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Abstract

Agricultural transformation has been ongoing for decades in Ethiopia where the agenda to improve nutrition has also gained momentum. We use a dynamic computable general equilibrium model combined with a multicriteria decision-making technique to assess ways in which the government could coherently pursue the objectives of reducing the cost of the least-cost healthy diet for Ethiopians (which is unaffordable to millions) and achieving faster inclusive agricultural transformation (IAT), i.e. increasing agrifood output, creating rural off-farm employment and reducing rural poverty. Simultaneously improving on these objectives will require a different prioritization of the public budget allocated to agriculture. We find that when the objective of reducing the cost of the least-cost healthy diet is pursued alone, such cost decreases the most, allowing for the highest improvement in the affordability of healthy diets. However, this is at the expense of not improving as much as possible towards IAT objectives, because the budget is biased towards the production of the nutritious foods that make up the least-cost healthy diet. Thus, the opportunity to additionally create thousands of jobs and get thousands of Ethiopians out of poverty is foregone. On the contrary, we find that pursuing IAT objectives alone seizes this opportunity while also reducing the cost of the least-cost healthy diet in Ethiopia. Ethiopian policymakers may consider repurposing the budget for agriculture to pursue IAT objectives as suggested in this paper in order to increase value for public money, not only in terms of agrifood output growth, job creation and poverty reduction, but also in terms of increasing the affordability of healthy diets.

Keywords: computable general equilibrium, optimal policy design, economic development, agricultural transformation, nutrition.

JEL codes: C61, C68, E61, O18.

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As such, it has benefited from the extensive technical review across the five partners of the report: the Food and Agriculture Organization of the United Nations (FAO), the International Fund for Agriculture Development (IFAD), the United Nations Children's Fund (UNICEF), the World Food Programme (WFP) and the World Health Organization (WHO).

The paper also presents a methodological innovation in the framework of the policy prioritization workstream of FAO's Monitoring and Analysing Food and Agricultural Policies (MAFAP) programme.

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1 Introduction

Agricultural transformation is still under way in many parts of the world, particularly in low-income countries and sub-Saharan Africa at the regional level. In these countries, agriculture still represents a significant share of total output and employment generation and is a source of livelihoods and food for millions of people. Focusing on sub-Saharan Africa makes sense when it comes to the issue of agricultural transformation considering that in this region industrialization, the main driver of past transformations, is not occurring in most countries (FAO, 2017).

Agricultural transformation helps countries achieve a number of development objectives in the realms of agricultural productivity, employment, productive linkages between agriculture and the rest of the economy, and market integration. Timmer (1988) describes it as a process of four consecutive phases: (i) a rise in agricultural productivity per worker resulting in a surplus of labour, expenditures and savings; (ii) the tapping of such surplus (e.g. through taxation and factor flows) to enable development in non-agricultural sectors through better integration of factor and product markets between the rural and non-rural sectors; (iii) the progressive integration of the agricultural sector into the macroeconomy, via improved infrastructure and market-equilibrium linkages; and, (iv) the establishment of agriculture's role in an industrialized economy. The end of the process is expected to result in a higher economic growth state. This process is also characterized by economy-wide and multisectoral interactions that take place over time, which are also affected by policy choices.

Notwithstanding decades of economic growth and poverty reduction globally, many countries have not yet witnessed such similar progress in inequality reduction. Hence, there is currently consensus in scholarly and policy circles that agricultural transformation should also be inclusive,[1] which adds complexity to policymaking. In this case, policymakers will be transforming agriculture with inclusion only when multiple objectives have been achieved, not just in the realms of agricultural productivity growth, agricultural and national economic growth and employment, and food industry development, but also in terms of objectives such as poverty reduction and eradication of hunger and food insecurity, among others. Policymakers face the challenging task of making the optimal policy choices to achieve such multiplicity of inclusive agricultural transformation (IAT) objectives, while minimizing trade-offs between them.[2]

Policymakers will also face the challenge of accommodating other emerging developmental priorities next to those of transforming agriculture without leaving anyone behind. In 2020, FAO began to publish data on the cost and affordability of healthy diets. This brought global attention to the fact that, in countries both rich and poor, low disposable income relative to the high cost of food is one of the most serious impediments to accessing nutritious foods essential for a healthy, active life. Using these data, FAO *et al.* (2020) pointed to an alarming number: More than 3 billion people cannot afford even the average cost of the cheapest healthy diet in the world. These UN agencies presented this number not only as a serious manifestation of food insecurity in the world but also as a warning that over time, the resulting poor diet quality of those who cannot afford a healthy diet will lead to different forms of malnutrition, including undernutrition, micronutrient deficiencies, overweight and obesity. Ever since such an alarming

[1] See, for example, Osabuohien (2020) for an in-depth discussion on the need for inclusive agricultural and rural development in the context of Africa.

[2] There is also an increasing focus on the environmental sustainability of agricultural transformation so that it is achieved within the limits of the available natural resources. This dimension, while critically important, is beyond the scope of this paper.

number was published, and the nexus between overweight and obesity in the world and the unaffordability of healthy diets became more apparent, the issue of reducing the cost and increasing the affordability of healthy diets was placed high up on the sustainable development agenda.

The lack of affordability of healthy diets does not spare low-income countries that are undergoing agricultural transformation. FAO data show that the cost of a healthy diet in 2020 was USD 3.46 and USD 3.44 per person per day in Africa and sub-Saharan Africa, respectively, which is lower than USD 3.54 per person per day in the world. In Asia and Latin America and the Caribbean, the cost of a healthy diet was significantly above the world average. Even so, 79.9 and 85.5 percent of African and sub-Saharan African, respectively, were unable to afford a healthy diet in 2020.[3] These percentages are significantly above those of any other region in the world. They point to the fact that the cost of a healthy diet is high relative to the limited income of the African population, particularly in sub-Saharan Africa where 38.3 percent of the population is extremely poor (according to the World Bank's poverty headcount ratio at USD 1.90 a day [2011 PPP] for 2019; World Bank, 2022).

Agricultural transformation strategies often prioritize sectors and commodities on the basis of economic, social and political criteria, expecting that these sectors will exhibit a productivity boost with important payoffs for the population, including their food security. However, this prioritization may not be entirely aligned with what is required to produce and make available all the nutritious, diverse and safe foods that make a healthy diet affordable to all.

A healthy diet provides adequate calories and nutrients and a diverse intake of foods from several different food groups (FAO *et al.*, 2020). The production of some foods in these groups may not be among the high priorities of ongoing IAT strategies. Many countries, particularly in sub-Saharan Africa, are still highly reliant on the production of one crop for national food security, which largely determines the total caloric intake of the rural population (Heumesser and Kray, 2019). The key question facing policymakers in sub-Saharan African countries undergoing agricultural transformation is: How can the necessity of making healthy diets more affordable to all and the achievement of agricultural transformation objectives be aligned? Can agriculture be transformed so that it also delivers lower cost and safe, nutritious foods that make healthy diets more affordable for all?

Delivering healthy diets at a lower cost to contribute to people's ability to afford them will require both an expansion in the supply of the nutritious and safe foods that constitute a healthy diet and a behavioural shift such that consumers demand them more. The expansion in the supply will require significant investments. However, the current context of economic recession, reduced household income (at least for the lowest deciles of the income distribution), erratic tax revenues, and inflation pressures is not one in which many low-income countries, not least in sub-Saharan Africa, could massively invest in agriculture. Even before the COVID-19 pandemic – that prompted governments all over the world to respond with restrictive measures that resulted in economic contractions globally – not only were sub-Saharan countries spending less on agriculture in per capita terms relative to other regions in the world, but also very few of these countries had met the 10 percent Maputo target, despite a renewed commitment in 2014 through the Malabo Declaration, which suggests that investment levels were already suboptimal (Pernechele *et al.*, 2021).

[3] FAO facilitated the data on the cost and affordability of a healthy diet for the elaboration of this background paper for the 2022 edition of *The State of Food Security and Nutrition in the World* report. The latter is where the data are officially published.

Even in such a difficult context, public spending and investments in agriculture are particularly important because many private investors (including farmers) are more risk averse in terms of investments in a sector where business is typically perceived as risky, particularly nowadays in the face of climate adversities. As this paper argues, using Ethiopia as an example, and taking as background, Pernechele *et al.* (2021) who have demonstrated that public budgets are suboptimal in sub-Saharan Africa, a rigorous examination and reallocation of agriculture's public budgets is needed to make them more efficient or optimal, and this is a critical step for governments to take for aligning healthy diets' affordability objectives and agricultural transformation objectives in this region. In this paper, following the principles of Pareto optimality, a public budget becomes optimal when policymakers reach a compromise to reallocate it in a unique way whereby it is not possible to improve in at least one policy objective without worsening any of the other policy objectives.

In addition to offering a better understanding of how both agendas (i.e. affordable healthy diets for all and IAT) do not need to contradict each other if optimal budgets are used and extending an existing policy optimization modelling framework to do so, this paper also contributes to a topic that has also been placed high up on the global agenda. Evidence is emerging that agricultural support policies in both developed and developing countries are providing vast transfers of resources to farmers – about USD 620 billion per year worldwide in 2018–2020 (Gautam *et al.*, 2022). Some agricultural support policies, such as input subsidies, have boosted global food production, particularly of staple crops, thereby reducing hunger and poverty. However, there are serious concerns about their impacts on achieving sustainable, healthy, and efficient agrifood systems. Several recent studies have thus recommended that redirecting or "repurposing" agricultural public support towards investments and incentives that encourage increased productivity, sustainable production practices and healthy dietary choices has the potential for win-win-win gains for people, planet and prosperity (Ding *et al.*, 2021; FAO, UNDP, and UNEP, 2021; Gautam *et al.*, 2022)

These studies have been addressing the problem at global level, while country-specific studies are generally unavailable to show how the repurposing of public resources that support agriculture is done in practice for win-win-win gains. This paper provides evidence to start filling the literature gaps with regards to repurposing public support for agriculture at country level to achieve win-win gains for Ethiopians and their prosperity. It thus also answers another key question: Would repurposing agriculture's public budget in ways that allow spending optimally help achieve the best possible results when pursuing IAT objectives and increasing the affordability of healthy diets?

