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Agricultural R&D: More and cheaper food

Just a century ago, two-thirds of the world lived in a permanent state of hunger. Now, economic development and agricultural innovation have reduced this problem to the point where it affects less than one-in-ten people. Nevertheless, hunger still affects 768 million people, killing 2.7 million mothers and children and costing the world more than a trillion dollars annually.

Fortunately, investment in more productive agriculture can make food much more plentiful and cheaper and prevent more than a hundred million people from starving, making it one of the best investments for humanity.

The answer is in how we've dealt with hunger before—and handily, too

A diet that provides enough energy and meets basic nutritional needs is essential for good health. Hunger and micronutrient deficiencies—especially in children and mothers—cause avoidable deaths and lifelong consequences.

In recent decades, the world managed to make significant inroads against hunger and reduce the number of people going without sufficient food.[1] However, the past half-decade has seen a disruption of that progress, partly caused by the far-reaching impacts of Covid and Russia's invasion of Ukraine.

In this and the nutrition chapter, the focus is on how to tackle the critical issue of nourishment for humanity. In this chapter, we will talk about how to get more, cheaper, and better food over the coming decades, whereas the nutrition chapter is focused on how to get better nutrition right now.

In the poorer half of the world, the death toll from hunger inflicts incalculable tragedy on the families who must grieve loved ones and measurable harm to the societies in which they live. Each year, malnutrition kills 878,000 children and mothers in low-income countries and 1.8 million people in lower-middle-income countries. In total, these deaths represent a social loss worth $1.15 trillion annually.[i] It is likely that the real number of deaths caused by malnutrition is significantly higher, and thus the cost estimate is conservative.

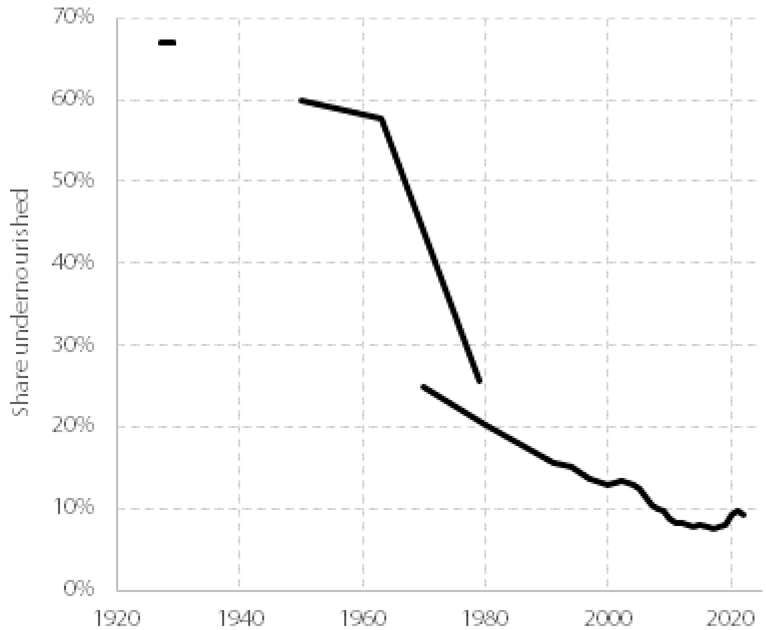
Yet the keys to erasing hunger today are largely the same as they were in the past: Economic growth and agricultural innovation.[ii] As people's incomes rise, they can afford more food, while new technologies and farming methods make food more plentiful and cheaper. That may sound too simple, but it's a recipe that has had a miraculous effect on malnutrition across the world.

For much of human history, the majority of people were undernourished (Grigg 1985, 1). Malnutrition plagued even the most developed nations. Less than 100 years ago, the League of Nations estimated that more than two-thirds of humanity still lived in a constant state of hunger (Castro 1952, 11).

Since then, global malnutrition has dropped dramatically, as Figure 7.1 demonstrates. By 1970, malnutrition afflicted just a quarter of all people. By 2017, the worldwide malnutrition rate had fallen still further to 8.2%. The rate has risen, unfortunately, partly as a result of Covid and

[1] In this chapter, I will use hunger, malnutrition, and similar wordings interchangeably.

Vladimir Putin's invasion of Ukraine. In 2022, 9.3% of the world was malnourished. But overall, the trend of hunger has been remarkable.



