Ceres2030
Sustainable Solutions to End Hunger

CHAPTER 6

The Scenarios for the Model

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INTRODUCTION

This chapter outlines the scenarios that will be used to estimate the cost of achieving SDG 2, specifically the sub-goals of SDGs 2.1, 2.3 and 2.4. There are different ways to quantify the sub-goals both in terms of targets and pathways, so it is important to explain the assumptions for the pathways chosen in the model and the process used for their selection.[1]

THE CONCEPT OF SCENARIOS

Traditionally, equilibrium models are used to quantify the impact of a policy shock (or of a package of policies) such as a reduction of tariffs linked to a new trade agreement, or introducing a biofuels target for a renewable energy policy. Using an equilibrium model, it is possible to compare what will happen in the future to a range of variables in the baseline, both with and without the policy shock. For example, if the scenario posits a doubling of corn tariffs, the model can show how other variables in the model—such as farm income—will be affected by this change from baseline conditions. Equilibrium models can show the full effect of a policy shock as it is transmitted through all the elements of the economic system that are presented in the model.

[1] For more on the importance of scenarios and their effect on cost estimates, see also Fan, S., Headey, D.D., Laborde Debucquet, D., Mason-D'Croz, D., Rue, C., Sulser, T.B., & Wiebe, K.D. (2018). *Quantifying the cost and benefits of ending hunger and undernutrition: Examining the differences among alternative approaches* (IFPRI issue brief). International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/9780896292994. https://www.ifpri.org/publication/quantifying-cost-and-benefits-ending-hunger-and-undernutrition-examining-differences

In contrast, the approach in Ceres2030 combines the structure of an equilibrium model without a pre-defined policy shock, but instead with a series of questions (the goals and targets set out in SDGs 2.1, 2.3 and 2.4). We then ask the model to optimize the total public costs of achieving the targets by allocating financial resources to a portfolio of interventions (such as social safety nets, rural infrastructure or subsidies for farm inputs). In order to simulate the portfolio of interventions, the model uses policy instruments (for example, research and development spending in the Consultative Group on International Agricultural Research [CGIAR] system) to represent the given intervention based on a complex set of direct and indirect relationships among the interventions and the defined targets. In the context of Ceres2030, the model results indicate the total public costs of achieving the targets of SDG 2 with the optimal funding allocations to the portfolio of necessary interventions (See Figures 1 and 2). The strength of the model lies in the fact that it captures the effects of the interactions between several interventions in order to optimize resource allocation to minimize the costs for achieving SDG 2.

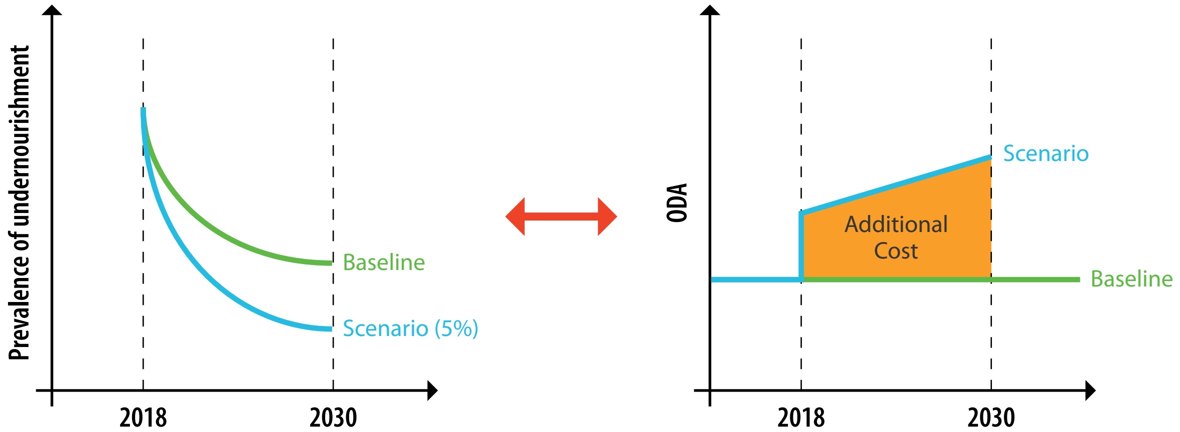
FIGURE 1. CONCEPTUAL FRAMEWORK

Source: Authors' diagram.