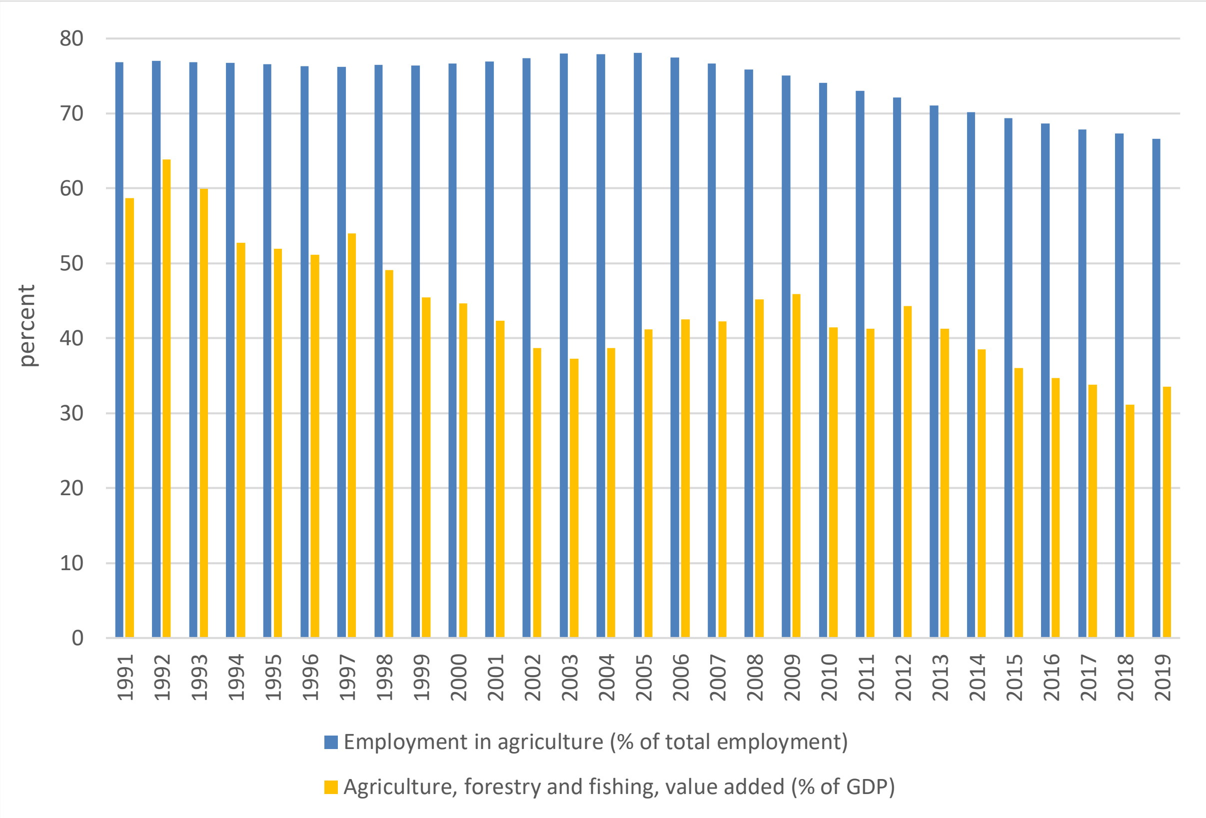
The remainder of the paper includes four more sections. Section 2 is descriptive of Ethiopia's vision, plans of agricultural transformation and the advances of the process over the years and the challenges it still faces; the country's more recent momentum for nutrition improvement and food nutrition security commitments and plans, and the nutrition challenges that still need to be addressed; the section also discusses the coherence between the two agendas' policy documents and plans. Section 3 presents the policy optimization modelling framework that we use and extend, in order to determine optimal ways to allocate Ethiopia's public budget to agriculture for better alignment of healthy diets' affordability and agricultural transformation objectives. This section also describes the data used to calibrate the modelling framework. Section 4 provides an analysis of optimal domestic public budget scenarios that would allow Ethiopia to get better results in transforming agriculture with inclusion while increasing the affordability of healthy diets. Finally, Section 5 highlights our main conclusions and future extensions to our modelling approach.

2 Agricultural transformation and nutrition agendas in Ethiopia

2.1 Agricultural transformation: a long but incomplete process

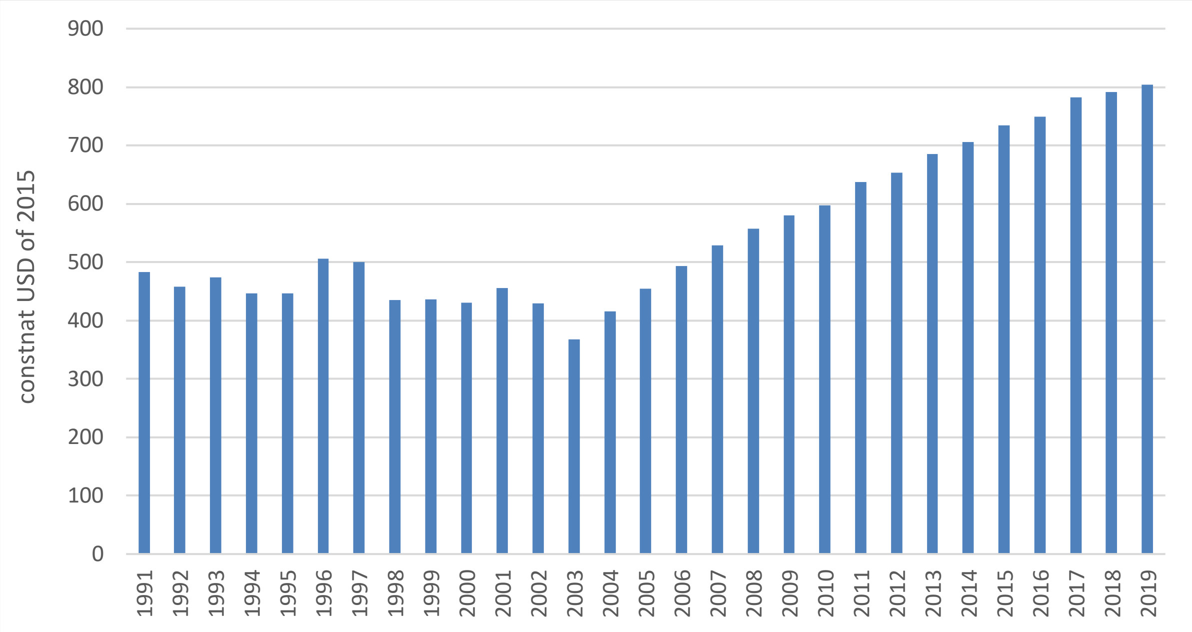
Ethiopia has not fully undergone agricultural transformation but, at the same time, is among the few developing countries which has its own agency (i.e. Agricultural Transformation Agency – ATA) and has invested significantly in agricultural transformation. The country's first and second growth and transformation plans (GTP) outlined the vision for a transformed agricultural sector aimed at increasing productivity of strategic crops, together with specialization, diversification and commercialization. Clear signs of agricultural transformation in Ethiopia include, among others, a declining share of agriculture in total employment and GDP (NBE, 2020; NPC, 2018; see also Figure 1); increased labour productivity in agriculture (NPC, 2016; see also Figure 2) and a more intensive use of other inputs and increased efficiency (Bachewe, 2012); movement of rural labour away from agriculture (NPC, 2018; World Bank, 2021); and a reduction in poverty and food insecurity (NPC, 2018).

Figure 1. Ethiopia: employment in agriculture (percent of total employment) and value added in agriculture, forestry and fishing (percent of GDP), 1991–2019



Source: World Bank. 2002. Employment in agriculture (% of total employment) (modeled ILO estimate) - Ethiopia. In: *World Bank*. Washington, DC. Cited 10 June 2022. https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ET

Figure 2. Ethiopia: agriculture, forestry and fishing, value added per worker, 1991–2019



Source: World Bank. 2002. Agriculture, forestry, and fishing, value added (% of GDP) - Ethiopia. In: *World Bank*. Washington, DC. Cited 10 June 2022. https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=ET

However, challenges persist. Ethiopian agriculture is predominantly cereal based and relies on a household-based and subsistence-oriented system. Rural off-farm employment creation remains below expected targets (NPC, 2018). Productivity growth is still below its potential because of underdeveloped input supply systems, poor incentives, and the predominance of rain-fed farming systems, moisture stress and eroded soils, and low levels of mechanization. Meja, Alemu and Shete (2021) have observed that technical change in the production of major crops such as teff, maize, barley, wheat and sorghum has increased with better use of available technology, but improving efficiency and technology adoption will be critical to boosting output levels. Rural poverty also continues to be more severe than urban poverty (UNDP, 2018).

In 2003, the Heads of State and Government of the African Union recognized that greater public spending was needed on agriculture across the continent and, including Ethiopia's, they made a political commitment – the Maputo Declaration – under the Comprehensive Africa Agriculture Development Programme (CAADP), to allocate at least 10 percent of total public spending to agriculture. In June 2014, Ethiopia's government signed the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods under the Comprehensive Africa Agriculture Development Programme.

Pernechele *et al.* (2021) show that, during the period 2004–2018, Ethiopia exhibited the highest annual average growth rate of expenditure on food and agriculture relative to 12 other sub-Saharan African countries. Even so, and despite a renewed commitment in 2014 through the Malabo Declaration, Ethiopia is among the countries who have not met the 10 percent of total public spending to agriculture target. It has been observed that countries with a decentralized administrative structure, such as Ethiopia, generally tend to spend less on food and agriculture than countries where public expenditure is concentrated at the central level of government (Pernechele *et al.*, 2021). As we show in this paper, another problem in Ethiopia (which may very well be the case of most sub-Saharan African countries) is that current public expenditures in agriculture are suboptimal from the perspective of their efficiency (or lack thereof), thus leading to an inefficient allocation of resources.

Clearly, agricultural transformation is still underway in Ethiopia, and the aforementioned challenges, particularly the fact that the country's agriculture sector is predominantly cereal based, raises questions as to how it will be possible to align the transformative agenda and the need to diversify production to produce more and increase the availability of the nutritious foods that make healthy diets at a lower cost, and without creating trade-offs that challenge ongoing agricultural transformation efforts.

2.2 Nutrition policy objectives

While Ethiopia has been investing in agricultural transformation for decades, nutrition improvement has been more recently gaining momentum in the country, prompted initially by the country's undernutrition problem. To address this, Ethiopia joined forces with global actors, starting in April 2012 with the Scaling up Nutrition (SUN) movement.[4] Two years later, Ethiopia's government supported the Rome Declaration on Nutrition endorsed at the Second International Conference on Nutrition (ICN2),[5] thus committing to eradicate hunger and preventing all forms of malnutrition – particularly undernutrition in children, anaemia in women and children, among other micronutrient deficiencies – as well as reversing the trend in obesity. At the Tokyo Nutrition for Growth Summit 2021,[6] Ethiopia's government committed to accelerating food nutrition security implementation through multisectoral nutrition-specific, nutrition-sensitive and infrastructure pathways foreseen in the scaling up of the Seqota Declaration.[7]

Ethiopia's main commitments to improving nutrition are also outlined in a number of national policy documents and plans. These include: the *Food and Nutrition Policy* (Federal Democratic Republic of Ethiopia, 2018); *The National Nutrition Program (2016–2020)* (Ethiopian Public Health Institute and NIPN, 2020); the *Seqota Declaration* (Ministry of Health – Ethiopia, 2015) – a 15-year roadmap that builds on the implementation of the National Nutrition Programme and the National Food and Nutrition Policy; the *Health Sector Transformation Plan II (HSTP II) 2020/21–2024/25* (Ministry of Health – Ethiopia, 2021); the *Nutrition Sensitive Agriculture Strategy* (MoANR and MoLF, 2016); and the *National Strategic Plan for the Prevention and Control of Non-Communicable Diseases 2013–2017 EFY (2020/21–2024/25)* (Ministry of Health – Ethiopia, 2020a).