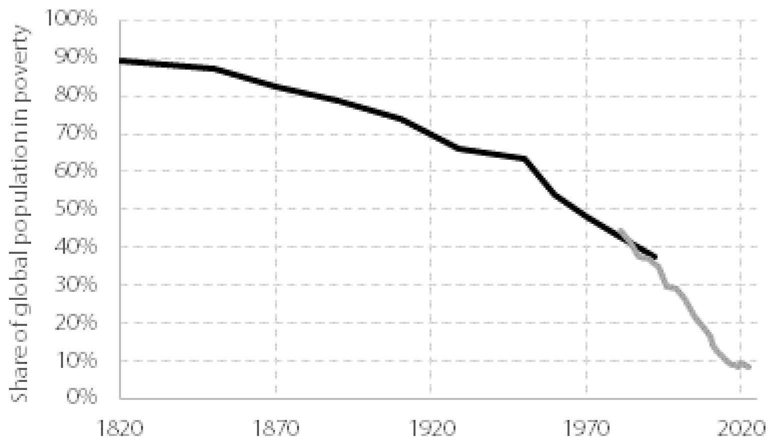
Source: The 1928 estimate from the League of Nations finds "more than two-thirds of humanity live in a permanent state of hunger" (Castro 1952, 11). Estimates from 1950−1979 show populations in nations with less than 2,200 calories per person (Grigg 1985, 49), 1970−1991 estimating undernourishment in the developing world (FAO 1996: table 3), 1990−2015 undernourished (UN 2015a, 20), 2000−2022 (FAOSTAT 2022), with 2022 estimated for a medium impact of the war in Ukraine. Global population numbers are used for absolute numbers (OurWorldInData 2021).

Figure 7.1 Share of the global population that is undernourished 1928–2022. From League of Nations estimate in 1928, to FAOSTAT's medium impact estimate of the war in Ukraine.

The first main driver of this sweeping change has been sustained global economic growth. Poverty has always been and still remains one of the main causes of hunger (Grigg 1985, 37–38). Generally speaking, when a country's annual GDP per person rises above $10,000, practically no one goes hungry.

Though unequal, economic growth over the past two centuries has contributed to a dramatic decline in the percentage of the global poor (see Figure 7.2), and since 1993, there has been a decline in the absolute number of poor people. In 1820, about nine in ten people in the world were extremely poor (Bourguignon and Morrisson 2002). In 2021, it was less than one in ten (Mahler et al. 2021).

The other main driver of the dramatic decline in malnutrition has been increased agricultural productivity. We have developed much better varieties of most crops and animals[iii]. For example, the development of better wheat cultivars has increased top yields significantly. At a research station in England, the best yields were quite constant for more than a century from 1852 but then doubled after 1960 and, with even better treatment, almost quadrupled today.



Source: Bourguignon and Morrisson (2002), Mahler et al. (2021) and Worldbank.[iv] The light World Bank line represents the share of people below the so-called $1 a day extreme poverty line, which is now estimated at $2.15. The impact of Covid is evident as a jump of 97 million additional people living in poverty or 1.2 percentage points above the pre-pandemic trajectory. The estimate for 2021—22 restarts the downward trajectory but from a new, higher level.

Figure 7.1 Share of the global population in poverty 1820–2022. From 1981 the share of people below World Bank's extreme poverty line in grey.

Most of the world's farmers produce far below the best attainable yields. More irrigation and fertilizer can help. The global area under irrigation has doubled since 1961. After the chemists Haber and Bosh invented the process to extract ammonia from the air in the early 1900s, the world increased its fertilizer use 100-fold.[v]

The best measure of this productivity increase from better varieties and more fertilizer and irrigation is in global yields. Figure 7.3 shows the fantastic, sustained growth in global cereal yields from the 1950s onwards that has allowed farmers to deliver more than three times as much food for every hectare or acre farmed.

Source: Data from 1966–2021, global simulation from 1850–1965, aligned to fit data average for the 1960s.

Figure 7.2 Global cereal yields 1850–2021. Data starts 1966, before an historic simulation.

The boom in yields has spurred global food production. From 1900 to 2000 alone, there was a six-fold increase in total crop harvests (Smil 2000, 4). Over that same period, the global population increased less than four-fold—meaning that, on average, each person has around 50% more food available. Global grain production has more than quintupled since 1926, as Figure 7.4 shows.

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Because the world now gets far more food from each hectare of land than we once did, we have been able to substantially increase production without needing much more land. Since 1961, global cereal production has increased by 249%, while we have only needed to increase the total cereal land area by less than 12% (FAOSTAT 2021).

Source: Brown, Renner, and Halweil (2000, 35), FAO (1954, 20) and USDA (2021). The FAO estimates covering 1926−1954 of world cereal production is only about two-thirds of modern estimates and have been adjusted upwards to the common 1950 estimate.

Figure 7.3 Global grain production 1926−1938 and 1949−2021.

This precipitous increase in the supply of food far beyond population growth has led to a predictable reduction in prices.

