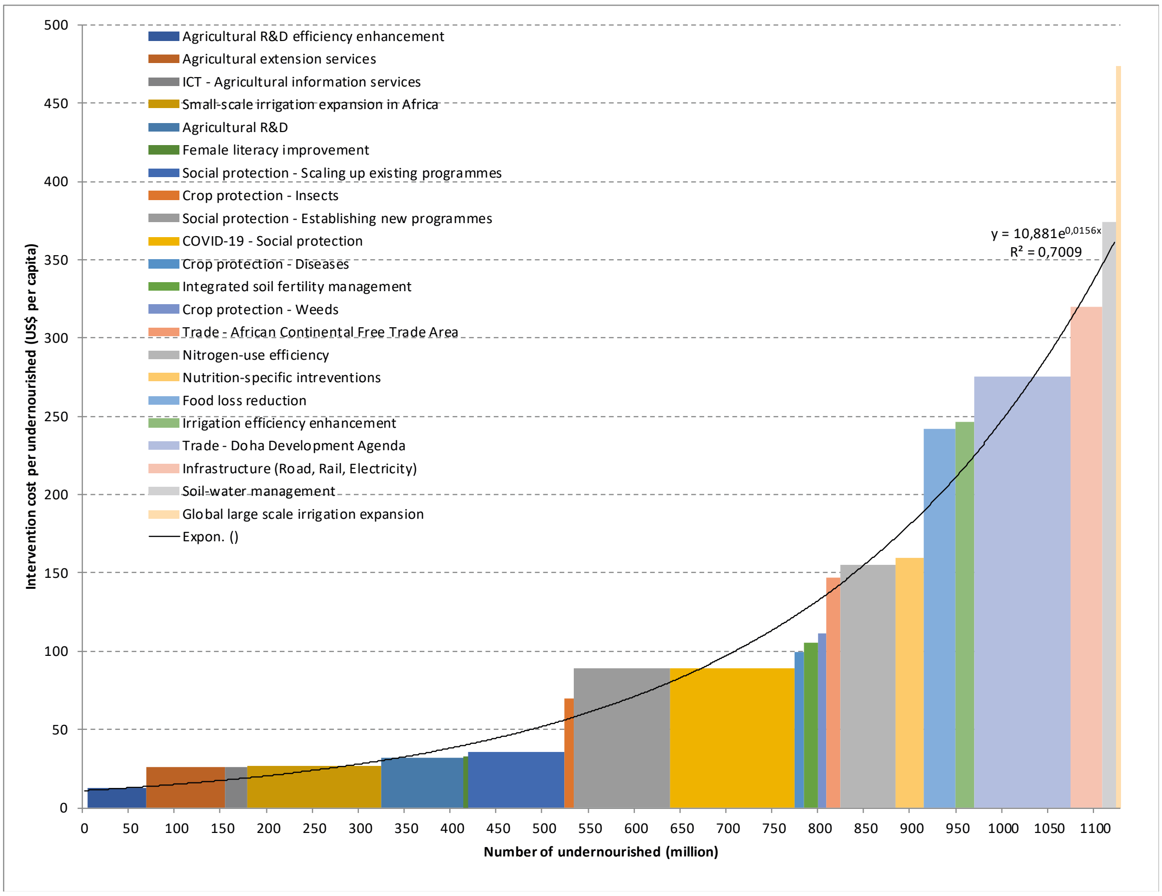
Table 19: Child malnutrition reduction potential of interventions from 2020 to 2030

Interventions	Reduction in number of stunted children (million)
Agricultural R&D	3.97
Agricultural R&D efficiency enhancement	3.33
Irrigation expansion - Global large-scale irrigation expansion	0.26
Irrigation efficiency enhancement	0.77
Soil-water management	0.51
Crop protection – Diseases	6.01
Crop protection – Insects	6.10
Crop protection – Weeds	6.05
Integrated soil fertility management	4.57
Nitrogen-use efficiency	3.97
Food loss reduction	2.35
Infrastructure (Road, Rail, Electricity)	1.41
Female literacy improvement	2.61
Nutrition-specific interventions	31.01

Notes: See Table 18 for the average annual incremental investment cost of interventions.

Source: Authors' own elaboration.

Figure 11: Marginal cost curve of the suggested interventions to eradicate hunger and malnutrition



Note: The MaCC for hunger shows the cost of each hunger reduction measure such that each bar represents a single intervention where the width shows the number of individuals lifted out of hunger, the height its associated per-capita cost, and the area its associated total cost. The total width of the MaCC reflects the total hunger reduction possible from all interventions, while the sum of the areas of all of the bars represents the total cost of reducing hunger and stunting through the implementation of all interventions considered. The positions of the bars along the MaCC reflect the order of each intervention by their cost-effectiveness. When moving along the MaCC from left to right, the cost-effectiveness of the interventions worsens as each next intervention becomes more expensive than the preceding.

Source: Authors' own elaboration.

While most of the parameters used in building the global hunger MaCC are compiled from system- and economy-wide model-based studies, the cost and hunger reduction potential of several interventions were assessed based on a specific and large-scale cost-effectiveness studies. A next step, in this respect would be to evaluate the various measures using economy-wide modelling that could capture synergies and trade-offs between the different measures, as well as risks and uncertainties. Theoretically that would be an advantage, but it remains difficult to embed the level of granularity and programmatic detail in such modelling, as pursued with the 24 interventions considered in the MaCC approach here. Yet additional sensitivity analysis and interpretation of the different results would be helpful to policymakers to support their decision-making.

6.4 Policy Implications of MaCC Analyses

This chapter has synthesized the findings of various model- and cost-benefit analysis-based studies on food and nutrition security interventions to assess the expected levels of the undernourishment and malnutrition and the costs of achieving zero-hunger by 2030. The most recent State of Food Security and Nutrition in the World estimated levels of undernourishment by 2030 to be about 840 million without considering the impact of COVID-19, or 879 million when considering a moderate impact of COVID-19 on hunger.

MaCC analyses are a basis for policy strategies and policy mobilization. The MaCC for hunger reduction developed by synthesizing the outcomes of multiple studies indicates the overall potential of the interventions identify what it takes to end hunger by 2030. Considerable investment is required, but it is a question of political commitment to get the finance mobilized at national and global levels and the actual investments implemented in sound ways. Compared to the hundreds of billions of US$ for economic rescue packages to mitigate COVID-19 in many OECD countries, the investments to end hunger presented in this analysis are rather modest. The results from the MaCC indicate that:

- Achieving targets 2.1 and 2.2 of SDG 2 need not be prohibitively expensive, provided that a mix of least-cost measures with large hunger reduction potential are prioritized.
- Investments with long-term effects should be frontloaded in the decade to have a large effect soon before 2030.
- To end hunger by 2030, options that require high up-front investments but also have a high long-term impact need to be in the investment mix.
- Overall, the measures included in this MaCC analysis have the potential to lift about a billion people out of hunger and malnutrition over ten years till 2030.
- The G7 should not just target their investments at least-cost or focus on short-term interventions but should consider a portfolio of short- and long-term investments, such as female literacy, agricultural R&D, social protection, food loss reduction, and trade policy reforms.

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ANNEXES

Annex 1: Boxes to Chapter 1

Box 1: Extract from the Leaders' Declaration, G7 Summit, 7-8 June 2015 – food security

Food Security

Good governance, economic growth and better functioning markets, and investment in research and technology, together with increased domestic and private sector investment and development assistance have collectively contributed to increases in food security and improved nutrition.

As part of a broad effort involving our partner countries, and international actors, and as a significant contribution to the Post 2015 Development Agenda, we aim to lift 500 million people in developing countries out of hunger and malnutrition by 2030. The G7 Broad Food Security and Nutrition Development Approach, as set out in the annex, will make substantial contributions to these goals. We will strengthen efforts to support dynamic rural transformations, promote responsible investment and sustainable agriculture and foster multisectoral approaches to nutrition, and we aim to safeguard food security and nutrition in conflicts and crisis. We will continue to align with partner countries strategies, improve development effectiveness and strengthen the transparent monitoring of our progress. We will ensure our actions continue to empower women, smallholders and family farmers as well as advancing and supporting sustainable agriculture and food value chains. We welcome the 2015 Expo in Milan ("Feeding the Planet – Energy for Life") and its impact on sustainable agriculture and the eradication of global hunger and malnutrition.

Box 2: Targets of Sustainable Development Goal No. 2 – Zero Hunger

Targets of Sustainable Development Goal No. 2: Zero Hunger

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

2.A Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries.

2.B Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round.

2.C Adopt measures to ensure the proper functioning of food commodity markets and their derivatives, and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility.

Annex 2: Instrumental Variable Approach Employed in Chapter 4.5

Details on the instrument and econometric specification are described in Box 3 and 4 below. We refer to this estimate as zero-stage regression. The estimated aggregate supply of aid is then used as an excluded instrument in the first-stage regression of the main estimates detailed in Box 4. The choice of the variables for the zero-stage regression (equation (1)) follows the usual conditions of instrumental variables: they are expected to be strong determinants of the donor-recipient aid flows, while at the same time they need to satisfy the exclusion restriction, i.e. be exogenous and do not affect the PoU of the recipient country other than via supply of aid. We employ several donor characteristics and variables that describe the donor-recipient relationship that we expect to exogenously determine variations in aid flows to recipient countries. The supply-side approach has been used extensively in the aid-growth literature for instrumentation but has been subject to some concern. The validity of the approach depends on the selection of instruments in the zero-stage regression. To test the validity of our supply of aid instrument, we proceed in several steps: we present the results of the zero-stage regression (equation (1)) and show that the selected variables are good predictors of the supply of aid; we show that log of population ratio (and its interaction terms), which is the main predictor of the supply of aid meets the exclusion restriction, in line with Arndt et al. (2010); finally, we show that the conventional F-Test statistic of the first-stage regression (equation (3)) fails to reject the validity of exclusion restriction.