Focusing on food security in the past years and scaling up nutrition programmes have made a tremendous contribution to reducing undernutrition in Ethiopia over the last two decades. However, problems persist, as noted in FAO, ECA, and AUC (2021). Ethiopia's prevalence of undernourishment (PoU) declined between 2013–2015 and 2018–2020 levelling off below the average PoU for Eastern Africa. However, in 2018–2020, on an annual average basis, 18.2 million Ethiopians experienced hunger and the prevalence of moderate or severe food insecurity was 56.3 percent. Unsurprisingly, malnutrition problems persist, particularly undernutrition. Among Ethiopian children under five, the prevalence of stunting (35.3 percent

[4] See https://scalingupnutrition.org

[5] See www.who.int/news-room/events/detail/2014/11/19/default-calendar/fao-who-second-international-conference-on-nutrition-(icn2)

[6] See https://nutritionforgrowth.org/events

[7] For more details on Ethiopia's commitment, see: https://nutritionforgrowth.org/wp-content/uploads/2021/12/Tokyo-Compact-on-Global-N4G_Annex_Dec-14.pdf

in 2020) and wasting (7.2 percent in 2019) are above Africa's prevalences. Anaemia among women of reproductive age (15–49 years) is lower than in Eastern Africa, but it still affects around 23 percent of women in Ethiopia. At the same time, there is another malnutrition burden: the prevalence of obesity among Ethiopian adults, which rose between 2000 and 2016 (the last year for which data are available) affecting about 4.5 percent of the adult population.

These multiple forms of malnutrition have important implications for survival and for incidence of acute and chronic diseases, healthy development, and economic productivity, at both individual and societal levels. As such, they are adverse outcomes that can potentially offset the intended consequences of structural transformation efforts, not least in agriculture.

The Ministry of Health in Ethiopia has identified that the main challenges the country is still facing regarding nutrition include poor awareness, lack of integration of nutrition-specific interventions, poor coordination at all levels, lack of accountability, limited use of data, unreliable forecasting approaches, low coverage of Vitamin A, low coverage of deworming treatment, low rates of nutritional screening, and others (Ministry of Health – Ethiopia, 2020b). However, the unaffordability of healthy diets is a problem as the cost of these diets is high relative to people's incomes. Data from World Bank (2022) show that, since the late-1990s, extreme poverty (as measured by the poverty headcount ratio at USD 1.90 a day [2011 PPP]) has diminished considerably from 69 percent in 1995, but it still affected 30.5 percent of Ethiopians in 2015 (the last year for which data are available).

Meanwhile, FAO data for 2020 show that the cost of a healthy diet in Ethiopia was lower than in sub-Saharan Africa (USD 3.37 vs USD 3.44 per person per day). However, due to how low people's incomes are relative to such cost, 86.8 percent of Ethiopians (99.7 million) could not afford a healthy diet in 2020, compared with 85 percent in sub-Saharan Africa, or 79.9 percent in Africa as a whole. This indicates that while nutrition policies and programmes put in place to address the nutrition problems are important, it seems that for such problems to be addressed more boldly, improving people's incomes and livelihoods is urgently needed, particularly in rural areas where poverty is higher. To this end, this paper argues that inclusive agricultural transformation is among the answers to address nutrition problems in Ethiopia, but this will depend on the coherence between the policies (i.e. the public budgets) allocated to implement the two agendas.

2.3 Coherence between agendas

Policy documents and national plans to improve nutrition contain important aspects of agricultural transformation, which suggests there is some coherence between the two agendas.[8] The National Food and Nutrition Policy (2018–2030) is the main policy guidance for food and nutrition interventions and is aligned with national development strategies. It looks at the link between attaining optimal nutritional status at every stage of life at a level that is consistent with a high quality of life, productivity and longevity. The policy seeks to improve availability and accessibility of adequate, diversified, safe and nutritious foods for all in a sustainable way through numerous strategies. Interestingly, some of the strategies in this policy document are coherent with Ethiopia's agricultural transformation strategies (i.e. strengthening agricultural crops, livestock and fisheries health, and care services; developing food-processing technology training (incubation) centres at community and household levels; establishing small-, medium- and large-scale agroprocessing industries and infrastructures to

[8] The agricultural transformation agenda predates the nutrition policy agenda in Ethiopia; hence, we determine if nutrition-related policy documents and national plans include agricultural transformation aspects.

enhance value addition; and improving postharvest management and implementing transfer of appropriate technologies). In addition, some of the strategies also seek to achieve key outcomes that are typically the result of agricultural transformation (i.e. improved income, job creation, purchasing power and market linkage for commodities). A key question is: What are feasible means to implement such strategies and achieve such outcomes when public resources are constrained?

Strengthening Ethiopia's multisectoral nutrition coordination and capacity building and implementation of nutrition-sensitive interventions across sectors was prioritized through the National Nutrition Programme (NNP II). The Seqota Declaration also foresaw the collaboration of nine ministries, including agriculture, and it included as a strategic objective transforming smallholder productivity and income.

The coherence between Ethiopia's agricultural transformation and nutrition agendas, however, is more clearly seen in the Nutrition Sensitive Agriculture Strategy (2017–2021). This strategy's overall goal is to contribute to the NNP II goal of improving the nutritional status of children and women by increasing the quantity and quality of food available, accessible and affordable and promoting utilization of diverse, nutritious and safe foods for all Ethiopians at all times. To do so, its strategic objectives look closer at agriculture, not only to establish and strengthen multisectoral coordination within the agriculture sectors and with signatories of the NNP and other development partners, but also to leverage nutrition into agriculture and livestock policies, strategies, programmes and work plans.[9]

As far as policy intention is concerned, agricultural transformation and nutrition seem to be well defined and aligned in Ethiopia. Considering that both agendas need important investments to be adequately implemented, the question facing Ethiopian policymakers is: What are ways of using existing resources to invest such that both agendas are coherently supported?

[9] There are other policies and programmes aiming at improving nutrition in Ethiopia which are not discussed here, even though they may have (less direct) linkages with agriculture. These include, for example, the School Health Programme Framework, the main policy guiding school feeding programmes in Ethiopia, as well as the National Strategic Plan for the Prevention and Control of Non-Communicable Diseases (2020/21–2024/25).

3 Method and data

Policymakers face a complex decision-making problem when pursuing several goals or objectives at the same time, some of which may even be conflicting. As noted in the introduction, agricultural transformation, in particular, is typically aimed at achieving several development objectives and entails several processes over time that are shaped by policy choices.

Typical objectives of agricultural transformation would be, for example, to increase agrifood output and to generate more rural off-farm jobs. While pursuing such objectives, in order to make the transformation inclusive, the policymaker may also aim at ensuring that agrifood output growth trickles down to the poor, particularly in rural areas where poverty is higher. This inclusivity of agricultural transformation is also desirable to raise the purchasing power of poor households for them to afford healthy diets. Even if this is the case, if one adds to the objectives of transforming agriculture with inclusion the objective of reducing the cost and increasing the affordability of healthy diets, the policymaker is confronted with an even more complex problem. For example, if the way of increasing agrifood output is not one whereby agricultural production becomes more diversified and agriculture continues to be predominantly cereal based, then it will be difficult to reduce the cost of nutritious foods in order to make healthy diets more affordable for poor households.

Moreover, some of these IAT objectives may be in conflict with other policies; for example, rural poverty reduction programmes to make agricultural transformation more inclusive (or mitigate its negative impacts on the most vulnerable populations) may conflict with the objective of, for example, reducing the fiscal deficit and public debt accumulation. The following question then arises: What would be the optimal policy mix to achieve a compromise that enables progress towards all these important objectives simultaneously in the face of face of limited public budgets while minimizing trade-offs?

We address this question in the context of Ethiopia, following the policy optimization modelling approach proposed in Sánchez and Cicowiez (2022). Specifically, we use a dynamic computable general equilibrium (CGE) model combined with compromise programming (CP), a multicriteria decision-making (MCDM) technique, to deal with situations of multiple (potentially) conflicting objectives. In recent years, MCDM techniques, widely used in operations research/management science (OR/MS), have been applied to solve several economic problems in which it is not reasonable or operational to assume the existence of a single goal or objective. In turn, CGE models are currently considered the workhorse models of policy analysis focusing on economy-wide effects induced by exogenous economic shocks or policy interventions (De Melo, 1988; Shoven and Whalley, 1992; Dixon and Jorgenson, 2013).[10]

Sánchez and Cicowiez (2022) demonstrate how a selection of optimal policies for IAT may be carried out also in the context of Ethiopia. In their MCDM-CGE policy optimization modelling framework, policy instruments are optimally determined to achieve IAT objectives – thus moving away from the standard CGE modelling practice whereby policy instruments are exogenously determined. For instance, government investment is considered among the endogenous policy instruments available to achieve IAT objectives. The modelling framework

[10] The combination of a CGE model with MCDM techniques was originally proposed by André, Cardenete and Romero (2009) but using a static CGE model. Sánchez and Cicowiez (2022) expanded the technique to consider a dynamic setting.

helps identify synergies but also the potential conflicts (i.e. trade-offs) between IAT objectives (as well as any other objective one may want to add) as a result of implementing optimal policies. Ultimately, a compromise that helps improve on all the objectives being pursued is reached, which is a novelty of the approach.

Three IAT objectives are considered in Sánchez and Cicowiez (2022): maximizing agrifood GDP,[11] maximizing agrifood exports, and minimizing rural poverty. In this paper, we have replaced the second objective with the objective of maximizing off-farm rural employment relative to on-farm rural employment (for simplification, hereafter, maximizing rural off-farm employment). We have also expanded the approach by including as a fourth policy objective minimizing the cost of the nutritious foods that form a healthy diet. Therefore, a contribution of this paper is to expand the MCDM-CGE policy optimization modelling approach by adding the cost of a healthy diet as an objective in the policymaker problem. Needless to say, such extension requires expanding the capabilities of the CGE model and its database, as further explained below.

3.1 Policy optimization modelling approach

Instead of solving a CGE model as a system of simultaneous equations, as is typically done, we solve an optimization problem in which the CGE model equations act as constraints to a policy optimization problem. The policymaker has policy objectives and policy instruments to pursue them. In CP, the first step is to identify an ideal or utopian solution (or point) in which all the policy objectives are individually optimized (Yu, 1973; Zeleny, 1974). This ideal solution is only a point of reference for the policymaker. Then, CP assumes that the policymaker will set the available policy instruments in such a way that the policy objectives are as close as possible to their ideal value. Consequently, a distance function is introduced to measure the distance from the ideal solution to any set of values for the policy objectives. Therefore, the concept of distance is not used in its geometric sense but as a proxy measure for the policymaker's preferences.