The scenarios are based on the targets defined in SDGs 2.1, 2.3 and 2.4, under some constraints (mainly from SDG 2.4, which commits to minimizing the environmental footprint from agriculture). We understand these targets as objectives, which are presented by the specific SDG sub-goals. In these scenarios, the objectives are defined by indicators such as percentage of the population that is undernourished and the level of economic productivity of small-scale food producers.

The model calculates the public costs associated with achieving the baseline scenario and then the *additional* public costs incurred if governments are to meet the targets of SDGs 2.1, 2.3 and 2.4. The emphasis on the additional public cost is the difference between the baseline (business-as-usual) and the scenario (what more needs to be done to achieve the target). For this reason, agreement on which baseline to use is critical to the outcome. Model results are derived from specific combinations of scenarios and baselines. Cere2030 provides alternative baselines and scenarios to show how the assumptions in the baseline affect the model results.

FIGURE 2. FROM TARGET TO COST ESTIMATE



Source: Authors' diagram.

TARGETS AND TIMELINES FOR THE CERES2030 SCENARIOS

This section clarifies the SDG 2 targets as well as the speed with which they are achieved and through which instruments.

TARGETS AND CONSTRAINTS

Within the objective to achieve SDG 2, we define:

Two **targets**:

1. **End hunger** (SDG 2.1): We use the prevalence of undernourishment (PoU) as defined by the Food and Agriculture Organization of the United Nations (FAO), which is expressed as the percentage of the population that is systematically failing to obtain enough calories to maintain a normal, active and healthy life.[2] For the PoU, we use a 5% upper bound target for countries by 2030. Details about the 5% upper bound were presented in Laborde et al. (2016). One of the scenarios will generate a cost for realizing the 0% PoU target, which requires a strategy where the hardest-to-reach segment of the population affected by hunger will have their needs met through the use of a social safety net payment (costed on a per capita basis). The payment is estimated to cover the cost of a minimal (but sufficient) food basket, rendered as a dollar figure per day, that the model can compute.
2. **Double the agricultural productivity and incomes of small-scale food producers** (SDG 2.3): We consider economic productivity (as opposed to a narrower definition of crop productivity), as discussed in Chapter 4. This is closely associated with net income of households for small-scale food producers, which captures the concept of doubling not only crop productivity but income as well.

And two **constraints**:

1. **Ensure sustainable food production systems** (SDG 2.4): This would be achieved through a constraint on greenhouse gas (GHG) emissions as a proxy to reduce land, energy and fertilizer use in agriculture. Where

[2] See http://www.fao.org/sustainable-development-goals/indicators/211/en/

available, we use the 2015 Paris Agreement National Determined Contributions (NDCs)[3] to define the target for GHG reductions in each country. This approach fits best with the SDGs, as they are inspirational goals that should be based on individual country ownership and commitment rather than externally imposed targets. We also monitor other environmental indicators such as water use, but this is not used as a constraint on the model. This is because there is no globally agreed target similar to the NDCs for water use. Instead, we monitor and compute water use indicators in the modeling exercise, but do not impose constraints and thresholds *ex ante*. Chapter 5 explains the approach for integrating SDG 2.4, including the selection of the constraint and indicators.

2. **The co-funding rule:** The model determines the total additional public spending required for each country annually and the split between the country share and the donor share. To calculate the donor share, we created a rule based on average annual donor contributions from 2009 to 2013: the "co-funding" rule.[4] Governments provide the remaining costs through increased taxes. In this sense, there is no "free lunch," and the financial costs are provided by economic agents in the model (either donors or governments) and therefore their opportunity cost is captured.