Box 3: Instrument - supply of aid

Drawing upon Arndt et al. (2010) and Arndt et al. (2015), as well as Rajan and Subramanian (2008), we use the supply of aid of donor d to the recipient country r as the instrument in the cross-sectional growth regression. The supply of aid is estimated from actual aid flow data:

$$\frac{Aid_{dr}}{Pop_r} = \beta_0 + \beta_1 COLONY + \beta_2 \log\frac{Pop_d}{Pop_r} + \beta_3 COLONY \times \log\frac{Pop_d}{Pop_r} + \beta_3 CURCOL + \beta_5 COMLANG + \beta_6 FE_d + \beta_7 DIST_{dr} e_{dr} \quad (1)$$

where COLONY is a dummy variable taking the value of one if the recipient country was ever a colony (of any country); CURCOL is a dummy variable taking the value of one if there is a contemporaneous "colonial" relationship of the recipient with the donor; COMLANG is a dummy variable taking the value of one if the recipient country uses the same language as the donor; POP is population size; DIST is the distance between donor and recipient, and FE_d are donor fixed effects. We construct this instrument based on data obtained from CEPII. Note that equation (1) is not the final instrument. Instead, we aggregate the supply of aid predicted by equation (1) over ODA recipients to obtain the instrument.

The earlier econometric analyses mainly focused on the aggregate impacts of agricultural ODA on hunger reduction and child malnutrition, without considering the specific channels through which agricultural ODA affects global hunger and malnutrition. As explained above, aid can influence food security through a range of direct and indirect impacts that flow through different transmission channels. However, accounting for all of the potential channels is not advisable as they are driven by public investment and ODA. Several studies in the aid – growth literature, where the data on both economic growth and ODA cover several decades, were able to include these indirect channels in a multivariate framework; e.g. by employing vector error regression models (Juselius et al., 2014). However, such exercise is not feasible in this case, as PoU data before 2000 is not necessarily comparable with later series.

Globally, low national income remains a major determinant of undernutrition and food insecurity (ZEF and FAO, 2020). During the period 2000-2017, few countries experienced a negative growth rate and one can establish a clear association between GDP growth and a reduction in hunger. According to FAO et al. (2019), 65 out of the 77 countries in which hunger increased between 2011 and 2017 had experienced an economic slowdown or downturn. Under Covid-19 conditions, this is now going to be much more wide-spread. Economic disruptions prolong and worsen the severity of food crises and impair the capacity of the state to mitigate food crises through policy responses (FAO et al., 2019). A slowdown in global economic growth through the COVID-19 pandemic, will, therefore, have significant implications for the fight against hunger as the discussion and analysis in section 3.2 shows.

Box 4: Econometric specification – Instrumental variable approach

To account for the long-term nature of the expected relationship between ODA and PoU, while, at the same time, accounting for various sources of endogeneity, we closely follow Arndt et al. (2015):

$$PoU_{r,2017} - PoU_{r,2000} = \theta\left(\widehat{A\bar{\imath}d_{r2000-2017}}\right) + \beta PoU_{r,2000} + \gamma(pcGDP_{r,2017} - pcGDP_{r,2000}) + \xi' W'_r + u_{r,t} \quad (2)$$

where $A\bar{\imath}d$ refers to the average annual agricultural ODA a recipient country received over the period 2000 to 2017. Agricultural ODA is measured as a 3-year moving average. To normalize ODA, we compute per capita ODA flows and ODA flows relative to the GDP of the recipient country. $PoU_{r,2000}$ is the prevalence of undernourishment in 2000 and W'_r is a vector of country group dummy variables. In the 2SLS regression, $A\bar{\imath}d$ is instrumented by all other exogenous variables plus the external instrument supply of aid:

$$\left(\widehat{A\bar{\imath}d_{r2000-2017}}\right) = \delta\left(Supply\ A\bar{\imath}d_{r2000-2017}\right) + \beta PoU_{r,2000} + \gamma(pcGDP_{r,2017} - pcGDP_{r,2000}) + \xi' W'_r + e_{r,t} \quad (3)$$

In the regressions for stunting, wasting and underweight, $PoU_{r,2000}$ is replaced by the prevalence of malnutrition of the respective indicator. The JME data for the nutrition indicators comes from various Demographics and Health Survey (DHS) which is typically conducted every 3-5 years, in some countries, less infrequent. To get values for the years 2000 and 2017, we interpolate linearly between the data points and replace the remaining missing values by the closest available data point if it was not more than 5 years away.

To account for (and also test for) convergence, we include the level of undernourishment and the prevalence of stunting, wasting, and underweight in 2000 as an explanatory variable in the model. The complete econometric model is explained in detail in Box 4. The two-stage least squares (2SLS) model is estimated by limited information maximum likelihood using the supply of aid as an external instrument. The results and their implications are presented below. To test the relevance of the instrument and to rule out weak instrumentation, we show the results of the zero-stage and first-stage regression below.

The rule of thumb for instrument relevance is an F-statistic above 10. Below we present the F-statistics for the supply of aid instrument and the zero-stage instruments separately.

We test for overidentification of the three instruments log population ratio, the recipient was a colony since 1945, and their interaction. The associated Anderson-Rubin chi2 statistics is 2.34 and the probability is 31 percent. Therefore, we cannot reject instrument validity. Overidentification of the supply of aid instruments is not possible since agricultural ODA is just identified in our instrumental variable approach. Last, we follow Arndt et al. (2010) and test the exclusion restriction of the three

Table A1: Zero-stage regression of bilateral aid flows between 2000-2017

Variables	Dep. Variable Bilateral per capita agricultural ODA 2000-2017
Recipient is currently a colony (Yes=1)	-5.28e-07** (2.60e-07)
Common language (Yes=1)	1.37e-07*** (4.09e-08)
Distance between donor and recipient	-2.88e-11*** (3.64e-12)
Recipient was colony since 1945	-2.95e-08 (2.74e-08)
Log population ratio	4.49e-08*** (1.13e-08)
Recipient was colony since 1945 x Log population ratio	2.24e-08* (1.16e-08)
Donor FE	Yes
Constant	1.45e-07 (2.11e-07)
Observations	3,609
R-squared	0.11

Source: Authors' elaboration.

potentially invalid predictor variables of supply of aid, namely log population ratio, the recipient was a colony since 1945, and their interaction by regressing the error of the instrumental variable regression on the three instruments. From the results of the instrumental variable regression and the error regression, which are shown below, we conclude that there is no evidence for a problem with the exclusion restriction associated to neither the supply of aid instrument nor the individual instruments of the zero-stage regression.

Table A2: First-stage regression of agricultural ODA

Variables	Dep. Variable per capita agricultural ODA 2000-2017	
Average supply of aid between 2000-2017	3205936** (453731.7)	
Common language (Yes=1)		-0.3315 (1.90)
Distance between donor and recipient		-0.00048 (0.00424)
Recipient was colony since 1945		-0.6343 (1.871)
Log population ratio		3.900*** (0.926)
Recipient was colony since 1945 x Log population ratio		-0.5193 (1.253)
Constant	-0.495 (1.716)	
F-statistics	49.92	7.89
R-squared	0.42	0.38

Source: Authors' elaboration.

Table A3: Instrumental variable regression and error correlation with potentially problematic predictor variables

Variables	Dep. Variable per capita agricultural ODA 2000-2017	Dep. Variable Error of column (1)
Average supply of aid between 2000-2017	-0.0881 (0.130)	
Recipient was colony since 1945		-.0502 (2.149)
Log population ratio		.82993 (0.7788)
Recipient was colony since 1945 x Log population ratio		-1.536 (1.0796)
R-squared	0.54	0.03

Note: The other explanatory variables: change in GDP, PoU in 2000, and the dummies for SSA and Latin America were included in the regression but not reported in the Table.

Source: Authors' elaboration.

Table A4: Linear-Log Instrumental variable regression for change in PoU between 2000-2017

	Change in PoU between 2000-2017		
Variables	(1)	(2)	(3)
Log per capita agricultural ODA 2000-2017	-1.7850* (0.973)		
Log agricultural ODA/GDP 2000-2017		-1.868* (1.047)	
Log per capita overall ODA 2000-2017			-1.568 (1.031)
Change in GDP per capita 2000-2017	-0.00177*** (0.000500)	-0.00233*** (0.000734)	-0.00167*** (0.000494)
PoU 2000	-0.546*** (0.0664)	-0.510*** (0.0749)	-0.565*** (0.0650)
Constant	8.859*** (2.765)	-3.991 (5.474)	11.21** (4.408)
Observations	70	70	70
R-squared	0.550	0.525	0.552

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. We included a dummy variable for countries in Sub-Saharan African and Latin American countries but omitted the coefficient estimates for the sake of space. We excluded small states and countries that were classified as fragile and conflict-affected states by the World Bank.

Source: Authors' elaboration.

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Annex 3: Statistical Tables to Chapter 5

Table A5: Best performers according to a percent change classification, 2001-2018

Best performers (%) Top 25 percent of low and lower-middle income countries that recorded highest % reduction in PoU, 2001-2018				
Country	**Income group**	**PoU (2001)**	**PoU (2018)**	**% change**
Uzbekistan	Lower-middle	18.0	2.6	**-85.5**
Tajikistan	Low	13.3	2.9	**-78.1**
Nepal	Low	23.6	6.1	**-74.3**
Cameroon	Lower-middle	23.1	6.3	**-72.9**
Angola	Lower-middle	67.5	18.6	**-72.5**
Mali	Low	16.4	5.1	**-69.0**
Vietnam	Lower-middle	19.8	6.4	**-67.6**
Myanmar	Lower-middle	37.7	14.1	**-62.6**
Senegal	Lower-middle	24.2	9.4	**-61.3**
Ethiopia	Low	47.1	19.7	**-58.2**
Kyrgyzstan	Lower-middle	15.3	6.4	**-57.8**
Benin	Low	17.4	7.4	**-57.5**
Ghana	Lower-middle	15.0	6.5	**-56.6**
Indonesia	Lower-middle	19.3	9.0	**-53.4**
Lao PDR	Lower-middle	20.0	9.8	**-51.1**
Sierra Leone	Low	50.7	26.0	**-48.8**
Bolivia	Lower-middle	27.9	15.5	**-44.3**
Sudan	Lower-middle	21.7	12.4	**-42.6**
Pakistan	Lower-middle	21.2	12.3	**-42.2**

Notes: PoU reported in 3-year moving averages.