Real food prices have dropped by more than half since 1900, as Figure 7.5 shows. As you can see, this decline would be greater if we were looking at life before the price upswing of the Covid pandemic. Though the difference is notable—a 59% decline rather than a 53% one—the Covid change is likely temporary and rather small compared to the wider trend. Likewise, we can see that the often-discussed price bump in the late 2000s was certainly noticeable but mostly petered out by 2019.

Source: From Jacks (2019: with updates) 1900–2020, 20 grown commodities, including wheat, rice, corn, beef, pork, cocoa, peanuts, and sugar. 1960−early 2023 shows the World Bank Agriculture Commodity Price Index (adjusted to a longer index in 1960). Both indices are in current US dollars, and both are inflation-adjusted with US CPI (GFD 2021).

Figure 7.4 Global Food Prices, index 1900=100, 1900−2023. From 1960 the World Bank Agriculture Commodity Price Index, before 20 grown commoditities.

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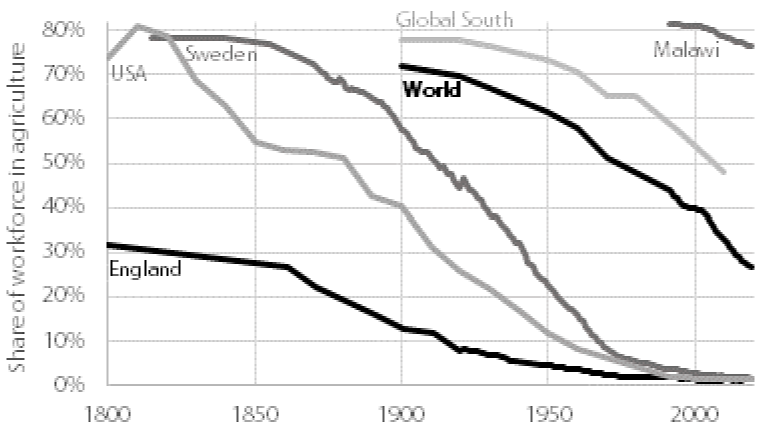
Astonishingly, we have managed to increase yields and reduce prices using much fewer workers. A couple of centuries ago, when much of humanity was in a permanent state of hunger, about four-in-five in people worked in agriculture, as seen in Figure 7.6. England was an anomaly because it was already trading with a large empire, and so had been able to trade farming for industrial production. Even by 1900, almost three-quarters of the world's labor force worked in farming.



Source: All estimates from 1991−2019 (World Bank 2021b). World (Grigg 1975: table 1). England (Bank of England 2021: A53; Broadberry, Campbell, and van Leeuwen 2013: table 9), USA (Lebergott 1966: table 2), Sweden (Edvinsson 2005; Jonsson and Sandgren 2009: table 1), Global South or developing world (Cheong, Jansen, and Peters 2013, 33; Grigg 1975: table 1), Malawi (World Bank 2021b).

Figure 7.5 Share of the workforce in agriculture 1800−2019.

Yet the past 120 years have dramatically transformed agriculture to the point that today less than a quarter of the world's workforce is in farming. Broad mechanization has made it possible for a much smaller workforce to work a larger area of land more effectively. This also means that as more food is produced by a smaller segment of society, more people can work productively in other sectors.

Perhaps the one man most responsible for the global movement towards more effective agricultural production is agronomist Normal Borlaug, who, in the 1950s and 60s, pushed higher-yielding varieties to many countries that badly needed higher food production. Together with more fertilizer and irrigation, he helped usher in the first Green Revolution, which helped the world produce far more food, causing food prices to fall and the percentage of the world that was malnourished to drop. In 1970, Borlaug received the Nobel Peace Prize for his work, which saved an estimated billion people's lives.

Beyond putting more food on the table, the Green Revolution has also made societies richer. One academic paper[vi] studied the impact of the Green Revolution on national economies and discovered that a 10-percentage point increase in the share of area under high-yielding varieties in 2000 is associated with a 10−15 percentage point increase in per capita GDP.

But if humanity has the wherewithal to make food plentiful and cheap, why are we failing to achieve our promises of hunger?