A DYNAMIC MODEL THAT OPTIMIZES SPENDING

Ceres2030 uses a dynamic model, which means that the speed of achieving the SDG 2 objectives influences the cost and the mix of interventions and related instruments used. For example, the sooner hunger can be reduced through remunerative employment, the less expensive the recurring cost of any social protection programs will be. Thus, it matters to the overall cost and policy mix whether small-scale food producer income is increased by 50% by 2025 or if it takes until 2027. The sooner it is achieved, the fewer other interventions are needed to protect against hunger, thereby lowering the overall cost.

The Ceres2030 model does not try to identify the optimal time profile to achieve the objectives. This would require making assumptions regarding the development of the local and specific political economy choices, which would not be appropriate. Furthermore, the modeling technology is not sufficiently fine-tuned to provide accuracy with regard to the optimal time profile. Instead, we prefer to assume a time path that is external to the model in which implementation is smooth and progressive.

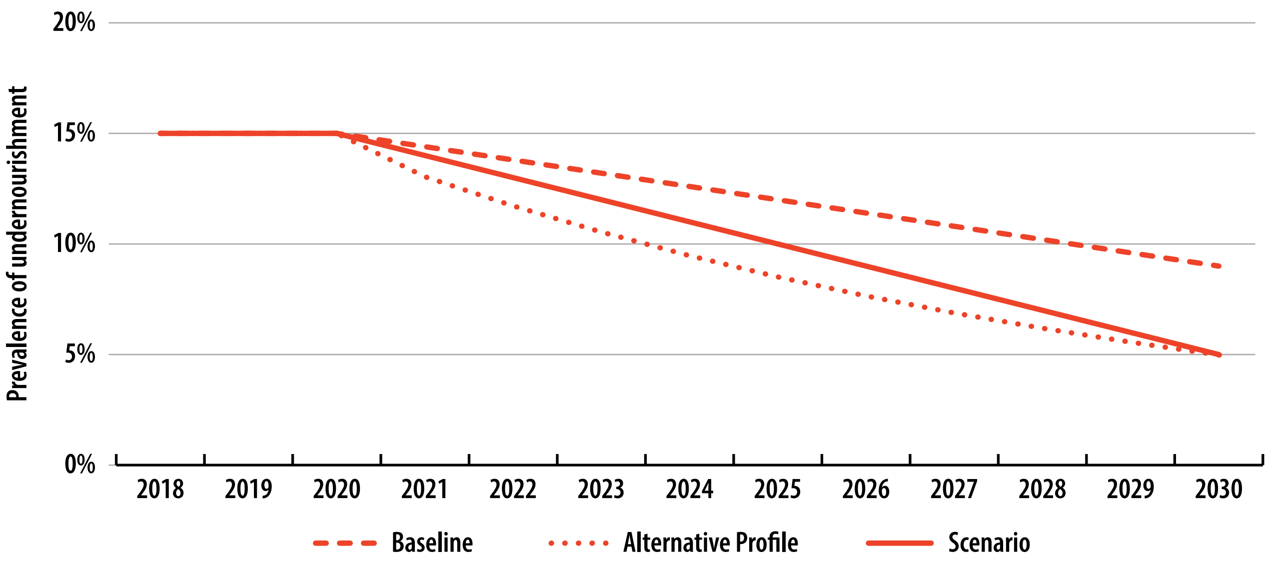
In line with the SDGs, the targets must be achieved by 2030 in the model. Given this externally imposed deadline, the model will favour spending on certain instruments over others in order to optimize the costs. Furthermore, the final deadline must be translated into intermediate deadlines because the model is run annually and corrects itself (and the spending on each intervention) in order to reach the targets by the final deadline.

The intermediate deadlines can be translated either linearly or non-linearly. For example, if we want to go from a PoU of 15% to 5% between 2020 and 2030, we can reduce the PoU by 1% each year for 10 years. This would be a linear approach. The alternative is to reduce the PoU on a relative basis, in other words, by the same proportion each year until we reach the 5% target. This would be a non-linear approach. We prefer the non-linear approach because it will require lagging countries to spend relatively more during the period 2021–2025, thereby reducing the overall costs (see Figure 3).