Source: Authors' own elaboration based on FAO et al. (2020).

Table A6: Best performers in number of people lifted out of hunger, 2001-2018

Best performers (number of people lifted out of hunger) Top 25 percent of low and lower-middle income countries that recorded highest reduction in the number of undernourished people, 2001-2018				
Country	**Income group**	**PoU (2001)**	**PoU (2018)**	**Change in the number of un-dernourished people (million)**
Indonesia	Lower-middle	19	9	-17.3
Ethiopia	Low	47	20	-10.6
India	Lower-middle	19	14	-10.4
Myanmar	Lower-middle	38	14	-10.2
Vietnam	Lower-middle	20	6	-9.9
Angola	Lower-middle	67	19	-5.7
Pakistan	Lower-middle	21	12	-4.9
Nepal	Low	24	6	-4.0
Uzbekistan	Lower-middle	18	3	-3.7
Cameroon	Lower-middle	23	6	-2.1
Ghana	Lower-middle	15	7	-1.0
Senegal	Lower-middle	24	9	-0.9
Mali	Low	16	5	-0.9
Sudan	Lower-middle	22	12	-0.9
Bolivia	Lower-middle	28	16	-0.6
Cambodia	Lower-middle	24	15	-0.6
Tajikistan	Low	13	3	-0.6
Sierra Leone	Low	51	26	-0.4
Syria	Low	35	32	-0.4

Notes: PoU reported in 3-year moving averages. Numbers do not add up because of rounding. Change in the number of undernourished people is not adjusted for population growth.

Source: Authors' own elaboration based on FAO et al. (2020).

Table A7: Worst performers in both percentage change and percentage point change classifications

Worst performers Top 25 percent of low and lower-middle income countries that recorded the lowest p.p. reduction or an increase in PoU, 2001-2018				
Country	**Income group**	**PoU (2001)**	**PoU (2018)**	**p.p. change**
Lesotho	Lower-middle	20.2	32.6	12.4
Korea DPR	Low	35.7	47.6	11.9
Madagascar	Low	33.9	41.7	7.8
Eswatini	Lower-middle	10.7	16.9	6.2
Cabo Verde	Lower-middle	14.6	18.5	3.9
Nigeria	Lower-middle	9.1	12.6	3.5
Mauritania	Lower-middle	8.4	11.9	3.5
Vanuatu	Lower-middle	7.5	9.8	2.3
Papua New Guinea	Lower-middle	21.1	23.0	1.9
El Salvador	Lower-middle	7.3	8.9	1.6
Congo, Rep.	Lower-middle	27.1	28.0	0.8
Liberia	Low	36.7	37.5	0.8
Chad	Low	39.0	39.6	0.7
Solomon Islands	Lower-middle	13.1	13.2	0.1
Niger	Low	38.1	38.0	-0.1
Somalia	Low	38.1	38.0	-0.1
Democratic Republic of Congo	Low	38.1	38.0	-0.1
Burundi	Low	38.1	38.0	-0.1
Guinea Bissau	Low	38.1	38.0	-0.1

Notes: PoU reported in 3-year moving averages. Source: Authors' own elaboration based on FAO et al. (2020).

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Annex 4: Investments Scenario Assumptions and Hunger Reduction Potential of Investments Considered in the Marginal Cost Curve

1. Investment in agricultural R&D and agricultural R&D efficiency enhancement

Continued investment in agricultural R&D is crucial for addressing the challenges of food security and providing healthy sustainable diets for all, today and for the future (Fears, ter Meulen, & von Braun, 2019). Sustained growth in agricultural productivity is vital to match the growing demand for food and to ensure food security. Investments in agricultural R&D coupled with increased research efficiency are viewed as a potential solution to the food security challenges of food availability, accessibility and utilization. Innovations in improved crop varieties, methods to improve soil fertility, and efficient irrigation technologies can increase agricultural productivity and address food availability. The resulting increase in agricultural productivity further contributes to increased agricultural income, improved purchasing power and reduced food prices, which when combined with innovations in post-harvest technologies can improve access to food, increase calorie consumption, increase dietary diversity, and thus enhance food accessibility and utilization. Biofortified crop varieties also offer a potential solution to increase dietary intake of essential nutrients, complementing preferred fortification and supplementation programmes (Kristkova, van Dijk, & van Meijl, 2016; UNCTAD, 2017).

Rosegrant et al. (2017) simulated the impact of increased investment in agricultural R&D and research efficiency enhancement on global hunger and malnutrition by 2030. Incremental to the investment projected under the reference scenario, this scenario simulates increased investments by the CGIAR plus increased complementary investments by National Agricultural Research Systems (NARS). An additional annual average investment cost of US$ 2.96 billion per year is estimated under this scenario, where US$ 1.97 and US$ 0.99 billion per year is invested by the CGIAR and NARS respectively. The largest investment in agricultural R&D is projected for Sub-Saharan Africa amounting to US$ 1.99 billion per year, where the CGIAR invests US$ 1.66 billion per year of the total additional investment. For the research efficiency scenario, a higher CGIAR research efficiency is simulated to achieve a 30 percent yield gain from the additional US$ 2.96 billion per year investment. Research efficiency is achieved by advancing breeding techniques and effective regulatory and intellectual property rights systems that speed up the time needed to identify and disseminate new varieties. We additionally assume the agricultural R&D efficiency enhancement scenario will cost 30 percent of the annual average incremental investment in agricultural R&D with a total of US$ 0.89 billion. According to the simulation results (Table 18 and 19), increased investment in agricultural R&D would lead to a reduction of 92.0 million undernourished persons and 4.0 million stunted children by 2030. Increased investment in research efficiency enhancement would lead to a reduction of a further 69.9 million undernourished persons and a further 3.3 million stunted children by 2030. The incremental annual average investment in agricultural R&D and research efficiency enhancement would cost about US$ 32.2 and US$ 12.7 per individual lifted out of hunger. However, given the long-time horizon between investment and returns, the investment in agricultural R&D should be frontloaded in the early years to have a large effect before 2030.

2. Investment in agricultural extension services

Improving access to knowledge and new technologies via timely dissemination of new and useful information is said to be an important tool in the fight against hunger and undernourishment. For instance, in Sub-Saharan Africa where there is a relatively high prevalence of undernourishment, it is estimated that agricultural productivity can be improved in two or three folds through better use of existing knowledge and technology (Foresight, 2011). Agricultural extension services are a useful tool for helping farmers increase their productivity (UN, 2013). Agricultural extension services that help with the dissemination and training are thus vital in the context of food security. However, while agricultural extension workers are very important, the number of extension workers available is insufficient, against the backdrop of the needs of the small-scale farmer.

Ragasa and Mazunda (2018) assessed the impact of agricultural extension on food security through the lens of a highly subsidized agricultural input system. Using a correlated random effects regression model with value of agricultural production per hectare and extension as explanatory variable, the study found that that access to agricultural extension could increase total household value of production by 36 percent for a farm household of five members with a total annual income of US$ 11,503, which translates to US$ 6.30 per person per day.

In this study, to estimate the hunger reduction potential of investing in agricultural extension services, first data from FAO's suite of food security indicators namely the DES, MDER and the CV was obtained (FAO, 2020a). Then following FAO's methodological notes for calculating PoU (FAO et al., 2019), the new PoU and NoU as a result of an impact of agricultural extension was calculated. To estimate the impact of extension services on the DES, we use the correlation coefficient Ragasa and Mazunda (2018) and multiply it by Ecker and Qaim's (2011) income elasticity of dietary energy supply (calories) of 0.66. The additional number of individuals rescued from hunger due to agricultural extension is the difference between the new NoU and the business as usual scenario, i.e. about 81.5 million people rescued from hunger.

To estimate the investment needs for agricultural extension services, we follow Blum and Szonyi (2014) who proposed that if countries commit 1 percent of their GDP to agricultural extension, it could be possible to achieve SDG 2 by 2030. Following the 1 percent GDP commitment to agricultural extension, it is estimated that an annual investment of about US$ 2.09 billion in agricultural extension has the potential to lift 81.5 million people out of hunger at a cost of US$ 25.7 per undernourished annually (Table 18).

3. Investment in irrigation expansion, water use efficiency and soil-water management

Stability of agricultural production and food security largely depends on water availability (Rosegrant et al., 2014). Climate change and population growth has caused the gap between water demand and supply to rapidly increase over time, necessitating the implementation of water supply enhancement and water demand reduction measures (2030 WRG, 2009). Investment in efficient irrigation systems is seen as one important option to adapt to socio-environmental change (Mbow et al., 2019). Soil-water management technologies such as no-till agriculture and water harvesting can also help improve food security by enhancing productivity and farmers' resilience to extreme climate events, as they contribute to increased soil quality and water-retention capacity (Rosegrant et al., 2017; Mbow et al., 2019). Soil-water management systems capable of managing adequate water infiltration rates and water storage in the soil can significantly improve crop yields and hence the availability of food (Mbow et al., 2019).

Rosegrant et al. (2017) have estimated the impact of increased investment in irrigation expansion, water use efficiency, and improvements in soil-water management systems that affect agricultural production through changes in water availability. For **irrigation expansion**, it is assumed that about 20 million hectares of agricultural land will be converted to irrigated land in developing countries, offsetting about 22 million hectares of rainfed area. This irrigation expansion would cost an additional US$ 3.52 billion per year, with the largest share of about US$ 1.2 billion per year going to Sub-Saharan Africa.