As explained, the following policy objectives are at the core of our optimization problem: (a) maximize agrifood GDP; (b) maximize rural off-farm employment; (c) minimize rural poverty (i.e. maximize rural household consumption per capita, since we do not explicitly target a decrease in inequality); and (d) minimize the cost of a healthy diet (i.e. by minimizing the ratio between the cost of a healthy diet and the consumer price index). On the other hand, to pursue these four objectives, the set of policy instruments at the policymaker's disposal comprises different government recurrent and investment expenditures. Mathematically, the optimization problem that we solve is as follows:

[11] In what follows, agrifood GDP comprises the value added from crops, livestock, fishery, forestry and the food processing industry.

$$\min L_p = \left(\sum_{t\in T}\frac{1}{(1+\rho)^t}\left(wt^p_{RGDPTRG}\left(\frac{rgdptrg^*_t - RGDPTRG_t}{rgdptrg^*_t - rgdptrg_{t*}}\right)^p\right.\right.$$

$$+ wt^p_{QHPCTRG}\left(\frac{qhpctrg^*_t - QHPCTRG_t}{qhpctrg^*_t - qhpctrg_{t*}}\right)^p$$

$$+ wt^p_{QLABAGRNAGR}\left(\frac{qlabagrnagr^*_t - QLABAGRNAGR_t}{qlabagrnagr^*_t - qlabagrnagr_{t*}}\right)^p$$

$$\left.\left.+ wt^p_{RATZDIETCPI}\left(\frac{RATZDIETCPI_t - ratzdietcpi^*_t}{ratzdietcpi_{t*} - ratzdietcpi^*_t}\right)^p\right)\right)^{\frac{1}{p}}$$

subject to

$$invg^{min}_{fcap,t} \leq INVG_{fcap,t} \leq invg^{max}_{fcap,t}$$

$$qg^{min}_{c,t} \leq QG_{c,t} \leq qg^{max}_{c,t}$$

$$tq^{min}_{c,t} \leq TQ_{c,t} \leq tq^{max}_{c,t}$$

and all the CGE model equations, including the policy instruments as endogenous variables

where,

$t \in T$: set of time periods

L_p: distance measure between a given solution and the ideal (and unattainable) solution

p: determines the relevance of the mean divergence between objectives and their ideal values vis-à-vis the distribution of divergences between each objective and its ideal value (see its discussion below)

ρ: discount factor for the policymaker

$RGDPTRG_t$: agrifood GDP

$QHPCTRG_t$: rural household consumption per capita (i.e. our proxy for rural poverty)

$QLABAGRNAGR_t$: ratio between rural off-farm and on-farm employment (i.e. our proxy for rural off-farm employment)

$RATZDIETCPI_t$: the cost of a healthy diet relative to the CPI

$rgdptrg^*_t$ and $rgdptrg_{t*}$: ideal and anti-ideal values for agrifood GDP; the ideal value is obtained by setting $wt_{RGDPTRG} = 1$ and $wt_{QHPCTRG} = wt_{QLABAGRNAGR} = wt_{RATZDIETCPI} = 0$; the anti-ideal value is obtained as the minimum value for $RGDPTRG_t$ that results from solving equation (1) with $wt_{RGDPTRG} = 0$ and only one of the other three policy objectives with a weight equal to 1 (i.e., $wt_{QHPCTRG} = 1$, $wt_{QLABAGRNAGR} = 1$, or $wt_{RATZDIETCPI} = 1$); a similar method is used to calculate the ideal and anti-ideal values of the other three policy objectives.

$qhpctrg^*_t$ and $qhpctrg_{t*}$: ideal and anti-ideal values for rural household consumption per capita

$qlabagrnagr_t^*$ and $qlabagrnagr_{t*}$: ideal and anti-ideal values for ratio between rural off-farm and on-farm employment

$ratzdietcpi_t^*$ and $ratzdietcpi_{t*}$: ideal and anti-ideal values for the cost of a healthy diet relative to the CPI

$wt_{RGDPTRG}$, $wt_{QHPCTRG}$, $wt_{QLABAGRNAGR}$, and $wt_{RATZDIETCPI}$: weights attached to each of the four policy objectives

$INVG_{fcap,t}$: government investment in priority area $fcap$

$invg_{fcap,t}^{min}$ and $invg_{fcap,t}^{max}$: lower and upper bounds for government investment in priority area $fcap$

$QG_{c,t}$: government recurrent spending in priority area c

$qg_{c,t}^{min}$ and $qg_{c,t}^{max}$: lower and upper bounds for government recurrent spending in priority area c

$TQ_{c,t}$: tax (or subsidy) rate on commodity c; where c only applies to fertilizers

$tq_{c,t}^{min}$ and $tq_{c,t}^{max}$: lower and upper bounds for tax (or subsidy) rate on commodity c

Technically, a general characterization of a dynamic CGE model is given by a nonlinear continuously differentiable function

$$X_t = F(X_t, X_{t-1}, Y_t, Z_t)$$

$$t = 1, \ldots, T$$

that defines a set of structural equations for n contemporaneous endogenous variables, represented by the *n*-element vector X_t. The model F is a function of X_t (i.e. not a reduced form) as well as of lagged values of the endogenous variables X_{t-1}, which reflect the structural dynamics of the model. The vector Y_t denotes a set of *m* contemporaneous endogenous variables which are assumed to be the policy instruments (i.e. they are controllable by the policymaker).[12] The last argument of the model's functional specification, Z_t, is a *k*-element vector which represents exogenous variables that are outside the control of the policymaker. Naturally, the policy objectives and policy instruments in the optimization problem mathematically stated above are contained in X_t and Y_t, respectively.

The best compromise solution to the optimization problem is the nearest solution to the infeasible ideal solution (i.e. the alternative with the lowest value for L_p) (Zeleny, 1973). In other words, the ideal solution (or point) represents the joint location of the individual maximum values of all the policy objectives. Therefore, arriving at a compromise solution can be viewed as minimizing the policymaker's regret for not obtaining the ideal solution.

Naturally, arriving at a compromise solution depends on the values of the parameter p and the weights wt_i that are chosen – ideally by the policymaker. The parameter p is a real number in the interval $[1, \infty]$ that acts as a weight attached to the deviations from the ideal solution according to their magnitudes. In turn, wt_i are the weights for various deviations capturing the relative importance given to each policy objective. It is possible to generate different

[12] In a typical CGE model application, the elements of Y_t are generally considered as exogenous variables.

compromise solutions for different sets of values for p and wt_i. However, the literature has showed that, in most applications, the compromise set is bounded by the solutions obtained when $p = 1$ and $p = \infty$. In Section 4, we set $p = 2$ and we consider alternative weighting schemes that in fact represent alternative scenarios. In practice, $p = 2$ offers a balance between (a) maximizing the overall achievement of all the policy objectives ($p = 1$), and (b) maximizing the balance among all policy objectives ($p = \infty$).

Because units of measurement may differ depending on the policy objectives (e.g. percent for the poverty rate vs number of workers for employment), we normalize the units of measurement for the various policy objectives to avoid a meaningless summation. In addition, if the absolute values for the achievement levels of the several objectives are different (e.g. two target values might be very different even when both policy objectives are measured using the same units, such as sector-specific profits and overall GDP), then the normalization of the distances is necessary to avoid solutions biased towards those objectives that can achieve larger values.

In equation (1), $RGDPTRG_t$ (agrifood GDP), $QHPCTRG_t$ (rural household consumption per capita), $QLABAGRNAGR_t$ (ratio between rural off-farm and on-farm employment), and $RATZDIETCPI_t$ (cost of a healthy diet relative to the CPI) are the achieved (endogenous) values for the policy objectives. On the one hand, the first three policy objectives (i.e. "more is better" policy objectives) are normalized by subtracting them from their ideal value and dividing by the difference between their anti-ideal and ideal values. On the other hand, the last policy objective (i.e. a "less is better" policy objective) is normalized by subtracting its ideal value from it and dividing by the difference between its ideal and anti-ideal values. Then, by construction, each ratio in equation (1) is bounded between 0 (i.e. when the objective is equal to the ideal) and 1 (i.e. when the objective is equal to the anti-ideal). In practice, this normalization eliminates units of measurement and allows the summation in equation (1) to be economically meaningful. The weights $wt_{RGDPTRG}$, $wt_{QHPCTRG}$, $wt_{QLABAGRNAGR}$, and $wt_{RATZDIETCPI}$ are preference parameters that help us represent, on the basis of information and/or actual policy dialogue, how concerned the policymaker is about each policy objective. Interestingly, this CP procedure ensures that the solution found is efficient, but it does not guarantee that all the policy objectives improve with respect to the initial (base) situation.

The recursive-dynamic CGE model is made up of a set of simultaneous linear and non-linear equations that are solved first for each period (typically, a year), and then each within-period solution is linked up over time through dynamic variables. It is economy-wide in the sense that it provides a comprehensive and consistent view of an economy, including the linkages among production sectors and the incomes they generate, households, the government and the rest of the world. It is an appropriate tool to answer this paper question as it captures, in an integrated framework, the economy-wide and multisectoral interactions over time that are affected by policy choices, which are a characteristic of the process of agricultural transformation as defined in the introduction.

In each period for which the recursive-dynamic CGE model is solved, the different agents (producers, households, government and the country in its dealings with the rest of the world) are subject to budget constraints: their receipts and spending are fully accounted for and must balance out (as they must in the real world). For example, households, while setting aside a part of their incomes to pay direct taxes and save, allocate the remaining part to their consumption with a utility-maximizing composition. In turn, producers maximize their profits by choosing the optimal quantities of labour, capital and natural resources. For the country, the real exchange rate adjusts to ensure that the external accounts are in balance. Wages and rents, as well as prices, play the crucial role of clearing markets for factors and commodities (goods and services), respectively. For commodities that are traded internationally (exported and/or imported), domestic prices are influenced by international prices. It is assumed that Ethiopia is a small country, in the sense that it can demand imports and supply exports in international markets at given world prices.

Over time, economic growth in the recursive-dynamic CGE framework that we combine with the MCDM technique is determined by changes in factor employment and total factor productivity (TFP). The accumulation of capital stocks is endogenously generated by the model, depending on investment and depreciation. For other factors, the growth in employable stocks is exogenous to the model, i.e. the supplies in each time period are projected exogenously. For labour, the projections reflect the evolution of the population at labour-force age and labour-force participation rates. For natural resources, the projections are closely linked to production projections. The unemployment rate for labour is endogenous. TFP growth is made up of two components, one that responds positively to growth in government infrastructure capital stocks and one that, unless otherwise noted, is exogenous.

Sánchez and Cicowiez (2022), in their Supplementary Material A, provide a complete mathematical statement of the CGE that we are using in this paper. A contribution of this paper, though, is to have extended the CGE model to include the cost of a healthy diet and associate it with a new policy objective. We present this addition to the CGE model in Annex 1, since the objective of our paper is to respond an empirical – rather than methodological – question. The same annex explains the way in which we use the cost of a healthy diet to calculate the share of the population that cannot afford a healthy diet following a relatively simple microsimulation model.

3.2 Data

The basic accounting structure and much of the data required to calibrate the MCDM-CGE policy optimization modelling framework to Ethiopia's context, particularly to obtain its base-year solution, is derived from a social accounting matrix (SAM) for the year 2015/2016. We took as our departing point the SAM documented in Mengistu *et al.* (2019) and adapted it to include an unconventional treatment of financial flows and a relatively detailed disaggregation of government spending (recurrent and investment) in agrifood sectors.

For this paper, the Ethiopian SAM singles out 41 activities and 41 commodities (of which 21 are agricultural and six are food related in both cases), eight factors of production (six labour categories, land, private capital and government capital), five institutions (rural and urban households, enterprises, government and rest of the world), and auxiliary accounts for trade and transport margins and indirect and direct taxes. The six labour categories are obtained by combining location (rural and urban) and skill level (unskilled [less than primary education], semi-skilled [primary education], and skilled [secondary or more education]).