[3] https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/ndc-registry

[4] The co-funding rule is established through an econometric analysis of existing donor support to developing country budgets over the period 2009–2013. The analysis provided an external share of donor contributions to developing country budgets by level of GDP per capita. The donor contributions declined as a country got richer: the co-funding rule is applied on an annual and country basis, and the external share decreases over time depending on each country's economic performance.

FIGURE 3. SAMPLE PATH FOR HUNGER REDUCTION FOR A COUNTRY WITH 20% POU.



Source: Authors' diagram.

Since each country has its own performance profile in the baseline, expressed as the achievement of a PoU and doubling in small-scale food producer income by 2030, the actual speed and trajectory are country-specific. The actual targeted hunger level in year t, after 2020, in the scenario is given by $Baseline_t + Min\ (0{,}5\% - Baseline_{2030})\ /10)$, and for income, we consider that income growth after 2020, compared to the baseline year should be equal to

$$Max\ (\frac{Baseline_t}{Baseline_{2015}} -1,\ 1.0718^t - 1)$$

WHO PAYS?

To achieve the targets, we use financial resources that the model allocates to different instruments (See Box 1).

BOX 1. AN INTERVENTION OR AN INSTRUMENT – WHAT IS THE DIFFERENCE?

In order to make an intervention happen we need tools. Such tools can be called **instruments**. Defined by Merriam-Webster as "a means whereby something is achieved, performed, or furthered."

In general, **interventions** include "programs, projects, policy measures, reforms," while an instrument is the tool, in the form of "a deliberate structured effort by governors to solve a policy problem by modifying actions of the governed." There is a strong complementary relationship between the two; we need both to make changes in achieving targets such as those in SDG 2.

In Ceres2030, we use "interventions" as the broader term and "instrument" to describe how the intervention is represented in the modelling framework.

[1] *Merriam-Webster (2001). Merriam-Webster's Collegiate Dictionary (10th Ed.).*

Sources: Leeuw & Vaessen, 2009; Eliadis, Hill, & Howlett, 2005; and Laborde at al. (2018).

The fiscal surpluses or deficits in each country are imposed on the model based on their initial share of GDP in the baseline. The fiscal surplus or deficit evolves based on the economic projections for GDP over the period. The model assumes that the level of taxation is adjusted to account for the fiscal surplus or deficit. This is a hypothesis that allows us to understand how the additional public spending is paid for and by whom (donors or domestic resource mobilization).

Total public spending each year in each country is paid by a mix of external and domestic resources. The total costs are the sum of additional donor support and the sums required from domestic public spending. The split is defined by the co-funding rule established in *Ending Hunger: What Would It Cost?* (Laborde et al., 2016). The model assumes domestic taxation is used to raise the final sums needed to cover the total additional public costs.

Increased taxes are not assumed to cover the total amount not covered by donors. Macroeconomic adjustments can generate additional gains (or losses) to the public treasury. For example, higher economic growth will generate a larger tax base, while lower imports might reduce the tax base by reducing tariff revenues. Therefore, the model will use the tax rate adjustment only on the net amount needed (domestic bill minus the internal changes in tax revenue). In this version of the model, we consider a change in the final consumer tax rate (e.g., value-added tax [VAT]) as the adjustment variable that maintains government surplus or deficit constant in real terms. This policy can be considered as a regressive instrument since consumption taxes affect poor households relatively more than rich households.

Once a sum of money is created, it needs to be invested. The model channels the money through a variety of instruments. We start with the list of instruments used in *Ending Hunger: What Would It Cost?* (see Appendix 1) but update several parameters based on the data coming from the evidence review results from *Nature* research publications. Since several different estimates could exist for a given instrument (e.g., yield elasticity or level of price transmission), we use the 75th percentile of the distribution as a central value in our assessment. This means that we do not consider an average efficiency of the interventions but instead assume an above-average level of efficiency. This is based on the assumption that the evidence generated from the evidence reviews points to the most effective instruments to achieve SDG 2. We do not use the maximum value that may be associated with an intervention since these values were likely estimated under positive conditions (such as those found in lab trials). The types of interventions and their interactions are presented in Chapter 7.