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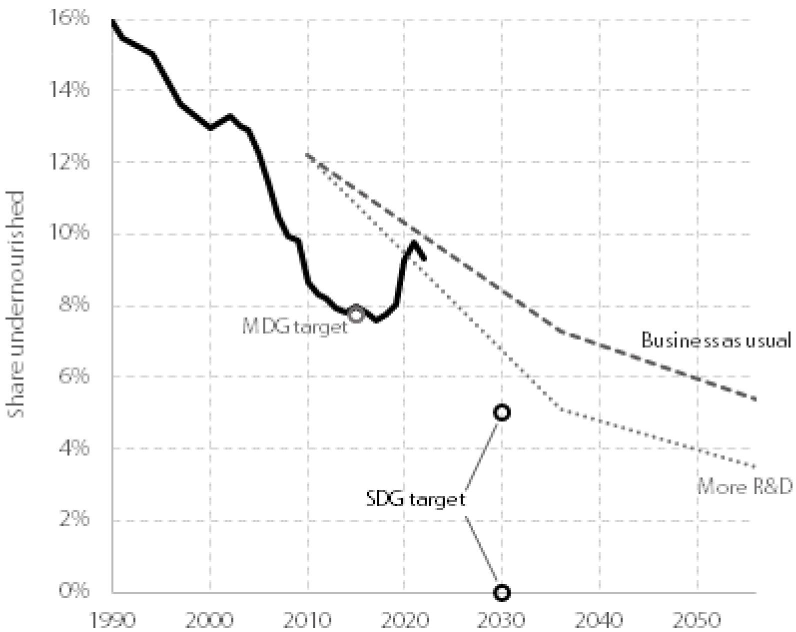
For all the SDGs' ambition, we're not solving hunger

The crystallizing focus of the MDGs helped accelerate undernourishment's global decline. The first goal of the MDGs was fairly simple: eradicate extreme poverty and hunger (UN 2015a, 14). Specifically, this meant halving the proportion of people suffering from undernourishment in 1990 by 2015 (UN 2015a, 20).

Urged on by this clear, concise goal, the world was able to cut hunger by 46%, almost succeeding on the MDG hunger target. As Figure 7.7 shows, 15.5% of people were undernourished in 1991, while only 8% were in 2015.



Source: 1990–2015 undernourished (UN 2015a, 20), 2000–2022 (FAOSTAT 2022), with [2022]() estimated for a medium impact of the war in Ukraine. *The MDGs target of 7.7% and SDGs target of 0% and 5% is shown (FAO 2015, 20; UN 2015a, 21). 2016–2056 shows reference and strongest R&D policy scenario from this chapter's academic paper.*

Figure 7.7. Share of the global population that is undernourished 1990–2056, with and without more agricultural R&D. The MDGs target was 7.7% and SDGs target of 0% and 5% for 2030.

Unfortunately, since then, the trend has gone the wrong way. After the proportion of hungry people hit a low point in 2017, undernourishment increased by 0.4 percentage points in 2019. And in 2020 and 2021, influenced by Covid, the world saw what was likely the single-largest increase in hunger over recent decades: 150 million more people or 1.7 percentage points. It is estimated that 2022 will be slightly better, despite the Russian invasion of Ukraine in early 2022, [adding]() another 8 million undernourished.

The SDGs haven't helped world leaders focus on this problem—partly because the goals themselves are remarkably unfocused. The hunger goal of [SDG 2]() sets a long list of ambitious targets related to hunger, food security, nutrition, and agriculture (UN 2015b, 15–16). One is directly related to decreasing hunger, but it's surrounded by many other targets. They promise secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets, and opportunities for value addition and non-farm employment. The SDGs also aim to double the agricultural productivity and income of small-scale food producers by 2030, particularly those that are women, indigenous people, family farmers, pastoralists, or fishers.

In addition, the SDGs call for sustainable food production systems and resilient agricultural practices that increase productivity and production; progressively improve land and soil quality; help maintain ecosystems; and strengthen the capacity for adaptation to climate change, extreme weather, droughts, flooding, and other disasters. The SDG agenda furthermore emphasizes the need to maintain the genetic diversity of seeds, cultivated plants, and farmed and domesticated animals and their related wild species. This explicitly includes the sound management of diversified seed and plant banks at the national, regional, and international levels, as well as the promotion of access to and fair and equitable sharing of benefits arising from the use of genetic resources and traditional knowledge.

It's not surprising that the target for addressing hunger gets lost among this wide array of complex goals. It reads more like a wish list of everything the world would possibly like to see done on food and farming than a concrete set of goals. While well-intentioned, these targets are staggeringly unrealistic in a world with limited means. They are all the more unrealistic given that the SDGs include similarly expansive and near-impossible promises across every other area of development.

Specifically, the SDGs set an entirely unrealistic aim of getting rid of hunger: "By 2030, end hunger." The UN systematically calls the entire goal "Zero Hunger."

Yet, the bureaucracy has reinterpreted "end hunger" to mean that we should reach a malnutrition incidence of 5%.[vii] Both the actual promise of zero hunger and the modified 5% are marked up in Figure 7.7, and it is evident that the difference is huge. The 5% figure is just about achievable with significant effort, whereas zero hunger is just impossible.