The government agricultural spending was disaggregated into the following categories: for recurrent spending, research and development (R&D) by commodity, extension services by commodity, improved seeds by commodity, fertilizer and irrigation by commodity, and cash transfers; on the other hand, for investment spending, mechanization by commodity, rural roads, and rural electrification. This disaggregation draws from the public expenditure in food and agriculture methodology from FAO's Monitoring and Analysing Food and Agricultural

Policies (MAFAP) programme.[13] It is numerically shown in the next section when simulation results are discussed.

In addition, our CGE model relies on complementary data on base-year employment and unemployment, factor stocks, and elasticities to calibrate the base-year solution. For the solution over time, we use data for capital depreciation rate, labour supply, and population projections from different sources. For capital depreciation rates, we follow Agénor, Bayraktar and El Aynaoui (2008) and assume 5.0 percent and 2.5 percent for private and public capital, respectively. For unemployment and underemployment, we use the estimates from the ILO ILOSTAT database (accessed on February 25, 2021): 2.2 and 25.8 percent, respectively. For projections of the population, split into multiple age groups, we use the 2019 UN World Population Prospects dataset. Finally, the results for poverty and affordability of a healthy diet are calculated using the 2018/2019 Ethiopia Socioeconomic Survey. The complete dataset for Ethiopia is available upon request to the authors.

Finally, to calibrate the CGE model, we use the cost of a healthy diet indicator proposed in Herforth *et al.* (2022). This indicator represents the minimum cost of purchasing a healthy diet that satisfies dietary recommendations from food-based dietary guidelines (FBDG), at a given place and time. It is calculated using food price data reported through the International Comparison Programme (ICP) of the World Bank, which covers 680 items and 177 countries in 2017.[14] The authors follow what they call the “Healthy Diet Basket method”, which relies on average food group amounts recommended across FBDG scaled to meet a consistent dietary energy intake target (i.e. 2 330 kcal). There are five food groups in the method, namely: starchy staples, vegetables, fruit, protein-rich foods and oils.[15]

FAO data facilitated for the application of our policy optimization modelling approach has allowed us to calculate the minimum cost of purchasing a healthy diet indicator for Ethiopia following said methodology, as it is not reported by Herforth *et al.* (2022). The diet is also regarded as the least-cost healthy diet in the context of Ethiopia. Other healthy diets adhering to FBDG would of course exist for Ethiopians, but these would not be the cheapest for the consumer, and this is the reason we use the least-cost healthy diet. Table 1 shows that this diet cost ETB 26.82 in 2017, and its composition permits obtaining 2 329 total kcal of a healthy diet per day. In terms of the composition of its cost per day, protein from fish as well as some fruits (i.e. fresh mangoes) are relatively more costly than the other foods that make up the least-cost healthy diet. It is important to note – and particularly because it has implications for the simulation results presented below – that protein from protein foods in this healthy diet is more cheaply available from fish (i.e. fresh small sardines and African Red Snapper) rather than meat, such as from beef which is an important sector in Ethiopia. The model database shows that beef represents 2.0 and 9.2 percent of total food consumption in rural and urban areas, respectively, which is an important aspect to consider for the discussion of simulation

[13] The MAFAP programme’s database also singles out government spending in cash transfers to the agricultural producers. However, we are not considering them as a policy instrument in this paper (for more details on public expenditure data and methodology, see www.fao.org/in-action/mafap/data/en).

[14] These prices were observed by each country’s official national statistics office (NSO) in coordination with the global office of the ICP, which carries out a process to ensure that item definitions are standardized, and that price reporting reflects a sufficient range of widely consumed items to represent national patterns of consumer expenditure.

[15] Protein-rich foods here combine dairy with other protein-rich foods, including meat, fish, egg, legumes, and/or nuts and seeds.

results. In calibrating the model, we assume that the share of individuals without access to a healthy diet was the same in 2016 (i.e. the model base-year) as in 2017, i.e. 79.4 percent.

Table 1. Least-cost healthy diet in Ethiopia, 2017

ICP name and total	FBDG food group	(a) Price per kcal of food (ETB)*	(b) Energy per gram of food	(c) Recommended grams of selected food item per day per person	(d) Total kcal of a healthy diet (≈2 329 kcal per day)**	(e) Price per day (ETB)***
Palm oil, WKB ****	Fat	0.01	8.84	33.03	292.00	1.57
Banana, short finger length	Fruit	0.03	0.89	88.76	79.00	2.49
Fresh mangoes	Fruit	0.05	0.60	131.67	79.00	4.03
Spotted beans	Legumes, nuts and seeds	0.01	3.47	82.71	287.00	2.20
Fresh Small Sardines	Protein foods	0.02	1.31	110.69	145.00	2.96
Red Snapper (AFR) ****	Protein foods	0.03	1.44	100.69	145.00	4.28
Maize grains, white	Starchy staples	0.00	3.65	160.55	586.00	1.54
Wheat flour, not self-rising, BL ****	Starchy staples	0.00	3.64	160.99	586.00	2.27
Fresh onions	Vegetable	0.04	0.40	108.33	43.33	1.53
Fresh cabbage, green	Vegetable	0.04	0.25	173.33	43.33	1.75
Fresh carrots	Vegetable	0.05	0.41	105.69	43.33	2.20
Total (where applicable)					2 329.00	26.82

Notes: * Based on 2017 ICP prices. ** (d) = (b) x (c). *** Cost of the least-cost healthy diet in Ethiopia based on 2017 ICP prices. (e) = (a) x (d). **** WKB: Well-known brand; AFR: African Red Snapper; BL: selected cheapest flour is brandless.

Source: Authors' elaboration based on FAO data and the method proposed in Herforth, A., Venkat, A., Bai, Y., Costlow, L., Holleman, C. & Masters, W.A. 2022. *Methods and options to monitor the cost and affordability of a healthy diet globally*. Background paper to *The State of Food Security and Nutrition in the World 2022*. FAO Agricultural Development Economics Working Paper 22-03. Rome, FAO.

4 Simulation results

4.1 Base scenario

The MCDM-CGE policy optimization modelling approach was solved from 2016 to 2025. Thus, starting from the base-year, 2016, and up to 2025, we generate a base scenario characterized by a business-as-usual assumption. To facilitate the presentation and the analysis, the base scenario assumptions are kept as simple and transparent as possible. Most importantly, it is assumed that (a) the GDP growth rate is exogenous, drawing on IMF data (IMF, 2021); (b) all international (export and import) prices are constant in real terms; and (c) drawing on the SAM data, most payments made by institutions (i.e. households, enterprises and the government) are kept constant as GDP shares, including all receipt and spending items in the government budget. This scenario also assumes that the base-year composition of the public budget for agriculture remains unchanged, as further explained below. Then, we generate optimal policy scenarios which deviate from the base scenario in between 2021 and 2025, which is the optimization period. The deviations from the base scenario result from alternative optimal allocations of the same domestic public budget to agriculture.

At the macro level, the CGE model that we combine with MCDM techniques – like any other CGE model – requires the specification of equilibrating mechanisms (or “closures”) for three macroeconomic balances: government, savings-investment, and the balance of payments. Here, the following closures are used: (a) the government balance clears through endogenous government foreign borrowing; (b) the saving behaviour of households and enterprises does not change (that is, their savings rates are exogenous), but real investment is endogenous to ensure aggregate private savings match aggregate investment; and (c) a flexible real exchange rate equilibrates the current account of the balance of payments by influencing export and import quantities and values. With regard to the government balance in the policy optimization scenarios, it is important to note that there is no increase in government foreign borrowing because the simulation is budget neutral.

It is important to understand how far Ethiopia will get if the current allocation of the domestic public budget to agriculture is projected to 2025 under business-as-usual assumptions. Table 2 shows the baseline values of the variables associated with the four policy objectives and also rural household per capita consumption in 2020 (i.e. one year prior to starting the policy optimization). In the base scenario, based on IMF projections, GDP growth is simulated at an annual rate of 7.5 percent up to 2025. In addition, given that private consumption growth exceeds population growth, which for 2017–2025 is projected at 2.5 percent, aggregate household welfare is increasing. In per capita terms, household consumption grows at a rate of 4.3 percent per year, leading to a decrease in the poverty rate, from 23.6 percent in 2019 to 15.4 percent in 2025. Moreover, due to different sectoral growth rates, there is an increase in rural off-farm employment relative to rural on-farm employment. Specifically, growth is lower for agriculture due to slow growth of land supplies and low-income elasticities of demand – in the context of an ongoing IAT and an unchanged government budget allocation. On the other hand, the change in relative prices under the base scenario makes the relative cost of the least-cost healthy diet slightly more expensive. However, given the increase in household per capita consumption, there is a decrease in the population share that cannot afford the least-cost healthy diet, from 79.3 percent in 2019 to 73.5 percent in 2025.

Table 2. Baseline values for policy objectives

Item	Agrifood GDP	Rural consumption per capita	Rural off-farm employment	Cost of the least-cost healthy diet	Rural poverty
	Billion ETB	ETB	Ratio	Ratio	%
2020	699.82	8 817.67	0.58	1.00	24.07
2025	874.96	10 847.77	0.64	1.04	16.10
Percentage change 2025–2020	25.03	23.02	10.66	4.36	-33.12

Source: Authors' calculations.

4.2 Optimal domestic public budget scenarios

To develop the alternative policy optimization scenarios, we solve the policy optimization problem identified in Section 3. First, we compute the ideal and anti-ideal values of the four variables associated with the four policy objectives under consideration. To that end, we solved four single-objective optimization problems (i.e. we generate four alternative optimal policy scenarios). To simplify, in Table 3 we show the so-called payoff matrix applied to our policy objectives for the year 2025, the final simulation year. The second row of the payoff matrix shows the values of the variables associated with the four policy objectives, when only agrifood GDP growth is maximized and the other three policy objectives are not part of the optimization problem. For instance, if Ethiopian policymakers are only concerned about increasing agrifood GDP, thus giving a weight equal to 1 to this policy objective (and weights equal to 0 to the other three policy objectives), they could optimally set the available policy instruments and attain an agrifood GDP percent deviation relative to the base in 2025 of 1.1 percent (i.e. the percent change from 875.0 in the base scenario to 885.0 in the ideal situation; see Table 3).

The payoff matrix also points to Ethiopian policymakers facing some degree of conflict, as it would not be possible for them to obtain the maximum for the four policy objectives simultaneously. In other words, the values in the main diagonal of the payoff matrix show the best attainable results when only one policy objective is considered. In addition, note that there are no trade-offs, in the sense that targeting only one policy objective does not have a negative impact on any of the other three policy objectives.[16]

The payoff matrix also shows that there are synergies between the IAT variables and the relative cost of a healthy diet. For instance, targeting one IAT policy objective reduces the relative cost of a healthy diet; see the last column of Table 3 for all the rows but the last one. Moreover, if the policy maker only cares about the objective of minimizing the cost of the least-cost healthy diet, improvements in IAT indicators such as agrifood GDP and rural poverty will also be observed; see the first columns of Table 3 for row 4. However, in this last case the improvements in the IAT indicators are not as large as in the other cases where each IAT is the priority. Interestingly, the ratio between rural off-farm employment and rural on-farm employment does not change.