SCENARIOS FOR CERES2030

As pointed out above, the scenarios will be the combination of a set of targets and a defined baseline. The baseline is defined in Chapter 2. To summarize, the first group of baselines includes a number of structural assumptions (for example, economic growth, demographic growth, yield dynamics) and some economic policy-related decisions (for example, trade regime, levels of official development assistance [ODA], domestic spending on food security and nutrition, and a country's climate mitigation strategy). While we do not interfere with the structural assumptions, we still update these as new data and information become available. In the second group of baselines, the policy-related baseline assumptions, we include a number of policy parameters linked to decisions that are not independent of the overall SDG agenda. Therefore, there are some important choices to make and some alternatives from which to choose.

Three dimensions are used to define and differentiate the scenarios (see Table 1):

i. The targets and constraints
ii. The type of interventions and instruments and their degree of efficiency
iii. The wider policy environment.

Items *ii* and *iii*, can be seen as experiments in terms of a sensitivity analysis of the results.

Many alternative combinations and options would have been possible, but not all will be relevant or useful. We consulted donor agencies through the SDG 2 Roadmap Group, as well as with representatives from international organizations, to make the final selection of six scenarios.

The final scenario selection is split into two categories: the central scenarios and three additional scenarios, to provide a more pessimistic or optimistic view. The additional scenarios provide a **sensitivity analysis** on some of the assumptions in the central scenarios.

The three central scenarios include:

1. **Central Scenario:** This includes the core targets: (1) a PoU of 5% or less in each country, (2) doubling of productivity and income of small-scale food producers, and (3) constant GHG emissions for agriculture, based on the Paris Agreement. The policy instruments are based on our extended library of interventions based on the evidence reviews, with an improved efficiency coefficient (75th percentile).
2. **Central Scenario + trade policy reform:** This includes the core targets, plus a change in the baseline based on the World Trade Organization (WTO) Doha Agenda and the implementation of the African Continental Free Trade Area (AfCFTA).
3. **Central Scenario + PoU 0%:** This includes core targets, but with a change to target (1) where we extend spending on **social safety nets** to guarantee a PoU of 0%.

The three additional scenarios include:

4. **Blue Sky Scenario:** The core targets but with the highest degree of efficiency of the instruments used, together with a number of new projects and "blue sky" technologies. For these new projects and technologies there is currently insufficient evidence on their use and effectiveness, but they may have a high potential in the future. This includes, for example, small-scale farm mechanization using drones, 2.0 extension services supported by smartphones, drones, artificial intelligence and blockchain technology.

5. **Pessimistic Scenario:** The core targets but with the average degree of efficiency of the instruments used. It assumes we do not improve our effectiveness and efficiency in the existing interventions and instruments. This increases the cost of achieving the targets, as more spending is needed to compensate for poor efficiency. It means that on average in the next 10 years we will be "as good" as before in deploying interventions, meaning that we did not really learn about "how" we should do things.
6. **Yield-Focused Scenario:** The core targets, but with a change to target (2), where instead of doubling the income of small-scale food producers, we only double the productivity of producers by doubling yields. This is to provide a cost estimate for actors that are still heavily focused on physical, partial productivity in agriculture.

TABLE 1. SCENARIOS FOR CERES2030

SCENARIO	TARGETS: 2.1/2.3/2.4	INSTRUMENTS	POLICY ENVIRONMENT
1. Central scenario	PoU 5%/ 2x Income / Constant GHG budget	Improved interventions based on Nature publication	No change
Pessimistic scenario	PoU 5%/ 2x Income / Constant GHG budget	Average interventions based on Nature publication	No change
Blue sky scenario	PoU 5%/ 2x Income / Constant GHG budget	Game-changer Interventions	No change
2. Central scenario with trade policy reforms	PoU 5%/ 2x Income / Constant GHG budget	Improved interventions based on Nature publication	WTO Agreement + AfCFTA
Yield-focused	5% PoU / 2x Yield / Constant GHG budget	Improved interventions based on Nature publication	No change
3. Central scenario + PoU 0%	0% PoU / 2x Income / Constant GHG budget	Improved interventions based on Nature publication	No change