In the **water use efficiency** scenario, basin efficiency is assumed to increase by about 15 percentage points by 2030, increasing agricultural output while conserving water.[1] The water use efficiency gained through adopting a sprinkler technology on the entire 412 million hectares of irrigated land in developing countries would cost about US$ 4.59 billion per year, which is 30 percent more than expanding irrigation with conventional technology. To estimate the additional investment cost for **water-soil management**, the scenario simulates the benefits of adopting practices such as no-tillage agriculture and rainwater harvesting to improve the water holding capacity of soils and make precipitation available for plants. The IMPACT model incorporates this aspect by increasing the parameter for effective precipitation in the water module. The parameter is increased over time by 5 to 15 percent to reach the maximum level in 2045. The parameter also varies by region, reflecting the technology currently applied within different regions. The cost of implementing these technologies is estimated by applying the US$ 179 per hectare cost to both rainfed and irrigated cropland in developing countries; an additional cost of US$ 4.58 billion annually.

The results indicate that irrigation expansion would help rescue 7.6 million undernourished people by 2030 and would cost US$ 473.4 per undernourished person per year. Irrigation efficiency improvement can help reduce a larger number of the undernourished, about 18.6 million persons by 2030, and comes at an annual average incremental cost of US$ 246.3 per undernourished person lifted out of hunger. The increased investment in soil-water management further reduces the number of hungry persons by about 12.2 million by 2030 with an incremental annual cost of US$ 374.5 per undernourished person lifted out of hunger (Table 18). All three investments additionally reduce the number of stunted children by 0.26, 0.77 and 0.51 million by 2030, respectively (Table 19). It should be noted, however, that investment in irrigation expansion requires a long lead time between planning and implementation, which also entails a long-term return on investment. Hence, the investments in irrigation expansion and irrigation efficiency enhancement should come earlier in the decade to achieve the maximum reduction in hunger by 2030.

4. Investment in small-scale irrigation expansion in Africa

While irrigation in Africa can potentially improve agricultural production by about 50 percent, the majority of agricultural production is rainfed. The irrigated area, estimated at 17 million hectares, only accounts for 6 percent of all of Africa's cultivated area, primarily in Egypt, Algeria, Morocco, South Africa and Sudan (AUDA-NEPAD, 2013). Thus, the potential for irrigation expansion in Africa is high, given the amount of water resources available, the high return from irrigated crop production on the continent, and the large mass of the rural poor that would benefit from enhanced productivity arising from irrigation investment (You et al., 2011). According to You et al. (2011), the potential small-scale irrigation expansion in Africa using small reservoirs and water harvesting technologies is 7.3 million hectares with an investment cost of US$ 37.9 billion and an internal average rate of return at 20 percent. Meanwhile, with an investment of about US$ 31.7 billion and an internal average rate of return at 6.6 percent, the potential for an expansion of large-scale irrigation, i.e. dam-based surface irrigation, is estimated at 16.2 million hectares (You et al., 2011). These estimates imply that the economic profitability from investing in small-scale irrigation schemes is potentially three fold, when compared to investing in large-scale irrigation schemes. Hence, the hunger reduction potential of investment in expanding small-scale irrigation in Africa is considered separately from large-scale irrigation expansion.

In estimating the hunger reduction potential of expanding small scale irrigation in Africa, we first obtained data from FAO's suite of food security indicators namely the DES, MDER and the CV (FAO, 2020a). Then following FAO's methodological notes for calculating PoU (FAO et al., 2019), the new PoU and NoU as a result of the impact of small-scale irrigation expansion in Africa is calculated based on 3SLS regression coefficient of 2.5 from Passarelli et al. (2018) who assessed pathways from scale irrigation to food security in Ethiopia and Tanzania. To estimate the impact of small-scale irrigation expansion on the DES, we use the correlation coefficient given by Passarelli et al. (2018) and multiply it by Ecker and Qaim's (2011) income elasticity of dietary energy supply (calories) of 0.66. The additional number of individuals rescued from hunger due to expansion of small-scale irrigation expansion is the difference between the new NoU and the business as usual scenario, i.e. about 142.3 million people rescued from hunger (Table 18). To estimate the annual investment required for small-scale irrigation expansion in Africa, we follow You et al.'s (2011) estimate of 7.3 million hectares of potential expansion with an investment cost of US$ 37.9 billion. Based on this estimate, about US$

3.8 billion per year would be required over a period of 10 years. The annual per capita cost of lifting an individual out of hunger would be US$ 26.6 (Table 18).

5. Investment in crop protection – Chemical control of diseases, insects, and weeds

Biotic stresses like weeds, pests and diseases have long plagued agriculture, and a variety of methods and practices to control them have now become mainstays in agriculture production. However, it is becoming obvious that these biotic stresses are also evolving and as such research efforts to find better ways to tackle their presence or effects in the agricultural ecosystem must be maintained to ensure food security at all levels. Increased agricultural production stemming from increased access to resources, improved inputs use and management practices come along with the increased risk of loss due to weeds, pests and diseases. Hence for agricultural intensification to be successful, there also needs to be a commensurate effort and investment in crop protection activities or efforts. Biosecurity efforts of restricting the spread of pest, weeds and diseases and improving disease resistance in crops with an integrated pest management system that utilizes fewer pesticides are sound imperatives vital to the protection of agricultural productivity and ensuring food security (Keating et al., 2014; Rosegrant et al., 2014).

Using the IMPACT model, Rosegrant et al. (2014) estimated that chemical protection of crops through the application of herbicides, insecticides and fungicides can reduce the number of people at risk of hunger by 1.62, 1.85, and 1.73 percent respectively by 2050 (Table A8). Based on linear interpolation, we estimate that investment in crop protection for insects, diseases and weeds would lead to hunger reduction of about 10.1, 8.8 and 9.4 million respectively by 2030. Rosegrant et al. (2014) also show the child malnutrition reduction potential of additional food supply enhanced by the adoption of chemical protection of the crops of about 18 million by 2030. Based on data on the total area and per hectare costs of the implementation of chemical protection application (Gianessi, 2013; Rosegrant et al., 2014), the total costs of each intervention can then be estimated. By dividing total intervention costs by the number of people lifted out of hunger, we obtained the cost of chemical protection of the crops per undernourished person. As calculated, chemical protection of crops varies between US$ 69.7 to 111.7 per undernourished.[2]

2 It should be noted that Rosegrant et al. (2014) do not consider the effects of pesticides on ecosystem health, farm workers, downstream settlements, and consumer health. Hence, the cost of unintended consequences as a result of pesticide applications is not considered in this study. However, we do acknowledge their importance across agriculture and public health.

Table A8: Crop protection potential to reduce hunger and related costs

			Chemical protection scenarios			
		Baseline	Crop protection - insects	Crop protection - diseases	Crop protection – weeds	Source or formula
A	Contribution of the technology to hunger reduction (2050, %)		-1.62	-1.85	-1.73	Rosegrant et al. (2014)
B	Number of people at risk of hunger (2050, million)	1087.5	-17.6	-20.1	-18.8	B3 = B2 xA3; B4 = B2 x A4; B5 = B2 x A5
B*	Number of people at risk of hunger (2030, million)	1033.1	10.1	8.8	9.4	Based on linear interpolation
C	Contribution of the technology to reduce child malnutrition (%)		-0.19	-0.34	-0.26	Rosegrant et al. (2014)
D	Number of malnourished children (2050, million)	116.8	-0.2	-0.4	-0.3	D3 = D2 xC3; D4 = D2 x C4; D5 = D2 x C5
D*	Number of malnourished children (2030, million)	130.4	6.1	6.01	6.05	Based on linear interpolation
E	Total area of implementation (Mha)		175	175	175	Gianessi (2013); Rosegrant et al. (2014)
F	Per ha cost (US$ per ha)		50	40	60	Assumption
G	Total annual incremental implementation cost (million)		875	700	1050	G = E x F/10
H	Cost per capita (US$ per capita)		69.7	99.4	111.7	H = G / (B*)

Source: Authors' own elaboration based on Rosegrant et al. (2014) and Gianessi (2013).

6. Investment in nitrogen-use efficiency and integrated soil fertility management

Experts agree that increased production to feed the growing global population must be achieved through sustainable intensification to minimize the environmental impacts of increased agricultural production. They argue that in most regions, the adoption of small, incremental changes, such as expansion of fertilizer use, improving varieties, using mulches and optimal spacing, can increase yields while limiting environmental impacts (Royal Society, 2009; Godfray et al., 2010; Clay, 2011; Foley et al., 2011; Balmford, Green, & Phalan, 2012). Using the IMPACT model, Rosegrant et al. (2014) evaluated the potential benefits of the adoption of alternative agricultural technologies, such as varieties showing enhanced nitrogen-use efficiency and integrated soil fertility management (the combination of chemical and organic fertilizers). They did so by assessing future scenarios for the potential impact and benefits on yield growth and production, food security, the demand for food, and agricultural trade. According to their estimates, investments that enhance the adoption of crop varieties showing enhanced nitrogen-use efficiency and integrated soil fertility management have the potential to reduce the number of people under risk of hunger by 113 and 33.3 million by 2050, respectively. Based on linear interpolation, we assume that 56.5 and 16.6 million people would already be lifted out of hunger by 2030. Based on data on the total area (175 Mha) and per hectare costs of the implementation of the two technologies (US$ 500 and US$ 100 per hectare), the incremental annual average costs of each intervention were estimated to be US$ 8.75 and US$ 1.75 billion over the ten-year period. By dividing incremental annual average intervention costs of the interventions by the number of people lifted out of hunger, we obtain a per capita cost of US$ 154.9 and US$ 105.1 per undernourished person, respectively (Table 18).