[16] The results regarding trade-offs would be different had other policy objectives been considered or policy instruments available to the government been restricted.

Table 3. Agrifood GDP, rural household consumption per capita, rural off-farm employment and cost of healthy diet in Ethiopia in the base and payoff matrix, 2025

	Agrifood GDP	Rural poverty	Rural off-farm employment	Cost of the least-cost healthy diet
Item	**Billion ETB**	**%**	**Ratio**	**Ratio**
Base scenario	874.96	16.10	0.64	1.04
Maximizing agrifood GDP	**885.02**	15.81	0.65	1.01
Minimizing rural poverty	884.36	**15.78**	0.65	1.01
Maximizing rural off-farm employment	883.11	<u>15.97</u>	**0.65**	<u>1.01</u>
Minimizing the cost of the healthy diet	<u>877.28</u>	15.95	<u>0.64</u>	**0.98**

Note: Bold and underlined figures represent ideal and anti-ideal values for each policy objective, respectively.
Source: Authors' calculations.

In what follows, we analyse optimization scenarios that are defined by applying different weighting schemes to the optimization problem introduced in Section 3. Specifically, we consider three scenarios:

- Scenario for minimizing the cost of the least costly healthy diet (i.e. $wt_{RGDPTRG} = 0$, $wt_{QHPCTRG} = 0$, $wt_{QLABAGRNAGR} = 0$, and $wt_{RATZDIETCPI} = 1$); this scenario corresponds to the last column in the payoff matrix (see Table 3)
- Scenario for pursuing IAT objectives: maximizing agrifood GDP, maximizing rural off-farm employment relative to on-farm employment, and minimizing rural poverty (i.e. $wt_{RGDPTRG} = 1$, $wt_{QHPCTRG} = 1$, $wt_{QLABAGRNAGR} = 1$, and $wt_{RATZDIETCPI} = 0$)
- Scenarios that pursue all objectives above (i.e. $wt_{RGDPTRG} = 1$, $wt_{QHPCTRG} = 1$, $wt_{QHPCTRG} = 1$, and $wt_{RATZDIETCPI} = 1$)

In these three scenarios, agriculture's public budget provides the policy instruments (i.e. expenditures by priority area and commodity),[17] and these are bounded. On the one hand, for public investments across agriculture, they can decrease (increase) up to 85 percent (400 percent) relative to their base-year values to achieve optimization. On the other hand, government consumption, which is used to model the provision of extension services, can decrease (increase) up to 50 percent (100 percent) relative to its base-year value to achieve optimization. For taxes and subsidies, the lower and upper bounds are -15 percent and 15 percent, respectively.[18]

Alternative optimal public budget reallocations

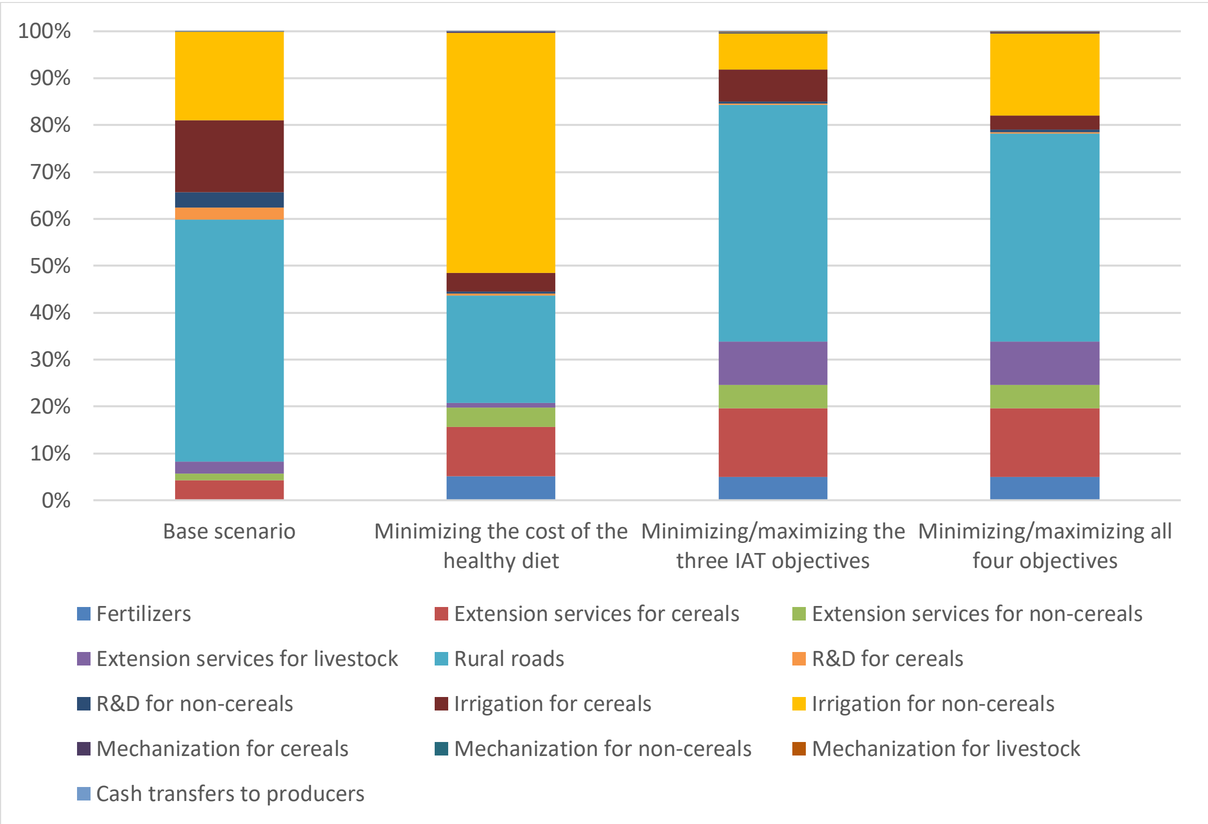
Prioritizing the policy objectives to improve on them individually or in combinations in the most optimal way possible requires allocating the public budget to agriculture differently in Ethiopia,

[17] Cash transfers to producers are also singled out in the public budget allocated to agriculture, but these are not considered in the optimization process, i.e. cash transfers are not endogenous policy instruments in our simulations.

[18] In our application of the policy optimization modelling approach for Ethiopia we are only using the subsidy on fertilizers as a policy instrument as far as taxes/subsidies are concerned. As a subsidy, it is part of government recurrent expenditures.

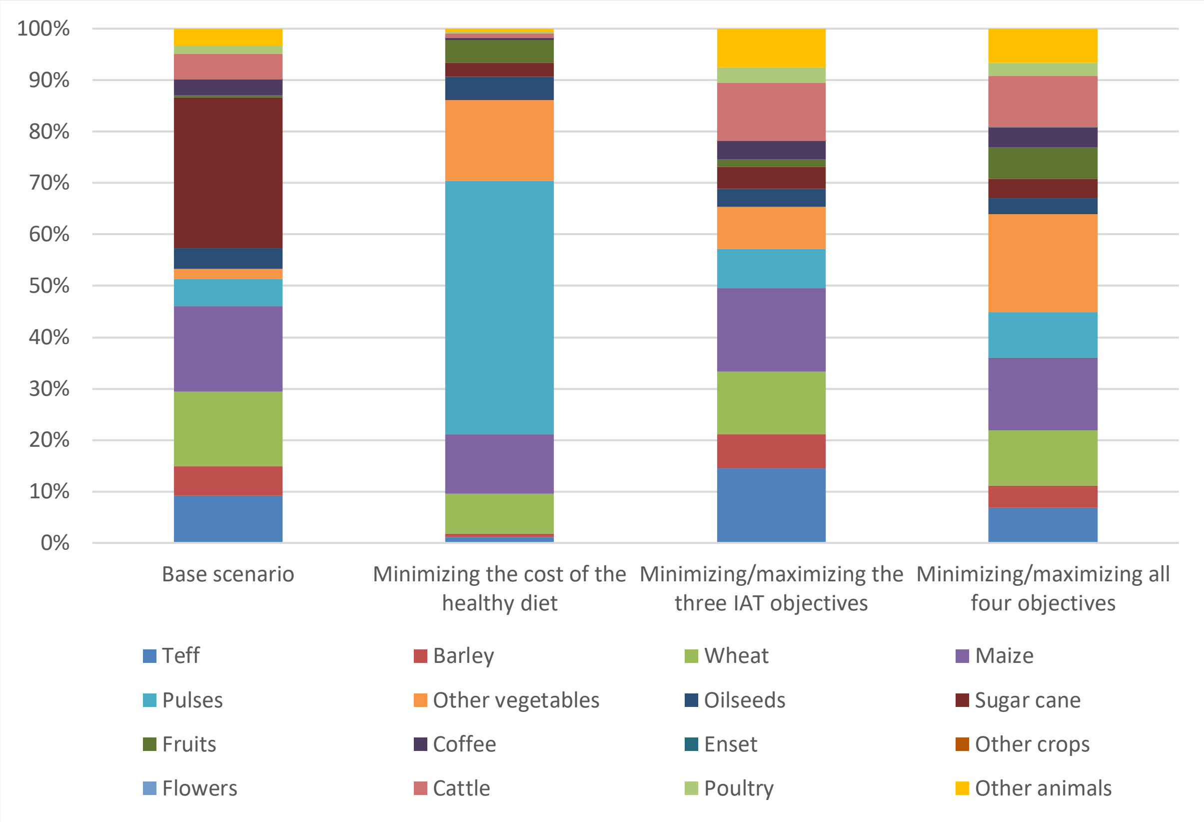
as shown for 2025 in Figures 3 and 4. When only IAT objectives are pursued, for example, extension services in both cereals and livestock farming, as well as fertilizers though to a lower extent, have to be prioritized at the cost of other budget lines, notably irrigation. When the objective of minimizing the cost of the least-cost healthy diet is considered together with IAT objectives, it is more optimal to increase the budget in irrigation, for example, notably because there will be more production and consumption of nutritious foods, such as fruits and vegetables which are relatively more water intensive. More budget is also allocated to the production of pulses, at the commodity level, while less budget is allocated to cereals and sugar cane. The share of irrigation expenditures within the budget increases significantly when the objective of minimizing the cost of the least-cost healthy diet is considered alone at the cost of other expenditures that are very important in the current budget allocation, such as those for rural roads and even irrigation for cereals. Irrespective of the scenario, these alternative public budget reallocations are more optimal because they allow for improvement on all four objectives as explained next.

Figure 3. Public budget allocation by type of spending in the base and optimization scenarios, 2025



Source: Authors' calculations.