Based on the FAO's target and data from the Sustainable Development Report,[viii] which goes to 2021, it's obvious that we're going to miss SDG 2 by quite a bit. Because there isn't much or any data for most of the SDG indicators on these topics, the SDG index in Figure 7.8 is based on nine reasonably well-documented indicators. These include cereal yields, closing the gap to achieve the best yields; the prevalence of undernourishment, stunting, wasting, and obesity; and some more esoteric measures such as nitrogen management, energy intensity in diet, and exports of hazardous pesticides. Because these indicators cover a much smaller and better-documented area than the full SDG 2, the world's performance on them is likely better than on the entirety of the second SDG. And, as you can see in Figure 7.8, it still hasn't been great.

When the SDGs were adopted in 2015, the world was already 63.2% of the way to achieving the promises in SDG 2. Since then, we've made very little progress on the remaining 36.8%.

From 2015–19, the world only inched 1.2 percentage points closer to achieving SDG 2. If that trajectory hadn't been disrupted by Covid, we'd still only be 67.7% of the way to fulfilling the second SDG come the 2030 deadline. On our current trajectory, we're even further behind; we'll only reach the goal in 2116.

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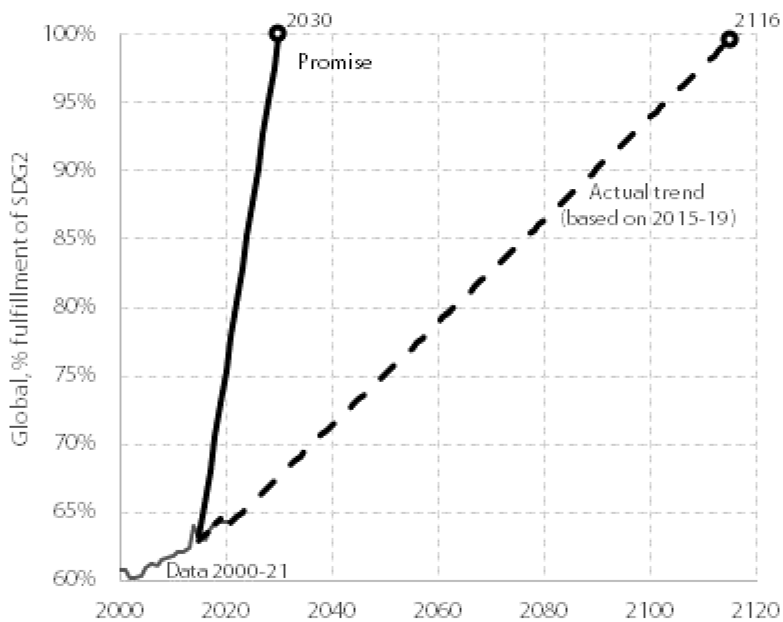


Source: The UN goal was focused on hunger, food security, nutrition, and agriculture. Data for 2000−21, based on Sachs et al. (2021). The promise of 100% fulfilment by 2030, trends based on progress from 2015−19, before Covid-19 hit, extrapolated from 2022, reaches 100% in 2116. The world had reached 63.2% fulfilment in 2015 and will, on 2015−19 trends, reach 67.7% by 2030.

Figure 7.8 Global fulfillment of SDG2, Zero Hunger, data from 2000–2021, trend after 2021, and the path to the 2030 goal.

As of 2021, low-income countries were 50.2% of the way to attaining SDG 2. On pre-Covid trends, they're on track to achieve it before the year 2171. Lower-middle-income countries are now at 56.5% and on track to reach 61.3% in 2030. They're on course to reach 100% slightly into the next century. The world isn't close to achieving zero hunger by itself, either. If you assume the trend of increasing hunger from 2015–19 continues, we'll never reach zero. Even stepping back to look at 2010–19, it'll take until 2141 to hit zero.

Many popular policies don't add up

Clearly, we need to speed up our progress on hunger. In addition to the urgent need of the world's undernourished, agriculture remains the largest economic sector in many low- and lower-middle-income countries. Improving farming output is, therefore, central to global development aspirations. Unfortunately, many of the agricultural policies that enjoy broad political support in developing countries actually achieve very little.

It's tempting, for instance, to focus on smallholder farms. In low- and lower-middle-income countries, they are a large constituency, so subsidizing inputs such as fertilizer and machinery or funding irrigation schemes can win over a sizeable voting bloc. But no nation has ever become rich when most workers are still smallholder farmers. Subsidization of small farms typically delivers fairly low benefits for society.

The complexity of finding good agricultural policies is a problem that goes beyond electoral politics. The Copenhagen Consensus has run 45 cost-benefit analyses on broadly used agricultural policies and consistently found that it's challenging for them to achieve spectacular returns. The main reason is that agriculture is a private enterprise with mostly private costs and benefits. If there were an easy way to generate large paybacks, farmers and companies would already be seizing those opportunities because there would be profit in them.

