Improving labour productivity in Kenya through food security and nutrition drivers: a food-related policy evaluation under CGE framework

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Paper prepared for presentation at the 28th Annual Conference on Global Economic Analysis
"Accelerating Economic Transformation, Resilience, Diversification, and Job Creation"
June 25-27, 2025, Kigali (Rwanda).

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Abstract: Hunger and malnutrition remain significant challenges in Kenya, affecting labour productivity and economic performance. This work integrates the effect of key micronutrients (haem iron, zinc, and vitamins A RAE and B2) on labour productivity into the DEMETRA single-country dynamic CGE model for Kenya. Aligned with the recent national plans, it simulates a national policy promoting better nutrition by introducing subsidies for healthy foods like fruits, vegetables, fish, and dairy. Preliminary results suggest that building the dynamic baseline micronutrients intakes contribute positively to improve labour productivity in all regions in Kenya; however, disparities of impacts appear across regions due to their differences in the current food security and nutrition conditions. A greater labour productivity is then reflected in an increase in GDP in the medium- and long-term due to micronutrients intake. The simulation of sale subsidies of healthy food commodities highlights the presence of two mechanisms over economic variables: an increase through micronutrients intakes but a decrease due to lower public budget for education and health expenditure that also impact on labour productivity and GDP. These results highlight the necessity to consider a comprehensive socio-economic cost-benefit analysis for each policy measure and further research into alternative strategies like food fortification and biofortification. Nutritional policies could serve as growth strategies by leveraging the hidden economic benefits of nutrient-rich diets.

Keywords: Kenya, micronutrients, labour productivity, economic growth, DEMETRA CGE model.

1. Introduction

Hunger and malnutrition problems persist nowadays in many developing countries, especially in Africa. One of the countries with high food insecurity and prevalent malnutrition is Kenya. The Integrated Phase Classification initiative estimated that 1 million people were in Phase 3 of acute food insecurity in the arid and semi-arid lands (ASAL) counties in 2024.[1]

Malnutrition witnessed some progress in the last years, but according to the last Demographic and Health Survey, 18% of children under age 5 are stunted, 10% are underweight, and 3% are overweight. These malnutrition forms are all related to poor diet quality reflected by the fact that only 30% of all children 0-23 months receive a minimum acceptable diet and less than 50% of the women of reproductive age achieve the minimum dietary diversity (Kenya National Bureau of Statistics and The DHS Program ICF, 2023).

The quality of diet has also a great impact on micronutrient deficiencies that are still highly prevalent in Kenya. This country has shown no progress towards achieving the target of reducing anaemia among women of reproductive age, with 28.7% of women affected[2] and 13.8% of children. According to the last Micronutrient survey conducted in Kenya, vitamin A, zinc, iron, and calcium are among the most common deficiencies in terms of micronutrients and that pose a great public health concern in Kenya (Kenya Ministry of Health, 2011). Apart from the consequences this deficiency has on the health and physical condition of the population, these problems have an impact on economic aspects, such as on labour productivity and thus, economic growth. Following the nutrition-wage hypothesis, an higher calories intake is positively related with productivity and wages in low-income groups (Leibenstein, 1957). However, recent research shows mixed results, and the hypothesis does not seem consistent (Berha et al., 2021; Weinberger, 2004). Indeed, nutritional intake and food diversity are equally important to increase labour productivity (Berha et al., 2021). An increase of household earnings and farm output in Thailand is associated with higher intakes of micronutrients such as calcium, vitamin A and iron (Tiwasing et al., 2019). Recently, Ramos et al. (2022) through an econometric estimation obtained a positive and significant association between vitamin A, zinc, iron, calcium and riboflavin (vit B2) and labour productivity (approached through monthly income) in Kenya. Thus, based on the evidence coming from the literature and following the results obtained in the previous work, the first aim of this work is to introduce the effect of micronutrients on labour productivity in a general equilibrium framework, in order to consider its pathway mechanism to economic growth. More technically, we incorporate micronutrients (iron, zinc, vitamin A (RAE) and vitamin B2) into the labour productivity function in the dynamic baseline of the Dynamic Equilibrium Model for Economic development Resources and Agriculture (DEMETRA) Computable General Equilibrium (CGE) model for the case of Kenya (Joint Research Centre, 2024).

The Government of Kenya has developed various plans and strategies to address the issue of malnutrition in the country: the Kenya Nutrition Action Plan 2018-2022 (Government of Kenya, Ministry of Health, 2018) (which will soon be updated to 2023-2027), and the Kenya Agri-Nutrition Implementation Strategy 2020-2025 (Government of Kenya, Ministry of Agriculture, Livestock, Fisheries and Cooperatives, 2020). Within these programs, there are two main areas of action towards improving diet quality and reducing micronutrient deficiencies. One of them refers to the improvement of diets through the increased consumption of safe and nutrient-dense diverse foods

[1] https://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1157146/?iso3=KEN
[2] https://globalnutritionreport.org/resources/nutrition-profiles/africa/eastern-africa/kenya/

such as cereals, pulses, fruits and vegetables, and the other one is about direct control and management of micronutrient deficiencies.