Figure 4. Public budget allocation by commodity in the base and optimization scenarios, 2025



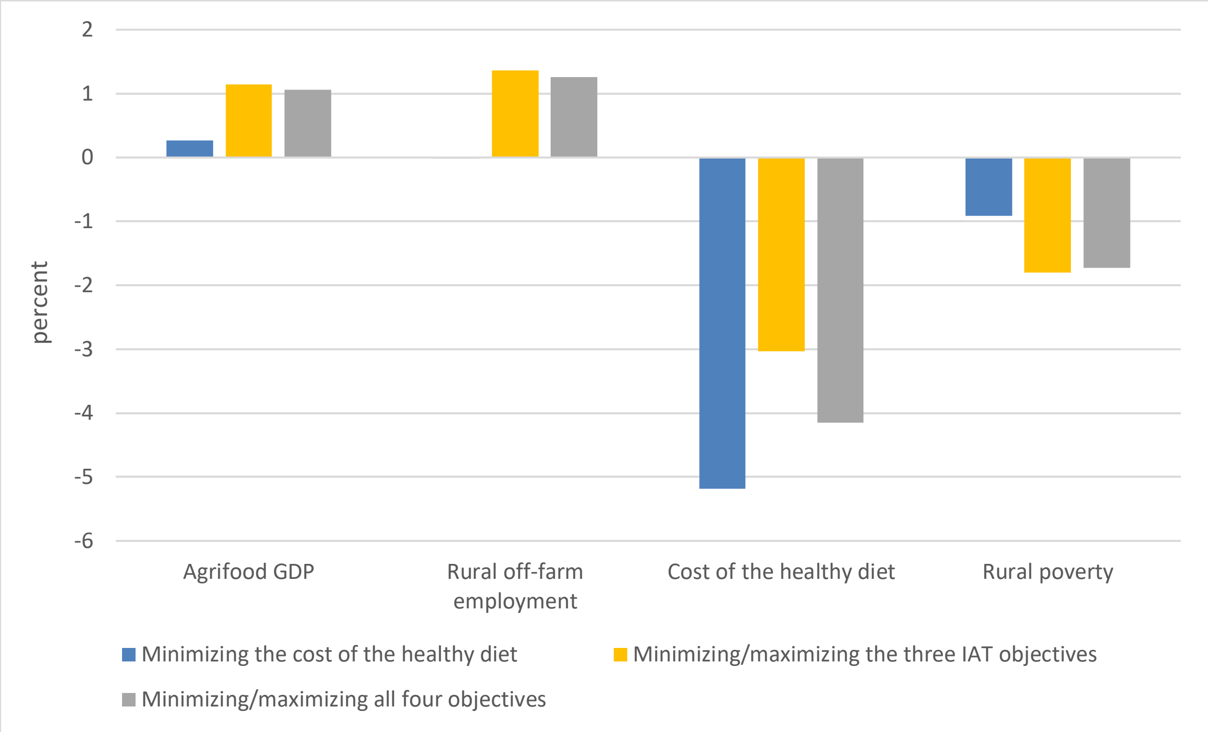
Source: Authors' calculations.

Improvement towards policy objectives and trade-offs

The value of the four variables associated with the four policy objectives improves in all scenarios due to the optimal reallocation of the budget given to agriculture, as indicated by their deviation from the corresponding values in the base scenario (Figure 5). This evidence suggests that Ethiopia's government could achieve better results if the same budget allocated to agriculture is repurposed.

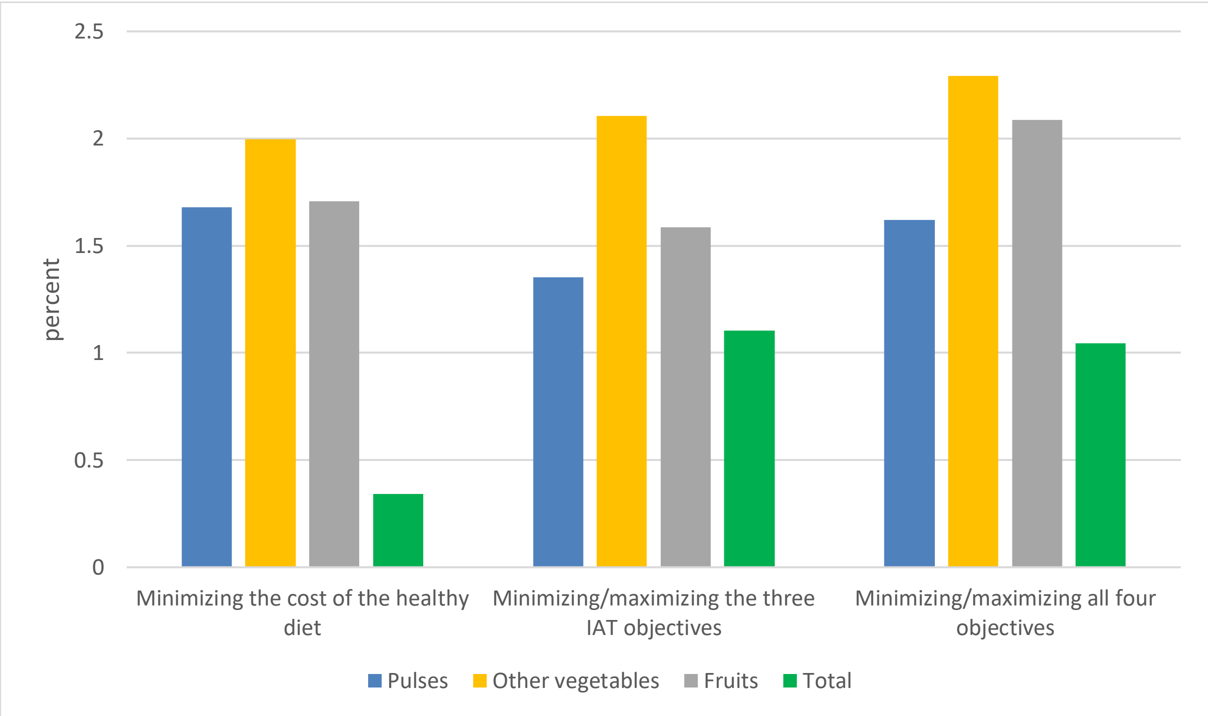
Interestingly, the most significant improvement – as measured from the deviation from the base scenario – is seen in the reduction of the cost of the least-cost healthy diet, irrespective of the scenario, even if only IAT objectives are pursued. This indicates that the current budget allocated to agriculture in Ethiopia is suboptimal for ensuring that the nutritious foods that make up the least-cost healthy diet can be produced and offered to more Ethiopians at a lower cost. No matter the scenario, the increase in the supply and availability of the nutritious foods that make up the least-cost healthy diet that results from more optimal budget allocations, which reduces the cost of such a diet, is reflected in a higher household consumption of pulses, vegetables and fruits – relative to total household consumption (Figure 6). The results suggest that over time, there could be an improvement in nutrition outcomes. Notwithstanding these potential benefits, there are also important potential trade-offs to consider, depending on what objectives Ethiopian policymakers choose to prioritize through the repurposing of the budget to make it more efficient.

Figure 5. Value of the variables associated with the policy objectives in the optimization scenarios, 2025 (% change relative to the base scenario)



Source: Authors' calculations.

Figure 6. Household consumption by selected food items and total in optimization scenarios, 2025 (% change relative to the base scenario)



Note: Total includes the consumption of all foods, in addition to pulses, vegetables and fruits, as well as non-food commodities.

Source: Authors' calculations.

Should the government optimally repurpose its current budget only to reduce the cost of the least-cost healthy diet, without pursing the IAT objectives, it would be giving up the possibility of, using the same budget, achieving also higher agrifood GDP growth, more rural off-farm employment creation, and more rural poverty reduction. This would actually slow down the ongoing process of agricultural transformation in the country. Interestingly, agrifood GDP, rural off-farm employment, and rural poverty reduction, but also the cost of the least-cost healthy diet (though to a lower extent), would all show improvement if the current budget were optimally repurposed to pursue only the three IAT objectives. This helps draw the conclusion that IAT would be coherent with the nutrition agenda of Ethiopia, even if the government were to repurpose its current budget only to achieve the (three) IAT objectives without explicitly targeting the objective of reducing the cost of the least-cost healthy diet.

Nonetheless, when the budget is optimally repurposed to pursue not only IAT objectives but also the objective of minimizing the cost of the least-cost healthy diet (Figures 3 and 4), the cost of this diet falls relatively more than when only pursuing IAT objectives, as expected (Figure 5). But then again, in this alternative scenario, the results in terms of agricultural transformation are relatively less encouraging. This is because minimizing the cost of the least-cost healthy diet and repurposing the budget to this end imply some degree of specialization towards the production of the foods that make up this diet which, as explained earlier, corresponds to the least-cost healthy diet in the case of Ethiopia. Hence, the optimal reallocations of the budget when the reduction of the least-cost healthy diet is among the policy objectives tend to benefit relatively more the production of the foods that make up this diet. The production of fish, which is the protein food in Ethiopia's least-cost healthy diet (see Table 1), for example, is promoted at the cost of producing fewer of other protein foods such as beef, which is highly consumed in Ethiopia, as noted earlier. The production of pulses, fruits and vegetables also increases at the cost of some production of cereals and sugar cane, in consistency with the budget reallocation at commodity level (see Figure 4). This of course affects the production structure of the country and generates some job losses in labour-intensive agricultural sectors that receive less budget support, all of which affects household consumption and income per capita and increases rural poverty. Nonetheless, the affordability of the least-cost healthy diet improves because the cost of this diet is lower.

The diminishing marginal productivity of public investments across sectors also partly helps explain the results. When public investments only prioritize the selected number of nutritious foods that make up the least-cost diet, then the diminishing marginal returns of such investments appear earlier (or are stronger), compared to the situation where such investments prioritize many more sectors to pursue IAT objectives. Furthermore, the sectors are different not only in terms of how the investment affects them and their labour intensity, but also in terms of how they are integrated with the different markets and other sectors. Generally, we observe that the nutritious foods that make up the least-cost healthy diet tend to be: (i) more oriented to the domestic market and (ii) less productively linked with downstream processing and other non-agricultural sectors' economic activity. In the first case, the demand curve of these nutritious foods is relatively more vertical than other foods (i.e. they are exported relatively less and/or compete less with imports, with both possibilities increasing the slope of the demand curve given the assumption that Ethiopia is a price taker in world markets). For instance, the budget allocated to an export-oriented sector such as oilseeds (i.e. a sector that exports 71.0 percent of its production) decreases when we move from optimizing the budget to pursue IAT objectives to optimizing the budget to pursue IAT objectives together with the objective of reducing the cost of the least-cost healthy diet. In turn, the ratio between exports and output for three key components of the least-cost healthy diet is much lower, i.e. 1.8 percent for vegetables, 2.0 percent for fruits and 9.3 percent for pulses. In the second case, due to its smaller input-output linkages, the sectors producing nutritious foods drive other sectors' productive activity relatively less than sectors such as sugar cane, wheat and cattle do.

The benefits and trade-offs of pursuing IAT objectives along with the objective of reducing the cost of the least-cost healthy diet, versus the situation where the latter objective is excluded from the optimization of the budget, can be easily deducted from the results presented in Table 4. The main relative benefit is in terms of increasing the affordability of healthy diets for more than 600 000 Ethiopians. However, this comes at the cost of not only slowing down agrifood GDP growth but also of losing the opportunity of creating 25 950 jobs (of which 14 412 would be in rural areas) and lifting 23 429 people out of poverty fairly evenly between rural and urban areas. To improve in all four policy objectives simultaneously in the best possible manner, then the compromise is to repurpose the budget to agriculture for pursuing only IAT objectives. Even in this case, 2 346 193 more Ethiopians would be able to afford the least-cost diet by 2025, using exactly the same resources.