7. Adapting agriculture to climate change – Cropping pattern change and crop variety choice

The impacts of climate change on agriculture are projected to result in decreased agricultural production, increased food prices and higher rates of child malnutrition by 2050 (Nelson et al., 2009). Smart and climate-oriented agricultural practices like adopting drought and heat tolerant crop varieties, and adapting planting seasons to expected climate conditions can contribute to improved agricultural productivity, increased income of farming households, and improved household food security (Hasegawa et al., 2014). By comparing modelling scenarios with and without adaptation measures, it is possible to evaluate the impact of optimal crop planting dates and crop variety choices on hunger reduction. Hasegawa et al. (2014) used the global-scale economy-wide model (AIM/CGE) to estimate food system changes under various climate change scenarios and socio-economic pathways. Calculations based on the results of the AIM/CGE model indicate that, compared to the reference scenario (no climate change), when proper adaptation measures are adopted under severe climate change (RCP8.5), the number of undernourished persons increases by 1.1 percent, by 2050. However, when no adaptation measures are considered the number of undernourished will increase by 5-5.2 percent (Table A9). Thus, depending on the socio-economic development scenarios considered, the number of people rescued from hunger through climate change adaptation varies between 4.9 and 29.8 million. Under the worst climate change scenario (RCP8.5) the impact of adaptation measures can be much higher, rescuing 11.7 to 77.7 million people from hunger by 2050. Following the SSP2 and RCP8.5 scenarios estimates, the hunger reduction potential of investing in climate change adaptation (changes in crop variety and planting dates) is estimated for 2030 using linear interpolation – amounting to 9.7 million.

Table A9: Climate change adaptation impact on the number of the undernourished, 2030 and 2050

		Climate change scenario								
		RCP 2.6				RCP 8.5				
Socio-economic scenarios	NoU (2050) - reference	with adapt. (%)	without adapt. (%)	Impact (2050, million)	Impact (2030, million)	with adapt. (%)	without adapt. (%)	Impact (2050, million)	Impact (2030, million)
Notation/ Calculations	A	B	C	D = A x (C-B) /100	E	F	G	H = A x (F-G) /100	I
SSP1	124.9	1.1	5	4.9	2.7	3.4	12.8	11.7	6.5
SSP2	169.9	1.1	5.2	7.0	3.9	3.5	13.8	17.5	9.7
SSP3	726.2	1.1	5.2	29.8	16.6	3.3	14	77.7	43.2

Source: Authors' own elaboration based on Hasegawa et al. (2014).

Table A10: Climate change adaptation scenarios: Annual incremental cost

		Climate change scenario cost							
		RCP 2.6				RCP 8.5			
Socio-economic scenarios	Food price (2011 US$ per 1000 kcal)	Adaptation impact (food supply, 10^12 kcal)	Adaptation impact (food supply value, 2011 US$ billion)	Adaptation costs (10% of value of food supply, 2011 US$ billion)	Adaptation cost per capita (US$ per capita)	Adaptation impact (food supply, 10^12 kcal)	Adaptation impact (food supply value, 2011 US$ billion)	Adaptation costs (10% of value of food supply, 2011 US$ billion)	Adaptation cost per capita (US$ per capita)
Notations	A	B	C	D	E	F	G	H	I
SSP1	0.9	54.2	50.4	5.0	1836.7	126.9	118.2	11.8	1815.4
SSP2	0.9	63.1	58.8	5.9	1521.5	142.9	133.1	13.3	1371.1
SSP3	0.9	66.5	61.9	6.2	374.0	157.3	146.4	14.6	338.0

Source: Authors' own elaboration based on Hasegawa et al. (2014).

Hasegawa et al. (2014) also provided an assessment of per capita calorie supply changes under various climate change scenarios. Along with data on population, the additional food supply changes due to climate change adaptation can be estimated (columns B and F in Table A10). Using the food price (column A), the economic value of the additionally produced food is calculated (column C). Costs of the climate adaptation (cropping date change and crop variety choice) are assumed to be 10 percent of the additional food value (economic) (columns D and G). Dividing the costs by the number of undernourished, we can calculate the per capita costs of investment in climate change adaptation measures (changes in crop variety and planting dates) to reduce hunger (columns E and I).

8. Climate change mitigation – Investments in soil organic carbon sequestration technologies

Climate change is closely associated with soil degradation and food insecurity. Carbon depleted soils are less productive and sequester less atmospheric CO2. Efforts to promote the adoption of restorative land use in agriculture can improve soil quality, increase agronomic productivity, boost food security, and mitigate climate change by the offsetting – through carbon sequestration – of fossil fuel emissions (Lal, 2011). While soil organic carbon (SOC) sequestration through the increased use of organic fertilizer, crop residues, and green manure is mainly considered a climate change mitigation option, it can also improve soil quality and greatly enhances crop yield, consequently contributing to hunger reduction. An assessment of SOC sequestration potential across the world and its related costs and benefits, by Lal (2011), shows that improvement in soil quality through an increase in the SOC pool of 1 tonne carbon per hectare per year in the root zone can increase annual food production in developing countries by 24 to 32 million tonnes of food grains and 6 to 10 million tonnes of roots and tubers.

Using the estimated additional cereal yield resulting from the SOC sequestration (C) by Lal (2011) and the elasticity of prevalence of undernourishment (PoU) to food supply (E), the potential to reduce the prevalence of undernourishment by implementing the SOC sequestration technologies was estimated to be 8 to 10.6 percent (Table A11). Based on the population size (H) and potential PoU reduction (J), it is possible to assess the reduction in the number of people at risk of hunger due to climate change mitigation through the implementation of soil organic carbon (SOC) sequestration practices. The total cost of the SOC sequestration (M) is calculated based on total GHG mitigation potential (A) and the cost of the mitigation per unit of organic carbon (L). The per-unit cost of the SOC sequestration per undernourished person is calculated by dividing the total cost of the soil carbon sequestration by the reduced number of people at risk of hunger (N). We estimated that this would lift about 36.4 million people out of hunger by 2030, with an annual average cost of about US$ 1758.2 per undernourished person (Table 18).

9. Investment in ICT - Agricultural information services

Recent developments in ICT for agriculture presents enticing prospects for a transition to precision agriculture which can be adapted to agroecological regions, especially in rural areas (UN, 2013). For instance, real-time weather information, real-time crop prices and new knowledge about on-farm practices from the radio or mobile telephones can be very useful to farmers in managing crop production, which easily translates to improved yields and output (Hoddinott, Rosegrant, & Torero, 2013). It is then noteworthy, that pushing the use of ICT in agriculture is a veritable pathway for increasing agri-

Table A11: Assessment of climate change mitigation impact on hunger reduction (kcal per day), 2030

	Indicator	Average value	Minimum value	Maximum value	Unit	Source or formula
A	Total GHG emission reduction potential of the SOC sequestration	2.15	1.2	3.1	billion tonnes C per year	Lal (2011)
B	Addition agricultural production potential	28	24	32	million tonnes cereals	Lal (2011)
C	Total cereals production (2010)	1,500	1,500	1,500	million tonnes cereals	FAO (2020a)
D	Additional food supply due to SOC sequestration	1.9	1.6	2.1	%	B/C x 100
E	Elasticity of PoU to food supply	-4.99	-4.99	-4.99		Own estimates (based on FAO 2020a)
F	Prevalence of undernourishment rate change	-9.3	-8.0	-10.6	%	E x D
G	Number of people at risk of hunger (2010)	780.3	780.3	780.3	Million	Rosegrant et al. (2017)
H	Population (2010)	6,870.5	6,870.5	6,870.5	Million	WDI in year 2019 (World Bank, 2020a)
I	Prevalence of undernourishment (PoU, 2010)	11.4	11.4	11.4	%	G/H x 100
J	PoU reduction due to additional food supply	-1.1	-0.9	-1.2	%	I x F/100
K	Number of people rescued from hunger through SOC sequestration (million) by 2050	72.7	62.3	83.1	Million	-H x (J/100)
K*	Number of people rescued from hunger through SOC sequestration (million) by 2030	36.4	31.2	41.6	Million	Based on linear interpolation of 2050 results to 2030
L	SOC sequestration cost	80	60	100	US$ per tonne per annum	Lal (2011)
M	SOC sequestration cost (reduced considering GHG emission benefits)	30	10	50	US$ per tonne per annum	Considering US$ 50 per unit of GHG mitigated
N	Total cost of the SOC sequestration	64	12	155	US$ billion	M x A
O	SOC sequestration cost per capita	1,758	385	3726	US$ per tonne	N / K*

Source: Authors' own elaboration based on Lal (2011); FAO (2019); Rosegrant et al. (2017); World Bank (2020a).

cultural production and ensuring food security. ICT can help in improving the efficiency of food distribution and marketing. With the advancement of technologies, it can be integrated with instant health monitoring and healthy nutrient intake.

Hoddinott, Rosegrant, and Torero (2013) evaluated the impact of improved access to market information through ICT on smallholder welfare and the related costs and benefits. The authors considered the RML programme (Renters Marker Light (RML) programme) in India that provides market information to farmers through mobile phones. The programme provides weather forecasts, local market price information, local and international commodity information tailored to the farmers' location and crop cycle in a local language that the farmers choose for a monthly cost of US$ 1.50. Hoddinott, Rosegrant and Torero (2013) applied the RML programme's setting to six countries – including Bangladesh, India, Tanzania, Kenya, Senegal, and Ghana, assuming the farmers receive the relevant information for six months per year with an annual cost of PPP US$ 21.92 per household with 5.5 household members. Considering the economies of scale, an alternative cost scenario is also estimated assuming a 50 percent reduction in costs. The cost of the handset is not included in the cost, as it is assumed to be bought by the beneficiaries to ensure households that intend to use the information self-select into the programme. By taking an average of four impact estimates from four studies in Africa and another four from South Asia that assessed the impact of improved market information,[3] the authors assume an average impact of a 3.75 percent and 2.4 percent increase in agricultural income through

3 The average impact estimates that Hoddinott, Rosegrant, and Torero, (2013) used relied on impact estimates from the following four studies: Svensson and Yanagizawa (2009), Futch and McIntosh (2009), Aker and Fafchamps (2010), and Muto and Yamano, 2009).

higher prices for farmers in Africa and South Asia respectively. Additionally, two alternative scenarios of benefits are considered in the study, where for the first scenario benefits are assumed to be 1 percent and 2 percent less in Africa and South Asia respectively, whereas for the second alternative scenario benefits are assumed to double in both regions. The benefits streams are then estimated using household survey data from the six countries on the per capita expenditure in rural areas as a proxy for income. Household expenditure is adjusted for inflation in 2010 PPP US$ terms to make the results comparable across the countries. The share of crop sales is assumed to be roughly 40 percent in Asia and 30 percent in Africa, while a 2 percent elasticity of poverty to income is assumed based on international experience to estimate the impact of improved market information on poverty. Finally, the study assumes the programme will reach 2 million households in India, 1 million in Bangladesh and 5 percent of the rural population in Africa. Based on the alternative cost and benefit scenarios, the study estimates an increase of agricultural income ranging from 1 percent to 4.8 percent for Bangladesh and India and 2 percent to 7.5 percent for the four African countries. Poverty reduction resulting from improved access to market information was estimated to range from 0.8 percent to 3.8 percent in Bangladesh and India, and 1.2 percent to 4.5 percent across the four African countries.