The strategies proposed to increase consumption of nutrient-dense diverse foods include the modernization of agriculture, or the introduction of subsidies to the production of certain foods. The effects of fiscal policies, both taxes and subsidies, on nutrition has been widely studied by previous literature. These are mixed and it is not clear if they help to achieve the governments' objectives. The most implemented fiscal policy in the last year has been subsidies to fruits and vegetables and other health food such as cereals, fish or diaries (World Health Organization, 2021). Previous literature shows that it allows an increase in their consumption, but the change seems to be small to imply a real improvement of diet at population level (Hammaker et al., 2022; Thow et al., 2014). Besides, this kind of policy could aggravate the debt of governments.

On the other hand, among the specific actions to scale up the prevention and control of micronutrient deficiencies these plans propose to strengthen production and consumption of fortified foods. Food fortification increases the micronutrient contents of foods through diverse processes such as mass fortification (adding micronutrients to widely consumed food across a population) or biofortification, which enhances nutrient content through crop breeding or biotechnological strategies (Ohanenye et al., 2021). The economic effects of fortification and biofortification have been less studied, but the available research shows their significant effect on the nutritional status of the population as well as on the economic, social and environmental dimensions (Olson et al., 2021).

In this study, a subsidy is introduced to encourage the consumption of healthy foods, such as fruits, vegetables, fish and dairy products. By reducing the price of these food categories through the subsidy, the final cost to consumers will be lowered, thereby promoting their consumption. This approach allows us to assess the impact of increased micronutrient intake on labour productivity within the CGE model, and to compare the results not only in terms of labour productivity but also across other economic variables. Additionally, as part of future research, a second simulation will focus on enhancing the qualitative (micronutrient) content of household diets through the fortification of foods with Vitamin A, Zinc, and Vitamin B2.

The rest of the report will be structured as follows. Section 2 will present a literature review about the introduction of nutrition within a CGE model and the implementation of fiscal policies to improve the nutritional intake. Section 3 focuses on the methodological approach and results will be presented in section 4. The report will finish with future research in relation to simulations based on fortification policies and the main conclusions derived from our results.

2. Literature review

Due to the critical issue of malnutrition in developing countries, there has been growing attention in the literature on how policy decisions impact nutrition. Rutten and Tabeau, 2013 introduced nutritional indicators like fats, proteins, and carbohydrates within the CGE MAGNET model, marking a significant development in the field. More recent efforts have incorporated nutrition modules in other models, such as GTAP (Chepeliev, 2022; Sands, 2022) and MIRAGRODEP model (Bouët et al., 2021), which allow for translating changes in consumption into calories, fats, proteins and carbohydrates, similarly to what is done in the MAGNET model. Since the introduction of these models, recent studies have focused on the effects of major events on nutrition. For example, the impact of the COVID-19 pandemic on the affordability of healthy, nutrient-adequate diets in low-income countries has been explored (Laborde et al., 2021) as well as the price increases resulting from the Russia-Ukraine conflict (Chepeliev et al., 2023). Additionally, within the RIAPA framework, new indicators have been proposed to measure diet quality (Pauw et al., 2023) and Escalante and Pauw (2024) highlight that agricultural productivity improvements play a crucial role in enhancing population diets.

While much of the existing literature has focused on macronutrients, micronutrients also play a vital role in influencing labour productivity. Indeed, as previously discussed, deficiencies in micronutrients can have a direct impact on productivity in the workforce (Tiwasing et al., 2019). In this context, Ramos et al. (2022) estimated econometrically the relationship between micronutrient intake and labour productivity in Kenya. The elasticities derived can be incorporated into a CGE model to capture the effects of micronutrient deficiencies on productivity. This is the central aim of this study.

International institutions are concerned about the prevalence of unbalanced diets in many countries and are investigating the effectiveness of policies addressing this issue, including fiscal measures (World Health Organization, 2021). Among the fiscal approaches, taxes on unhealthy foods—such as those high in sugar and fats—have become common (Thow et al., 2014, 2018). However, in recent years, subsidies have attracted the attention of governments, and emerging research highlights the potential benefits of combining taxes with subsidies in a mixed policy approach (Andreyeva et al., 2022). The effects of these policies are typically analysed through a microeconomic lens, employing various econometric models such as Monte Carlo simulations (Blakely et al., 2020), panel data analysis (Griffith et al., 2018), or difference-in-differences models (Rummo et al., 2019). Econometrics has been used to assess the effects in both developed countries (such as the US and UK) and developing countries (including South Africa and Iran) (Grindal et al., 2016; Moran et al., 2019; Pakravan-Charvadeh, 2024; Sturm et al., 2013).