REFERENCES

Laborde D., Bizikova, L., Lallemant, T., & Smaller, S. (2016). *Ending hunger: What would it cost?* (International Institute for Sustainable Development [IISD] and IFPRI briefing note). IISD. https://www.iisd.org/sites/default/files/publications/ending-hunger-what-would-it-cost.pdf

APPENDIX 1. INTERVENTIONS ASSESSED IN THE ENDING HUNGER PROJECT

#	INTERVENTION	TARGETING/COVERAGE	STRUCTURAL EFFECTS	NATURE OF EXPENDITURE
1.	Food subsidy	Food items for households with income below the poverty line (USD 1.95 purchasing power parity [PPP])	Food cost reduction per capita through an endogenous homogenous subsidy rate at the household level	Cost of the public subsidies
2.	Investment subsidy	All agricultural sectors, all producers	*Ad volumen* subsidy to domestic investments	Cost of the public subsidies
3.	Fertilizer subsidy	Crop sectors, all producers	*Ad valorem* subsidy on chemical inputs consumed by agricultural sectors and yield effects captured changes in the production function.	Cost of the public subsidies
4.	Capital endowment	All agricultural sectors, only smallholders	Allocation of physical capital (e.g., machinery, livestock) given to targeted households	Investment goods bought by through public expenditures
5.	Production subsidy	All staple crops sectors, all producers	*Ad valorem* production subsidy applied to the farm gate price.	Cost of the public subsidies
6.	R&D national agricultural research systems (NARSs)	All agricultural sectors, all producers	Agricultural total factor productivity (TFP) is increased based on the stock evolution of NARS R&D.	Additional NARS expenditures spent on public services
7.	R&D CGIAR	All agricultural sectors, all producers Affects all Africa at once	Agricultural TFP is increased based on the stock evolution of CGIAR R&D.	Additional CGIAR expenditures spent on public services
8.	Extension Services	Agricultural sectors, smallholders	Efficiency of production factors, i.e., difference between physical and efficient units, for smallholders	Public services expenditures
9.	Storage post-harvest losses	Crop sectors, smallholders	Efficiency of production factors for smallholders and reduction of an initial shadow tax on factors of production	Aggregated capital goods for expenditures based on unit costs by type of investments
10.	Rural infrastructure (irrigation)	Crops sectors, all producers	Agricultural TFP is increased based on the growth of irrigated area.	
11.	Rural infrastructure (road)	Agricultural sectors, all producers	Agricultural TFP is increased based on the growth of road infrastructure.	

APPENDIX 2. LIST OF INTERVENTIONS AND IMPLEMENTATION STRATEGY (2018/2019) – MATHEMATICAL APPENDIX

#	INTERVENTION	TARGETING / COVERAGE	STRUCTURAL EFFECTS	NATURE OF EXPENDITURE	COST BY COUNTRY
1.	Food subsidy	Food items Households with income below the poverty line (USD 1.95 PPP) defined in the set $HH\_FS(hh)$	Food cost reduction per capita $subPC_{r,t,sim}$ through an endogenous homogenous subsidy rate at the household level $suvEQ_{i,hh,t}$: $subPC_{r,t} \times Units\_hhld_{r,hh,t} = \sum_{i \in FOOD} suvEQ_{i,hh,t} \times PC_{i,r,hh,t} \times CHi_{i,r,hh,t}$ In the consumer demand system, the food price become $(1\text{-}suvEQ_{i,hh,t}) \times PC_{i,r,hh,t}$	Public Transfers	Cost of subsidies in year t and region r $\sum_{hh \in HH\_FS(hh)} subPC_{r,t} \times Units_{hhld_{r,hh,t}} \times Number\_hh_{r,hh,t}$
2.	Investment subsidy	All agricultural sectors, all producers	Ad volumen subsidy to domestic investments $SubInv_{i,r,t}$, increasing the rate of return in the investment function $(WK_{i,r,t}+SubInv_{i,r,t})$	Public Transfers	Cost of subsidies in year t and region r $\sum_{i \in AGRI,s} SubInv_{i,r,t} \times INV_{i,s,r,t}$
3.	Fertilizer subsidy	All crop sectors, all producers	Ad valorem subsidy on chemical inputs consumed by agricultural sectors $subicc_{\text{“chem”},AGRI,r,t}$ such as $PIC_{\text{“chem”},AGRI,r,t}=PDEMTOT_{chem,r,t}(1+taxicc_{\text{“chem”},AGRI,r,t} - subicc_{\text{“chem”},AGRI,r,t})$ To capture the yield effects, we replace the Leontief functional form between inputs and value-added (VA) by a CES function with calibrated CES elasticities to approximate the right yield elasticity.	Public Transfers	Cost of subsidies in year t and region r $\sum_{i \in AGRI,s} subicc_{\text{“chem”},i,r,t} \times PDEMTOT_{\text{“chem”},r,t} \times IC_{\text{“chem”},i,r,t}$
4.	Capital endowment	All agricultural sectors, smallholders $smallH(hh)$	Allocation of physical capital (e.g., machinery, livestock) given to targeted households $addK_{hh,i,r,s,t,sim}$ Sub-sectoral allocation of new capital is driven by current investment shares It leads to an increase in the capital endowment of the household and the productive capital of agricultural sectors.	Aggregated Capital Goods	$\sum_{\substack{hh \\ HH\_smallH(hh)}} PINV_{r,t} \times addK_{hh,i,r,s,t,sim}$