Take crop insurance. Dependent on weather and other uncontrollable variables, agriculture is always a bit of a gamble. That's why farmers in rich nations frequently take out insurance, but that sort of backing typically isn't available to their counterparts in poorer countries. These are the people who really need it the most; many farmers across the world are so poor that they cannot survive if just one harvest of a single crop goes badly. This leads them to plant 'safe' crops, which consistently produce some food but—on average—far less than better but more temperamental crops.

So, some conclude the government should fund insurance for these poorer farmers. Theoretically, this would allow them to plant more productive, somewhat risky crops. But if that were true, insurance companies likely would already be doing it because there'd be a profit to be made. Indeed, our research in Haiti and several states in India found that while this sort of intervention does help, the impact is rather small, and the cost is fairly high. Each dollar delivered less than $2 of social benefits. Moreover, the policy may not help vulnerable populations. Most of the benefits went to larger and better-organized landowners.

Fertilizer and energy subsidies are another policy with middling returns. Our research for Haiti found that fertilizer subsidies generate only about a $3 benefit per dollar. Subsidies also create distortions, are expensive, and often shift public resources to people who are already well off. Likewise, extension services—providing informal learning opportunities about agriculture—created only $3.50 of benefits for every dollar invested, our research on Bangladesh concluded.

These returns aren't bad, but, given that we live in a world with limited resources, they are likely not the best use of government money.

Unfortunately, some widespread policies do literally waste money, such as waiving farmers' loans. It's understandably a very popular policy with indebted farmers, and various governments have enacted agricultural loan waivers at the state and national levels. In India, the states of Uttar Pradesh, Maharashtra, and Punjab each undertook large-scale farm debt waivers that cost as much as 0.5% of the GDP of India.

Our research and other academic literature, however, find that a loan waiver scheme produce benefits below its costs, delivering just 95¢ of value to society for each dollar spent. And though these policies are cast as an aid to the poorest, loan waivers typically help bigger, already better-off farmers the most. In fact, previous waiver schemes have led banks to reduce credit for small farmers, thereby diminishing their chances of obtaining future formal loans. Small farmers are then forced to turn to informal loans, the rates for which are often far more expensive.

These are just a few examples, but you can see why it's so hard to find agricultural policies that are great investments. If there's an innovation, insurance system, or the like that can improve farm production and create benefits far beyond the costs, it'd already be in practice.

The one exception is when there's some constraint that keeps the private sector from acting or at least fully realizing the gains of a potential endeavor. And that's where the policy proposal of this chapter's paper comes in.

Solving hunger without having to bet the farm

Investing public resources in agricultural R&D for the poorer half of the world could generate truly impressive benefits at only a moderate cost. As this chapter already explored, innovation has played a major part in driving the global increase of food production and the reduction in hunger. Indeed, this chapter's paper finds that investing in agricultural R&D can result in more food being produced more efficiently, pushing down prices while reducing the number of malnourished.

Yet, agricultural innovation investment in the poorer half of the world has lagged for more than half a century. The vast majority of funding for agricultural R&D goes to rich nations.

That is because large-scale farms in rich countries with dependable property rights can afford to buy expensive but profitable technologies like new seeds. They have access to extensive agricultural science, funding, and infrastructure to enact innovations. Few of these things are available to poor farmers in low- and lower-middle-income countries.

Consequently, poor countries get very little global investment in farming technology. In 2015,[ix] 80% of global agricultural R&D funding went to the rich and upper-middle-income world, while lower-middle-income countries received almost all of the remaining 20%. Almost no funding went toward farming in the world's poorest countries.

It is one of the reasons why the original Green Revolution helped the poorest much less than others (Pingali 2012). Instead, innovation, along with fertilizer and irrigation, helped high-income countries much more. They saw their cereal yields almost triple from 1961 to 2021, whereas low-income countries saw a much smaller increase of just 60%. The issue isn't that poor countries can't grow much more food but that they don't have sufficient investment in the technology to do it.