Following Hoddinott, Rosegrant and Torero (2013), we first estimated the poverty reduction potential of scaling up the RML programme to farmers in 69 low- and lower-middle-income countries. To do so, we first obtained country level household expenditure data from WDI for the year 2019 (World Bank, 2020a). For countries that did not have 2019 data, we used a 5-year adjusted moving average. Then, following Hoddinott, Rosegrant and Torero's (2013) assumption that about 30-40 percent of household expenditure comes from crop sales, we multiplied the household expenditure by 35 percent. Then using the mean of the African and Asian programme impacts on income, as estimated by Hoddinott, Rosegrant and Torero (2013), i.e. 3.07 percent, we multiplied the impact by the household expenditure and the 2 percent poverty elasticity of ICT interventions to estimate the poverty reduction potential. To update the number of farmers that can be targeted through such programmes, we followed the 2019 GSM Association report which indicated a 48 percent increase in mobile access among rural populations (Baah & Naghavi, 2018). This implies a 5-percentage point increase in access to mobile phones in developing countries. We then multiplied the 5-percentage point increase to the rural population to indicate the additional number of people using ICT services. Summing the country level population using ICT services and adjusting it for the poverty reduced and later multiplying it with the hunger to poverty correlation coefficient – i.e. 0.68, gave the number of people lifted out of hunger by ICT interventions. Finally, we multiplied the cost from Hoddinott, Rosegrant and Torero (2013) of US$ 21.92 per person by the number of farmers that the programme is targeting to get the total cost of scaling up the intervention over five years. The annual cost per hungry person is simply the total cost divided by the number of hungry people addressed. It is estimated that the intervention can help in lifting 26.6 million people out of hunger and would cost on average US$ 26.2 per undernourished lifted out of hunger annually (Table 18).

10. Investment in infrastructure and market access

An important part of the food system is the enabling infrastructure for moving agricultural products from producers to consumers and supplying agricultural inputs to producers. Infrastructure development ensures that farmers or food producers can reach consumers at a low cost, in terms of transaction cost, food loss and waste. Accordingly, an affordable, reliable and accessible network of physical infrastructure, such as roads, rail networks and electricity, that ensures easy market access for both food producers and consumers, can boost agricultural productivity and income and in turn improve food security. Essentially, while it is vital to invest in agricultural efforts to ramp up food production, it is equally important to invest in infrastructure that ensures the quick and seamless distribution of the produced food (HLPE, 2014; Rosegrant et al., 2017; Turley & Uzsoki, 2018).

Rosegrant et al. (2017) simulate the impact of a substantial investment in expanding and improving energy and transportation infrastructure, including road, rail and port capacity. The investment scenario in infrastructure improvements was estimated based on an empirical analysis of the impact of infrastructure development on food availability and the unit cost of infrastructure (Rosegrant et al., 2015). The investment scenarios were incorporated in the IMPACT global food supply and demand model by adjusting the price wedges between producer and consumer prices, reducing the margin between the prices by 1 percentage point per year until 2030, and at the end simulating the impact of the investments on food security outcomes. In total about US$ 10.8 billion annual incremental investment in infrastructure is needed across developing countries to enhance productivity along the food value chain and reduce marketing margins by better matching supply and demand over time. According to this simulation, infrastructural development can help rescue 33.8 million people from hunger and 1.41 million children from being stunted, requiring an annual average incremental investment of US$ 320 per undernourished person (Table 18 and 19). Since investment in infrastructure is another long-term project which requires a lead period for planning and implementation, the investment should be made earlier in the decade.

11. Investment to reduce food loss along the food value chain

Food loss is a common feature in the agricultural and food value chain. Globally, an estimated 1.3 billion tonnes of food produced for consumption ends up not being consumed or wasted each year (FAO, 2011). The loss occurs throughout the value chain – on-farm, during transport, storage and processing, at the market and at the consumer end – the proportions varying significantly across countries. An array of complex technical, social and economic drivers are perceived to be responsible for these losses. In developing countries, food loss primarily occurs at the production points due to poor harvesting methods, storage infrastructure and processing capabilities, while in developed countries the food waste is primarily at the market and household level, due to products passing their due dates. The reduction of food loss and waste within the food value chain can potentially increase the availability of food. Action to reduce food loss will require different approaches for developing and developed countries. Particularly for developing countries, investments in infrastructure that foster efficient crop harvesting and improved storage and transportation facilities will potentially stem food loss (Rosegrant et al., 2015; FAO, 2019).

Rosegrant et al. (2015) applied the IMPACT model to assess the investment needs to reduce global food loss, by applying a weighted grouped logistic regression to estimate the potential reduction in post-harvest loss due to developments in various infrastructure variables. The results highlight the importance of infrastructure development in reducing post-harvest loss, particularly in Sub-Saharan Africa. Integrating the fitted results into the IMPACT global food supply and demand model, they simulated the impact of increased post-harvest reduction investment scenarios on food security. A scenario of a 10 percent reduction in post-harvest losses by 2030 would help to reduce food prices, increase food availability, and improve food security. Specifically, the assessment indicated that food loss reduction measures would help lift 70 million people out of hunger by 2050 with an annual average incremental investment of US$ 34 billion in infrastructure. Instead of taking the full annual US$ 34 billion incremental investment in infrastructure, we assume 25 percent or an annual allocation of US$ 8.58 billion to food loss reduction.[4] Using a linear interpolation, we estimated that this would lift about 36 million people out of hunger by 2030, with an annual average cost of about US$ 241.7 per undernourished person (Table 18). The investment would reduce the number of stunted children by about 2.35 million by 2030 (Table 19).

12. International trade – Completing the Doha Development Agenda (DDA)

Trade and commerce have become more global and interconnected, with nations relying on other nations for continued access to goods and services. However, trade has both negative and positive consequences for food security. As postulated in the virtual water concept, arid regions with inadequate food production can benefit by importing food from regions with abundant water supply (Allan, 1998). Focusing on international trade, Anderson (2018) assessed the poverty reduction impact and associated global costs and benefits of successfully completing the Doha Development Agenda (DDA) at the World Trade Organization (WTO). Based on a systematic review of CGE model-based economy-wide simulation studies, he identified the potential welfare gains that would accrue from the multilateral trade agreement. Considering Laborde, Martin and van der Mensbrugghe's (2011) estimate, the lower bound effect of the basic trade barriers and subsidies reduction proposed by the WTO would lead to a 0.36 percent higher global GDP. Alternatively, additionally considering economics of scale, monopolistic competition and dynamic gains from trade, the trade reform was estimated to potentially increase global GDP by about 3.0 to 3.6 percent on average over a ten-year period between 2015 and 2025, after which the incremental boost to GDP is assumed to decline linearly to the long run average growth rate by 2050. Based on back-of-the-envelope calculations, Anderson (2018) estimated that the global economic gains from the trade reform would lift about 160 million people out of poverty by 2030.

With a focus on estimating the impact of completing the DDA on hunger, we converted the poverty reduction estimates into hunger reduction estimates using a correlation coefficient estimate between hunger and poverty of 0.68 (FAO et al., 2019), amounting to 108.8 million. However small they might be, as trade reforms entail certain costs relating to the negotiation of the trade reform and the private costs of adjustments for firms and workers, 5

4 The investment in infrastructure required to achieve 10 percent reduction in post-harvest loss by 2030 has additional larger benefits in other sectors of the economy more broadly beyond the agriculture sector. Hence, 25 percent investment cost allocation is assumed for post-harvest loss reduction annually following Rosegrant et al. (2015).

percent of the estimated annual comparative static benefit of 2025 is assumed to be the adjustment cost of the trade reform for the period of six years, amounting to a total of US$ 300 billion investment. The adjustment cost was given a larger weight to reflect: (i) spending required to negotiate, and support policy think tanks to make a convincing case for reform, (ii) private costs of adjustment for firms and workers since the reform might force some industries to downsize or close to allow others to expand, and (iii) social costs that include social safety net provisions to losers from the reform, such as unemployment payments and training grants for displaced workers to build up their skills so that they can maintain their earning level as before. Thus, the annual average cost of completing the DDA negotiation per undernourished person is estimated to be US$ 275.7 (Table 18).

13. Intra-African trade - African Continental Free Trade Area (AfCFTA) agreement

The African Continental Free Trade Area (AfCFTA) agreement aims at creating the largest free trade area in the world by the number of countries involved. The major role of the AfCFTA is to provide a continent-wide regulatory framework and to support Africa's subregional economic communities by among other measures, removing tariff and non-tariff barriers, creating an environment for investments, and protecting intellectual property rights (World Bank 2020). A recent report by the World Bank quantified the long term economic and distributional impacts of AfCFTA using a dynamic CGE and microsimulation model (World Bank, 2020b). Using the most recent GTAP database, and complemented by other data on trade restrictions, the World Bank assessed the gendered implications on economic growth, international trade, poverty reduction, and employment and estimated that the AfCFTA could see an increase in average real incomes by 7 percent. Accounting for country heterogeneity, structural transformation, shifts in demand as income circumstances change, and changes in dynamic comparative advantage, the lowest impacts on real incomes were 2 percent, and the largest up to 14 percent.