Table 4. Number of individuals that are employed, with income below the (national) poverty line and cannot afford a healthy diet in optimization scenarios, 2025 (change relative to the base scenario)

	Minimizing the cost of the healthy diet	Minimizing/maximizing the three IAT objectives	Minimizing/maximizing all four objectives
Employment (number of employed individuals)			
Nation	128 806	489 612	463 662
Rural	92 929	282 702	268 290
Urban	30 213	153 306	144 869
Poverty (number of individuals below the national poverty line)			
Nation	-161 495	-450 786	-427 357
Rural	-143 795	-284 606	-273 151
Urban	-17 700	-166 180	-154 206
Affordability (number of individuals that cannot afford the least-cost diet)			
Nation	-3 160 305	-2 346 193	-2 962 234
Rural	-2 207 340	-1 497 269	-1 936 380
Urban	-952 965	-848 924	-1 025 854

Source: Authors' calculations.

5 Conclusion and the way forward

This paper has used and expanded an innovative policy optimization modelling approach to assess ways in which the objective of making healthy diets more affordable to Ethiopians and the achievement of inclusive agricultural transformation (IAT) objectives can be aligned, while minimizing potential trade-offs. The process of agricultural transformation has been ongoing in Ethiopia for decades and the agenda to improve on the nutrition front has more recently gained momentum in the country.

As far as policy intention is concerned, agricultural transformation and nutrition are well defined and aligned in Ethiopia, and there has been progress in both fronts. However, important challenges remain, particularly the fact that the country's agriculture sector is predominantly cereal based and relies on a household-based and subsistence-oriented system; rural off-farm employment creation remains below expected targets; and productivity growth is still below its potential, all while millions of Ethiopians face hunger, food insecurity and malnutrition, particularly undernutrition.

Addressing these challenges and delivering healthy diets at a lower cost to contribute to Ethiopian's ability to afford them will require both an expansion in the supply of the nutritious (and safe) foods that constitute healthy diets and a behavioural shift such that Ethiopian consumers demand them more. Expanding the supply will require significant investments. In the current context, however, where economic recovery is not as strong as expected, both the COVID-19 pandemic and now the war in Ukraine as well as growing climate adversities keep on disrupting agrifood systems; private investors (including farmers) may feel more risk averse than usual to invest in agriculture where business is typically perceived as risky. For Ethiopia's government, it will not be easy to step up the public budget to support agriculture in such a context and create the enabling environment for private investors to follow suit. In fact, despite a renewed commitment in 2014 through the Malabo Declaration, we recall that Ethiopia is among the countries who have not met the 10 percent of total public spending to agriculture target. However, this paper has shown that the Ethiopian government could achieve better results using the very same existing resources but allocating them very differently.

More specifically, our MCDM-CGE policy optimization modelling framework has helped simulate optimal reallocations of the existing public budget that Ethiopia's government allocates to agriculture. These optimal reallocations provide alternative ways of repurposing existing resources to move faster towards IAT objectives, i.e. increasing agrifood GDP growth, creating off-farm jobs in rural areas, and reducing rural poverty, while reducing the cost of the least-cost healthy diet for Ethiopians.

A key finding is that the current budget allocated to agriculture in Ethiopia would be suboptimal if the aspirations of the government were to accelerate IAT and ensure that the nutritious foods that make up the least-cost healthy diet be produced more widely and efficiently and offered to Ethiopians at a lower cost. We have shown alternative scenarios whereby the public budget is optimally reallocated, explicitly to: (i) reduce the cost of the least-cost healthy diet alone, (ii) pursue the three IAT objectives alone, or (ii) pursue all four objectives in unison. No matter the scenario, we find that the increase in the supply and availability of the nutritious foods that make up the least-cost healthy diet that results from optimally allocating the budget unambiguously reduces the cost of this diet and raises households' demand for pulses, vegetables and fruits. The results suggest that over time, there could be an improvement in nutrition outcomes; however, a thorough assessment of nutrition outcomes exceeds the scope of this paper, and this assessment should be subjected to future research.

Reallocating the budget only to explicitly reduce the cost of the least-cost healthy diet (alone or in combination with the pursuance of IAT objectives) provides the best results in terms of increasing the number of Ethiopians that could afford the least-cost healthy diet. However, this would come at the cost of delaying IAT; specifically, it is found to be at the cost of not achieving more agrifood GDP growth, job creation in rural areas and rural poverty reduction, which would still be possible to achieve using the same budget but differently. This is mostly due to the effects that would be seen if agriculture suddenly were to specialize in the production of the selected number of nutritious foods that form the least-cost healthy diet. This would penalize some agricultural subsectors that are traditionally generators of employment and are supportive of livelihoods in Ethiopia, certainly including staples' production, cattle farming, and so forth.

At the same time, we find that repurposing the budget to pursue any of the three IAT objectives, even individually, reduces the relative cost of the least-cost healthy diet. Hence, a key finding is that pursuing IAT without necessarily fully specializing the production to produce only those foods that make up the least-cost diet in Ethiopia is actually found to be quite positive for reducing the cost of this diet. In fact, repurposing the budget in a more optimal way, as shown in this paper, to pursue IAT objectives would allow 2 346 193 more Ethiopians to afford the least-cost diet in 2025 – compared with the situation where the budget allocation remains as usual.

Thus, Ethiopian policymakers may find it reasonable to compromise along the lines suggested in this paper. By reallocating the public budget more optimally to pursue IAT objectives (e.g. increasing the budget of extension services in both cereals and livestock farming, as well as fertilizers though to a lower extent, relative to other budget lines, notably irrigation), not only will these policymakers secure stronger economic recovery and accelerate IAT, but they will also ensure that the repurposing of the budget effectively supports healthy diets.

This is coherent with the fact that some of the nutrition strategies of Ethiopia also seek to achieve key outcomes that are typically the result of agricultural transformation (i.e. improved income, job creation, purchasing power and market linkage for commodities) because they matter for improving on nutrition. As noted in this paper, the cost of the least-cost healthy diet in Ethiopia was lower than in sub-Saharan Africa in 2020, but due to how low people's incomes were relative to such cost, almost 100 million Ethiopians could not afford such a diet in 2020. This indicates that while nutrition policies and programmes put in place to address the nutrition problems in Ethiopia are important, it seems that for such problems to be addressed more boldly, improving people's incomes and livelihoods is urgently needed, particularly in rural areas where poverty is higher. To this end, this paper argues that inclusive agricultural transformation is among the answers to address nutrition problems in Ethiopia, but this will depend on the coherence between the policies (i.e. the public budgets) allocated to implement the two agendas.

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Annex 1. Modelling the cost of the least-cost healthy diet as policy objective and estimating the share of the population that cannot afford a healthy diet

To include the cost of a healthy diet as policy objective in the CGE model, we start by calculating the value of a healthy diet, $ZDIET_t$, as

$$ZDIET_t = \sum_{c \in C} \sum_{h \in H} dietwts_{c,h} \cdot PQD_{c,h,t} \tag{A.1}$$

where,

$c \in C$: set of commodities in CGE model

$h \in H$: set of households in CGE model

$PQD_{c,h,t}$: price of commodity c for household h in CGE model

$ZDIET_t$: value of a healthy diet

$dietwts_{c,h}$: weight of commodity c in the healthy diet $ZDIET_t$ for household h

Here a healthy diet is defined (in value) as a weighted average of commodity prices. For simplicity, we assume that the commodity weights in the definition of $ZDIET_t$ are exogenous and estimated on the bases of the information presented in Section 3 where the data used to calibrate the CGE model is described.[19] In the model calibration, we link the food items in the least-cost healthy diet for Ethiopia presented in Table 1 to commodities in the SAM and hence the CGE model. For food items with a 1 to 1 mapping between the least-cost healthy diet for Ethiopia and the SAM/CGE model (i.e. vegetables and fruits), the weights are those in the least-cost healthy diet in Table 1. For food items in the least-cost healthy diet that are mapped to more than one food item in the SAM/CGE model (e.g. wheat and maize are mapped to starchy staples), we use the information on household consumption in the SAM to split the weight in the least-cost healthy diet of Ethiopia across commodities in the SAM/CGE model.

As explained, minimizing the cost of a healthy diet is one of the policy objectives that we consider in this paper. To that end, we define $RATZDIETCPI_t$ as the ratio between the cost of a healthy diet, $ZDIET_t$, and the consumer price index, CPI_t.

$$RATZDIETCPI_t = \frac{ZDIET_t}{CPI_t}$$

where,

CPI_t: consumer price index in CGE model

In Section 3, one of the policy objectives is to minimize the value of $RATZDIETCPI_t$. In other words, the policy objective is to minimize the cost of a healthy diet relative to the cost of the (average) household consumption basket.

[19] However, it is possible to make the commodity weights endogenous and determined by the results from the CGE model.

In a second step, we use selected results from the policy optimization exercise to feed, in a top-down fashion, a relatively simple microsimulation model that estimates, on the basis of household survey data from the *2018/2019 Ethiopia Socioeconomic Survey*, the share of the population that cannot afford a healthy diet. Specifically, in the microsimulation model, we link (a) $QHDIS_{cdis,hdis,t}$ with changes in $QH_{c,h,t}$, and (b) $PQDDIS_{cdis,hdis,t}$ with changes in $PQD_{c,h,t}$. Mathematically,

$$\Delta QHDIS_{cdis,hdis,t} = \sum_{c \in MCCDIS(c,cdis)} \sum_{h \in MHHDIS(h,hdis)} \Delta QH_{c,h,t} \tag{A.2}$$

$$\Delta PQDDIS_{cdis,hdis,t} = \sum_{c \in MCCDIS(c,cdis)} \sum_{h \in MHHDIS(h,hdis)} \Delta PQD_{c,h,t} \tag{A.3}$$

$$\Delta ZIETDIS_t = \Delta ZDIET_t \tag{A.4}$$

where,

$cdis \in CDIS$: commodities in microsimulation model

$hdis \in HDIS$: households in microsimulation model

$MCCDIS(c, cdis)$: mapping between c and $cdis$

$MHHDIS(h, hdis)$: mapping between h and $hdis$

$PQDDIS_{cdis,hdis,t}$: price of commodity $cdis$ for household h in microsimulation model

$QH_{c,h,t}$: consumption of commodity c by household h in CGE model

$QHDIS_{cdis,hdis,t}$: consumption of commodity $cdis$ by household $hdis$ in microsimulation model

Δ: percent deviation from the base scenario

Equation (A.2) maps representative households in the CGE model to real households in the microsimulation model. Equation (A.3) maps commodities in the CGE model to commodities in the microsimulation model. For instance, a change in the price of fruits (an element in c) would be applied to apples and oranges (elements in $cdis$).

Finally, we calculate the share of households (or individuals) that do not have a consumption spending that is large enough to cover a (healthy) diet, $AFFRAT_t$. Mathematically,

$$AFFRAT_t = \frac{1}{poptot_t} \sum_{hdis \in HDIS} 1 \cdot \left(EHDIS_{hdis,t} < ZDIET_t \right) \tag{A.4}$$

where,

$EHDIS_{hdis,t}$: consumption spending for household $hdis$ in microsimulation model

$poptot_t$: total population

The $AFFRAT_t$ indicator can be calculated for rural and urban households separately.

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