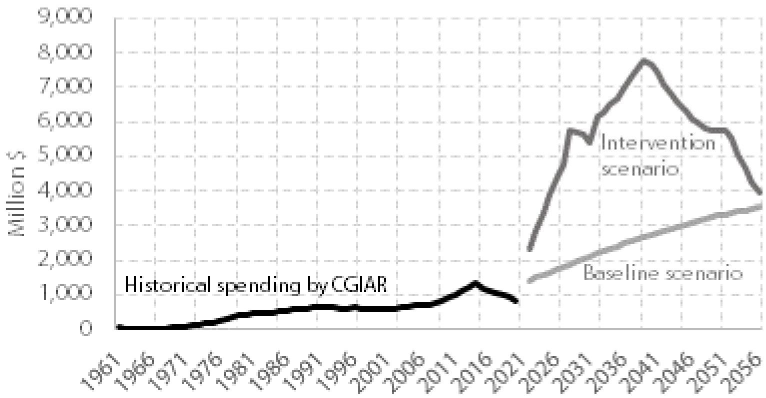
If governments step up to bring innovation investment to poorer countries, it could make a substantial difference. Every agricultural economist we've worked with as an advisor finds R&D is the single best agricultural intervention that can generate the largest benefits per dollar spent.

This is because each innovation can efficiently help millions of farmers. Making a higher-yielding seed, for instance, will help agricultural production everywhere where that seed grows well. Moreover, innovation can help even when many other parts of the agricultural system remain imperfect: Better seeds still mean better yields, even if there is too little irrigation or mechanization.

The additional R&D investment—shown in Figure 7.9 against historical levels—should be directed in four ways to help the Global South. First, money would need to go to internationally aligned research centers on innovation, technical, and policy support to improve food security, poverty, and ecosystem services globally—effectively, the international continuation of the original Green Revolution. These centers are known by the acronym CGIAR.

Second, the paper calls for investment by national agricultural research systems. This is crucial because these systems typically conduct locally relevant research for improving the agricultural efficiency of individual nations. Without their involvement, it will be difficult to create solutions that are tailored to particular climates and local contexts.

The third investment would be smaller and funneled toward innovation that can make those first two uses more effective. This could include, for instance, ensuring quicker and cheaper DNA sequencing of plants. Fourth, spending should go to the private sector toward improving food options for consumers in developing countries.



Source: All figures in millions are converted using GDP deflators from World Bank (2021a). Historical spending by CGIAR derived from Beintema and Echeverria (2020). Baseline and intervention scenario derived from IFPRI (2021).

Figure 7.9 Historical, baseline, and intervention funding for CGIAR 1961−2050.

The paper's authors use the IMPACT model to estimate the impact of investments across these four areas, as Table 7.1 outlines. IMPACT has a long peer-reviewed track record and can show physical results (like higher yields), producer economic impacts (like higher farm incomes), consumer impacts (like lower food prices and rates of hunger), and global outcomes (like higher GDP). The accounted benefits are the increased benefits for farmers as they can produce more and the consumer benefits because they pay less.

Each time you add one of these four avenues of funding, the total cost of the package, of course, goes up, but so do the benefits. These would help farmers, who would be able to produce more food and therefore generate increased total income, as well as help consumers who would get more food, cheaper.

The full package, which includes a 30% increase in private sector investments in developing countries, would cost $74 billion over the 35-year period. That is equivalent to an annual increase of $5.5 billion.

But this investment would generate $2,450 billion in benefits—a spectacular $33 return for each dollar invested. Per year, it would be equivalent to $184 billion in benefits, as shown in Table 3.1.

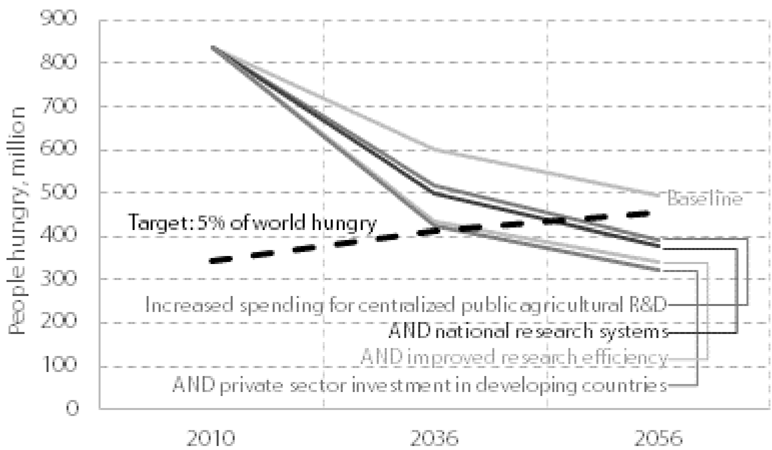
Table 7.1 Costs, benefits, and benefit-cost ratios of cumulative agricultural R&D interventions: 2015−2050.

	Total Benefits	Total Costs	BCR
Increased spending for centralized public agricultural R&D	$1,004	$35	29
AND national research systems	$1,294	$52	25
AND improved research efficiency	$2,178	$62	35
AND private sector investment in developing countries	$2,450	$74	33

Note: Each investment scenario (billions of 2020 US dollars), at an 8% discount rate.[x]

By 2050, the additional R&D in developing countries would increase agricultural output by 10% and reduce food prices by 16% as compared to keeping investment where it is today.