The World Bank (2020b) study estimates that by 2035, the AfCFTA will remove about 30 million people out of poverty. Using linear interpolation from the 2035 figures, we estimate that about 22.5 million people will be lifted out of poverty by 2030. Thus, converting the 2030 poverty reduction figures using the poverty-hunger correlation coefficient of 0.68 (FAO et al. 2019), we find that 15.3 million people could be lifted out of hunger. The World Bank (2020b) report also indicated that the total income gains of implementing the AfCFTA would reach about US$ 450 billion by 2035. As discussed above, Anderson (2018) assumes that about 5 percent of such gains would be lost to adjustment costs as trade reforms entail certain costs both for the implementation of the reform and the private cost of adjustments for firms and workers. Thus, having adjusted for the 5 percent cost and spreading the cost over the 10-year period, we obtained an annual implementation cost of US$ 2.25 billion. Dividing the annual implementation cost by the number of people lifted out of poverty gives a per capita cost of US$ 147.1 per hungry person.

14. Investment in social protection programmes

Social systems that protect the most vulnerable against short term economic crises are common in most developed countries. These safety nets insulate consumers from economic shocks like loss of income or food price hikes, thus ensuring that access to food is not endangered. For a large part of the developing world, such social safety nets are usually unavailable to support poor households who spend the largest share of their income on food. Social protections are widely regarded as important contributors to the long-term resilience of smallholder farmers or households, as they strengthen ability to manage risks and adopt new technologies with higher productivity (HLPE, 2012; UN, 2013). In the short-term, emergency food assistance and safety nets could be used to help the poor and vulnerable meet their urgent food needs offsetting the effects of price and climatic shocks. For instance, following the 2007-2008 food price crisis several countries introduced or scaled-up cash transfer and food assistance programmes, while others expanded disposable income measures (FAO, 2009). These safety nets for the vulnerable can be implemented in the form of food, voucher and cash transfers, subsidies, public works programmes and school feeding programmes. While multiple schemes or safety approaches are possible, the important factor for safety nets in terms of their ability to ensure access to food is the presence of at least one and the ability to scale it up if required. With cash transfer or food supplies provided during difficult times, people can maintain their food supply and stabilize their nutritional intake (UN, 2013).

Several studies from different regions have evaluated the cost-effectiveness and impact of social protection programmes on food security outcomes. A recent meta-analysis conducted by Hidrobo et al. (2018) identified 58 studies that examined the impact of 46 different social protection programmes on food security in developing countries. The meta-analysis covered a period of 22 years, from 1994 to 2016, across 25 countries in Latin America, East Asia, Southern Asia and Sub-Saharan Africa. These studies employed over 30 different types of food security measures, including the value of food consumed or food expenditure, dietary diversity, food insecurity and food share of total consumption. Based on these studies, the meta-analysis identified 40 impact estimates on caloric intake or availability. The estimates show that the average social protection programme increases caloric availability or acquisition by 8 percent.

As regards the cost-effectiveness of social protection programmes, a systematic review of journal articles, programme and policy documents was conducted to identify social protection programmes, objectives, number of beneficiaries, amount of transfer, their types, and programme costs. The review was broadly divided into conditional cash and in-kind transfers. Considering geographical representativeness, internal and external validity, and transferability in addressing issues surrounding the transfer, cost and impact on food security outcomes, studies from broader continental groupings was considered. Table A12 summarizes the studies considered.

Considering that most of the studies and programmes reviewed were targeted to reduce poverty and food security among other outcome variables, it is important to obtain a picture of the proportion of poor – and by extension the proportion of undernourished – individuals that they could address. Using data from the World Bank's World Development Indicators on poverty rates and household sizes (World Bank, 2020a), we adjusted and harmonized the studies' beneficiary data to individual level transfers and costs. Eventually the proportion of the poor covered by the study was also calculated by taking the ratio of beneficiaries to the total number of the poor. Table A13 summarizes these results.

Table A12: List of papers considered in estimating the cost of social protection

Authors	Year	Country	Method	Cost	Transfer	Beneficiaries
Mesquita et al.	2016	Brazil	Review	0.4% of GDP	US$ 35	24,000 households
Miller et. al.	2011	Malawi	RCT	US$ 1.3 million	US$ 14 per household per month.	83,000 households
Barber et al.	2008	Mexico	Review		US$ 15 per household per month	
Sumberg et al.	2011	Nigeria	Review		US$ 45 per child per year.	
Ahmed et al.	2005	Bangladesh	PSM		8.19/month	
de Lima et al.	2020	Brazil	Ethnographic		US$ 21.5	12 million
Booth et al.	2019	Indonesia	Review	1.6% of GDP (US$ 1.112 trillion)	US$ 119 per person	6.2 million
Raghunathan et al.	2017	India	Regression	US$ 30.77 million	US$ 75	3.89 million
Piperata et al.	2016	Brazil	Ethnographic	0.5% of GDP	US$ 21.5	
Cabral et al.	2014	Brazil	A cohort study	0.5% of GDP	US$ 21.5	10,000
Caldés & Maluccio	2005	Nicaragua				
Gaentzsch	2019	Peru	MDID	1% of GDP (US$ 1.897 billion)	US$ 152 (PPP)	750,000
Doocy & Tappis	2017	DRC	CTR		US$ 54	32,010
Caldés et al.	2006	Latin America		US$ 155.52 million	US$ 13 per month	2.6 million rural households
Hidrobo et al.	2014	Ecuador	RCT		US$ 40	3642

Source: Authors' own elaboration.

Table A13: Per capita cost of social protection programmes per month based on studies reviewed

Country	Transfer (US$) per month (1)	Cost Transfer Ratio (US$) (2)	Programme cost (US$) (3)	Household size (count) (4)	Transfer (US$) per capita per month (5)	Cost per transfer per capita per month (US$) (6)	Proportion of the poor addressed (7)
Brazil	28.25	0.41	11.63	3	9.42	3.88	0.24
Malawi	14	0.6	8.4	5	2.8	1.68	0.35
Ethiopia	9.8	0.6	5.9	5	2	1.18	0.01
India	6.25	0.25	1.6	5	1.3	0.3	0.25
Indonesia	6	0.25	1.5	4	1.5	0.38	0.18
Nicaragua	18	0.63	11.3	4	4.5	2.83	
Peru	12.67	0.5	6.3	4	3.2	1.58	0.22
DRC	4.5	1.74	7.8	5	0.9	1.57	
Nigeria	3.75	0.6	2.3	5	0.75	0.45	
Bangladesh	1.36	0.25	0.3	4	0.34	0.09	0.22
Mexico	13	0.1	1.3	4	3.25	0.33	0.46
Iraq	22	0.25	5.5	5	4.4	1.10	
Honduras	3.58	0.50	1.8	4	0.9	0.45	
Ecuador	40	0.61	8.19	4	10	2.05	0.17

Source: Authors' own elaboration based on the reviewed papers (see Table A12) and WDI (World bank, 2020a).

Table A14: NoU addressed by conditional cash transfers and associated costs

Classification	Population at risk of hunger (million)	Investment incremental costs per population rescued from risk of hunger (Million US$)	Investment incremental costs per person rescued from hunger (global average)
Social Protection - Scaling up existing programmes	103.1	3677	35.7
Social Protection - Establishing new programmes	103.1	9158	88.9

Sources: Authors' own elaboration based on reviewed papers (see Table A12).

To calculate the number of the undernourished potentially addressed by social protection programmes, we take the mode of the transfer and multiply it by the number of undernourished (NoU). Based on the systematic review, the assumption is that on average about 30 percent of the undernourished can be addressed by conditional cash transfers. We also multiply the cost by the proportion of the poor potentially reached by the programme. Considering that certain developing and emerging countries already have well-established social protection programmes and that efforts to scale up existing programmes would come at a low cost compared with countries which would need to establish new programmes at a higher cost, social protection is categorized into two interventions to differentiate these costs. For the new social protection programmes that would be established, the total cash transfer cost was assumed to be US$ 88.9 per person per year based on the most expensive per dollar cash transfer cost of US$ 1.74 identified from DRC, while for scaling existing social protection programmes, the total cash transfer cost was assumed to be US$ 35.7 per person per year based on the lowest per dollar cash transfer cost of US$ 0.1 identified from Mexico (Table A13).[5]

Table A14 summarizes the results of the reduction in the number of individuals affected by hunger and their associated incremental costs. Generally, conditional cash transfers could lift 206.1 million people from hunger – costing about US$ 3.7 and US$ 9.2 billion.

As discussed in section 3, the economic and food systems disruptions triggered by the COVID-19 pandemic are expected to increase hunger globally. According to the

5 To calculate the average annual cash transfer cost per capita, we took the average of column 5 in Table 23 which was equal to US$ 2.7 per month. And we took either the maximum or the minimum per dollar cash transfer cost in column 2 and multiplied it by the aforementioned average per capita cash transfer amount to get the US$ 4.7 and US$ 0.27 costs, respectively. We then added the costs to the average per capita cash transfer amount to get the monthly total transfers per capita US$ 7.41 and US$ 2.97 values, respectively and annualize the costs by multiplying the values by 12 months.

three simulation scenarios presented, hunger is estimated to increase globally by about 83 million to 132 million in 2020 and additionally by 62 million in 2021 (under the more pessimistic scenario). While these projections cannot be considered a precise estimate of the impact of COVID-19 on hunger, they demonstrate the urgent action needed to prevent millions more people from becoming undernourished. In this regard, social safety nets and income support are especially crucial to protect the poor and vulnerable from falling into hunger in times of such crisis. Yet, in many countries, social protection coverage remains limited and will need to be significantly scaled up to respond to the COVID-19 pandemic. To safeguard people and livelihoods from the adverse impacts of the pandemic, governments of developing countries would hence need to invest further in scaling up social protection programmes.