#	INTERVENTION	TARGETING / COVERAGE	STRUCTURAL EFFECTS	NATURE OF EXPENDITURE	COST BY COUNTRY
5.	Production subsidy	All staple crops sectors, all producers	*Ad valorem* production subsidy applied to the farm gate price $subProd_{STAP,r,t}$	Public transfers	Cost of subsidies in year t and region r $\sum_{i \in STAP} subProd_{i,r,t} \times PY_{i,r,t} \times Y_{i,r,t}$
6.	R&D NARS	All agricultural sectors, all producers	Agricultural TFP is increased by a multiplicative factor: $TFPNARS_{AGRI,r,t,sim} = \frac{NARSSTK_{r,t}}{NARSSTK_{r,\text{"}2011\text{"}}}^{\alpha\_NARS}$ With the stock of NARS R&D $NARSSTK$ and the increase in NARS expenditures $(NARSEXP)$: $NARSSTK_{r,t} = \sum_{k=0}^{t\text{-}2012} \gamma_{k,t} \frac{NARSEXP_{r,t\text{-}k}+NARSBAS_{r,t\text{-}k}}{PCG_{\text{"}PubServ\text{"},r,t\text{-}k}} +NARSBASO_{r,t}$ We assume a polynomial 30 lag structure defined by $\gamma_{k,t}$. with k the lag. The polynomial structure and the initial value of NARS expenditures $NARSBASO_{r,t}$ is redefined initially for each year to capture the evolution of R&D stocks for years before 2011. In the baseline, $NARSBAS_{r,t}$ follows the evolution of public expenditures.	$NARSEXP_{r,t}$ spent on public services	Additional NARS expenditures $NARSEXP_{r,t}$
7.	R&D CGIAR	All agricultural sectors, all producers Affects all Africa at once.	Agricultural TFP is increased by a multiplicative factor $TFPCGIAR_{AGRI,r,t,sim}$. Same modelling approach as in the NARS case with a regional approach.	$CGIAREXP_{t}$ spent on external Public Services	Additional CGIAR expenditures $CGIAREXP_{r,t}$ Not included in the external payment to the country and assumed a 100% payment by donor.

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ABOUT CERES2030

Ceres2030 brings together three institutions who share a common vision: a world without hunger, where small-scale producers enjoy greater agricultural incomes and productivity, in a way that supports sustainable food systems. Our mission is to provide the donor community with a menu of policy options for directing their investments, backed by the best available evidence and economic models.

The partnership brings together Cornell University, the International Food Policy Research Institute (IFPRI) and the International Institute for Sustainable Development (IISD). Funding support comes from Germany's Federal Ministry of Economic Cooperation and Development (BMZ) and the Bill & Melinda Gates Foundation (BMGF).

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