Moreover, the policy would allow more people to get the food they need. As Figure 7.10 shows, each added branch of funding would further drive down rates of hunger. The full package would almost achieve our modified SDG goal of reducing hunger to 5% by 2030 and reducing it even further by 2050.



Source: From IFPRI (2021) and (FAO 2021b).

Figure 7.6 Number of people hungry under baseline and ever more ambitious R&D investment scenarios as described in Table 7.1.

The added R&D would also likely boost GDP, but out of academic caution, this isn't added to the benefits summed in Table 7.1.

The full package would likely raise developing countries' GDP by an estimated $2.2 trillion by 2036 and $13.7 trillion by 2056—resulting in a 2% and 6% increase in per capita incomes, respectively. If the benefit-cost ratio was calculated using this GDP increase, the BCRs for each package would be an astounding eight times higher.

In addition, through improved efficiency, this additional agricultural R&D would reduce global climate emissions by more than 1%.

A chance to almost eradicate hunger

In agricultural R&D, world leaders have a policy that can make an astounding difference. Spending $74 billion will make farmers and consumers $2.5 trillion better off while reducing the number of malnourished by more than 130 million by 2030.

This policy is also much cheaper than what experts have projected. FAO has estimated that to reach a world in which only 5% of people go hungry, it would take $340 billion every year from 2016–30, totaling over $5 trillion (FAO 2015, 11). In addition, the FAO recommends an additional investment of $1.9 trillion annually, mostly into the non-agricultural economy, to drive up GDP to ensure a world with less than 5% hunger (FAO 2015, 21–27). Just about everyone favors fewer recessions and more economic growth, but it's hard to imagine that there's $28 trillion lying around for this FAO policy.

Funding agricultural R&D, by contrast, can reach the 5% hunger target with only $74 billion in additional spending. And it can generate far more economic growth for each dollar spent. In the process, the investment won't only make agricultural workers more productive but also enable more people to be productive and innovative in other sectors too. There will be more food, lower prices, and fewer people starving.

This intervention uses the same miraculous mix of innovation and growth that allowed much of the world to escape hunger. With just a small boost to investment, world leaders can save hundreds of millions from hunger and extend the gains of the Green Revolution for decades to come.

The academic paper is entitled "Benefit-cost analysis of increased funding for agricultural research and development in the global south"

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Footnotes

[i] The estimated number of DALYs lost for low-income countries is 84.4 million, and for lower-middle-income countries, 184.5 million in 2019 (IHME 2021; http://ihmeuw.org/5nfb), equivalent to a total of 268.9 million DALYs lost, evaluated at $2,893 each, or $778bn in total. The number of lives lost is 877,761 and 1,800,596 (http://ihmeuw.org/5nfc).

[ii] One can also distribute food more equally, but this has very little global data and likely has a smaller impact.

[iii] Chickens and pigs produce more than twice as much meat as they did 80 years ago, and cows produce twice the amount of milk. With modern fish farming, the Norwegian salmon has, since the early 1970s, also become twice as productive (Lomborg 2001, Skeptical Environmentalist, p. 63).

[iv] Using the average of Bourguignon and Morrisson's (2002) two poverty estimates, which fits better with the World Bank estimate than does either by itself.

[vi] Gollin, Hansen, and Wingender (2018).

[vii] The Food and Agriculture Organization suggests that zero hunger be reinterpreted to mean that 5% of people are undernourished (FAO 2015, 21). The FAO finds that this is the minimum hunger threshold; anything lower isn't possible to achieve through economic growth. The FAO estimates this target for each nation separately, but the calculations behind Figure 7.8 treat it as a global target for simplicity's sake. This is the same approach as that of the International Food Policy Research Institute (2021). Still, it's important to note that adopting it means that what you see in the figure is more optimistic than the national reality. Countries with a low incidence of hunger make up for the higher proportion of undernourished people in other places.

[viii] "Sustainable Development Report 2022: From Crisis to Sustainable Development." *The SDGs as Roadmap to 2030 and Beyond*. https://dashboards.sdgindex.org/

[ix] "Rekindling the Slow Magic of Agricultural R&D" by Julian M. Alston, Philip G. Pardey, and Xudong Rao published 3 May 2021 in *Issues in Science and Technology, National Academies of Sciences, Engineering, and Medicine*, Arizona State University, https://issues.org/rekindling-magic-agricultural-research-development-alston-pardey-rao/

[x] As a sensitivity analysis, we also conduct cost-benefit analyses using a 3% discount rate. In this case, the BCR of the recommended intervention (Scenario 4) jumps to 60.