To estimate the additional investment needed to address the impact of the COVID-19 pandemic on hunger, we adopt the more pessimistic scenario of 5.1 percentage points decline in the GDP growth rates presented in section 3.2.1. The scenario simulation result suggests that the number of undernourished people will increase by about 102.7 million in 2020 and 35.2 million in 2021. Using the scenario estimate, we calculate the additional investment needed to address the additional NoU due to COVID-19 by multiplying the estimate by the per capita cost of the cash transfer estimated for establishing new social protection programmes. Table 24 below presents the results of the COVID-19 related cost estimates.

Table A15: Additional investment needed to prevent the impact of COVID-19 on hunger

Classification	Additional NoU in 2020 due to COVID-19 (million)	Additional NoU in 2021 due to COVID-19 (million)	Additional cost of social protection to address NoU due to COVID-19 (million US$)
World	102.7	35.2	12255.2
Africa	31.9	17.4	4381.3
Asia	67.2	15.6	7358.4
Latin America and The Caribbean	3.5	2.2	506.6

Sources: Authors' own elaboration based on FAO et al. (2020) and reviewed papers (see Table A8).

15. Investment in nutrition-specific interventions

Globally, about 144 million children were chronically malnourished or stunted in 2019, highlighting an enormous global health and economic development challenge. Although the prevalence of stunting has declined globally by about 15 percent from 169.8 million in 2010, progress needs to be accelerated to achieve the target of halving the number of stunted children by 2030 (FAO et al., 2019). While achieving this target is still feasible, it requires a coordinated investment in key evidence-based nutrition interventions and a supportive enabling environment (Shekar et al., 2017). According to Bhutta et al. (2013), at least 20.3 percent of the current child stunting rate could be averted if ten evidence-based nutrition-specific interventions were scaled up to cover 90 percent of the population in countries with high stunting burden. These interventions include periconceptional folic acid supplementation or fortification, maternal balanced energy protein supplementation, maternal calcium supplementation, multiple micronutrient supplementation in pregnancy, promotion of breastfeeding, appropriate complementary feeding, vitamin A and preventive zinc supplementation in children aged 6–59 months, management of severe acute malnutrition, and management of moderate acute malnutrition. If these interventions were to be scaled up, they would help reduce nearly 15 percent of the deaths among children younger than 5 years and contribute to the overall development of human capacity. Bhutta et al., (2013) estimated the cost of scaling up these ten nutrition interventions to be about UD$ 9.6 billion per year. The scaling up cost and the impact on stunting was estimated by the authors using the Lives Saved Tool (LiST).

Similarly, Shekar et al. (2017) estimated the effect of scaling up of seven nutrition specific interventions to 90 percent coverage for 37 countries that account for 90 percent of stunting in the world.[6] Using the LiST model, they estimated 37 country models and combined the results to obtain a population-weighted reduction in the overall prevalence in the sample of countries. For the scale up, they modelled a linear expansion of coverage of the seven interventions from the level observed in 2016 to 90 percent in 2021 and maintenance of the 90 percent coverage from 2021 to 2025. The total financing needs required to scale up the seven intervention and achie-

6 The 37 countries included in the sample are Bangladesh, China, Democratic Republic of the Congo, Arab Republic of Egypt, Ethiopia, India, Indonesia, Kenya, Madagascar, Mexico, Mozambique, Myanmar, Nigeria, Pakistan, Philippines, Sudan, Tanzania, Uganda, Vietnam, Yemen, Benin, Burundi, Cambodia, Central African Republic, Eritrea, Guatemala, Lao PDR, Liberia, Malawi, Nepal, Niger, Papua New Guinea, Rwanda, Sierra Leone, Somalia, Timor-Leste, and Zambia.

Table A16: Cost of nutrition-specific interventions over 10 years and potential stunting reduction

	Indicator	Value
A	Child malnutrition (reference scenario; million)	159
B	Reduced child malnutrition due to nutrition-specific interventions (million)	**31.01**
B*	Reduced child malnutrition due to nutrition-specific interventions (million)	**30.9**
C	**Child malnutrition prevention costs (US$ billion, total for the period 2020-2030):**	
D	Antenatal micronutrient supplementation	2.31
E	Infant and young child nutrition counselling	6.82
F	Balanced energy-protein supplementation for pregnant women	6.95
G	Intermittent presumptive treatment of malaria in pregnancy in malaria-endemic regions	0.42
H	Vitamin A supplementation for children	0.72
I	Prophylactic zinc supplementation for children	14.21
J	Public provision of complementary foods for children	12.75
K	Subtotal (D+E+F+G+H+I+J)	44.18
L	Programme (monitoring and evaluation, capacity strengthening, and policy development)	5.30
M	**Total:** (M = K+L) (US$ billion, total for the period 2020-2030)	49.48
N	Annualized cost (billion US$) (N = M / 10)	4.95
O	Annualized cost per capita (US$) (O = N / B*)	**160**

Source: Authors' own elaboration based on Shekar et al. (2017).

ve the stunting reduction targets are presented in Table A16. We converted the estimated stunting reduction to hunger reduction using an estimated correlation coefficient between stunting and prevalence of undernourishment of 0.997, which amounted to 30.9 million people lifted out of hunger. The annualized cost of the nutrition intervention package per undernourished person lifted out of hunger would be US$ 160.

16. Investment in female literacy

The quality of maternal and child care practices is one of the non-nutritional factors that affect the nutritional outcomes of children (Smith & Haddad, 2015). Women play a key role in children's nutritional outcome as they give birth to them, breastfeed them and are their primary caretakers. Hence, maternal education has numerous positive impacts on the quality of maternal care that mothers receive during and after pregnancy and consequently on the quality of care that their children receive, ranging from the amount of breastfeeding to seeking health care in case of illnesses (Ruel et al., 2013). The strong link between female education and nutritional outcomes of children, particularly for stunting, has been well established (Headey, 2013; Smith & Haddad, 2015). Using secondary school enrolment ratio to measure women's education, Smith and Haddad (2015) conducted a cross-country econometric analysis using data from 116 developing countries over the period between 1970 and 2012 to assess the impact of women's education on stunting. Based on a fixed-effect regression specification, they show that women's education is indeed an important determinant of child stunting, contributing to a stunting reduction of about 5.5 percentage points. In the period 1970 to 2010, of the estimated 24.5 percentage points reduction in stunting, improvement in women's education contributed about 22 percent.

To estimate the potential stunting reduction due to investments in women's education, we follow Shekar et al. (2017) and base our estimates on recent WDI data on female secondary school enrolment for the 37 countries that account for 90 percent of stunting in the world. For each of the 37 countries, a trend is first calculated for female secondary enrolment on the basis of the changes over the period of five years between 2011 and 2015 (B), which is assumed to continue over the 10-year period between 2020 and 2030 (C) (Table A17). Then using the regression coefficient estimated by Smith and Haddad (2015) (E), reductions in stunting between 2020 and 2030 are calculated to be about 2.63 million (F), with the expectation that the five-year trend continues. This estimate can then be converted into hunger reduction using an estimated correlation coefficient between stunting and prevalence of undernourishment of 0.997 (Q), which is equivalent to 2.61 million people lifted out of hunger by 2030 (R). [7] To estimate the annual incremental investment required for female literacy between 2020 to 2030, we use the UNESCO (2015) estimates of the per capita annual expenditure required for lower secondary school in low and lower middle-income countries per student.

7 This estimate is however an underestimation of the impact of investments in women's education as it only considers the impact on child stunting and does not consider the additional benefits such as increased productivity and higher income which can further contribute to hunger reduction.

UNESCO (2015) estimated that in 2012 lower secondary enrolment in low income countries was 29 million (J) which costed US$ 130 per student (O). Thus, the cost was in total US$ 3.7 billion in 2012. Given the five-year trend estimated, there would be about 6.66 million additional female's secondary enrolment (N), which would come at a cost of US$ 93 million annually. This would mean that, a 2.6 million reduction in hunger would come at an incremental annual cost of only about US$ 33.1 per person lifted out of hunger.

Table A17: Cost of female literacy improvement over 10 years and potential stunting reduction

	Indicator	Value	Unit	Source
A	Baseline Female secondary school enrolment rate (FSSE) (2019)	83.02	%	WDI 2019 (World Bank, 2020a)
B	Growth rate of FSSE rate (2011-2015)	0.013	%	$\Delta\ lnFSSE$
C	Growth in 10 years (2020 – 2030)	0.13	%	$B\ x\ 10$
D	Actual growth in FSSE rate (2020-2030)	10.98	%	$A\ x\ C$
E	Stunting elasticity to female secondary school enrolment	-0.166		Smith & Haddad (2015)
F	Stunting prevalence reduced from 2030	1.82	%	$D\ x\ E$
G	Stunting in the base year (2019)	144	Million	WFP
H	No. stunting reduced from the base year (2019)	2.62	Million	$G\ x\ \frac{F}{100}$
I	Female secondary school enrolment rate in 2012	39.68	%	WDI 2019 (World Bank, 2020a)
J	No. of female students enrolled in secondary school (2012)	29	Million	UNESCO (2015)
L	Percentage change in female students' enrolment	1.09	%	$\frac{(A - I)}{I}$
M	No. female students enrolled in secondary school by 2030	60.67	Million	$J + J\ x\ L$
N	No. additional female students enrolled in secondary school by 2030	6.66	Million	$\frac{M + D}{100} * L - L$
O	Per capita secondary school expenditure per year (low income countries)	130	US$	UNESCO (2015)
P	Annual total incremental cost of the additional female students enrolled in secondary school	86.62	US$ in million	$N\ x\ \frac{O}{10}$
Q	Correlation coefficient between NoU and no. of stunted children	0.997		Own estimates
R	Reduction in the no. of people under risk of undernourishment (2030)	2.61	Million	$H\ x\ Q$
S	Annual per capita cost of female literacy improvement per person lifted out of hunger	33.1	US$	P / R

Source: Authors' own elaboration based on World Bank (2020a); Smith and Haddad (2015); UNESCO (2015).

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