Although there have been attempts to explore these issues using a macroeconomic framework, these studies often fail to account for the effects of nutrition on the broader economy (Mounsey et al., 2020). Within this context, taxes on sugar are the most frequently studied policy intervention in macroeconomic models. The models most commonly employed in these macroeconomic studies include input-output models, regional macroeconomics models, and computable general equilibrium (CGE) models in specific cases (Balbinotto and Cardoso, 2016; Powell et al., 2014; Theron, Nicola et al., 2016). CGE models have been used to assess the impact of agricultural subsidies (Springmann and Freund, 2022). However, as previously noted, nutrients and micronutrients are rarely incorporated into these macroeconomic studies and are more often analysed within microeconomic frameworks.

3. Methodological approach

Employing a single-country computable general equilibrium (CGE) modelling approach allows assessing the direct and indirect effects of exogenous changes to the different parts of the economy by comprehensively accounting for the interlinkages between production and consumption. Given their extensive description of commodity and factor markets, and that of the circular flow of income, CGE models are widely applied for many trade, development, and fiscal policy issues of developing countries.

3.1. Dynamic DEMETRA model: micronutrients as labour productivity drivers

The Dynamic Equilibrium Model for Economic development Resources and Agriculture (DEMETRA) model is an extension of the STAGE_DEV model, (McDonald et al., 2016). DEMETRA is a single-country recursive-dynamic open-economy CGE model. The model features allow us for an advanced characterization of impacts of a given shock at different levels: sectoral (output and production costs), household (income and consumption demand), factors (demand and income), and national (GDP, employment, and trade). DEMETRA also incorporates a set of behavioural equations that represent the economic relationships in developing countries that include nested production and consumption functions and factor market segmentations.

DEMETRA assumes that the provision of education and health services by the government enhances productivity through various factors, including labour. The productivity equation (1) is defined as the initial productivity level *ADFH0* augmented by changes in per capita expenditures on education (*EDUC*) and health (*HEAL*) relative to their initial levels, with specific elasticities *mu_ed_l* for education spendings and *mu_he_l* for health spendings. The equation is expressed as follows:

```
ADFH.FX(l,h) = ADFH0(l,h)
        + ((EDUC(h)/EDUC0(h))**mu_ed_l(h) - 1)
        + ((HEAL(h)/HEAL0(h))**mu_he_l(h) - 1)                    (1)
```

To incorporate the effect of micronutrients on productivity, the equation is further extended. The revised equation (R1) adds the sum of changes in micronutrient consumption per capita, weighted by the elasticity *mu_nu_l*. The updated equation is as follows:

```
ADFH.FX(l,h)   = ADFH0(l,h)
        +  ((EDUC(h)/EDUC0(h))**mu_ed_l(h) - 1)
        + ((HEAL(h)/HEAL0(h))**mu_he_l(h) - 1)
     +  sum(mnut$MicNUT0(mnut,h),(MicNUT(mnut,h)/MicNUT0(mnut,h))**mu_nu_l(h,mnut) -1)     (R1)
```

Here, *MicNUT0* and *MicNUT* represent the initial and final levels of micronutrient consumption per capita, categorized by micronutrient (*mnut*) and household type (*h*). These are defined by the following equations:

```
MicNUT0(mnut,h) = SUM(calim, micnutSh(calim,h,mnut)*ALIM0(calim,h))          (2)

MicNUT(mnut,h) = SUM(calim, micnutSh(calim,h,mnut)*ALIM(calim,h))
(3)
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Equation (2) and (3) define MicNUT for each type of household (*h*) as the sum the consumption per capita (*ALIM0* in the calibration and *ALIM* as final levels) of food products (*calim*) weighted by the contribution (share - *micnutSh*) of each food products in terms of micronutrients (*mnut*).

To implement equation (R1), additional sets and parameters are introduced. The first new set, *calim*, combines "home production for home consumption" commodities with their marketed equivalents. The second set, *mnut*, represents the micronutrients considered in this study: Haem Iron, Zinc, Vitamin A, and Vitamin B2 (denoted as Fe, Zinc, VitA, and VitB2, respectively).

Among the key parameters, *micnutSh(calim,h,mnut)* represents the shares of micronutrients by agri-food commodity and household type. For simplicity, these shares are assumed to remain constant despite changes in food consumption patterns. A detailed explanation of their calculation is provided in the subsequent section. Another significant parameter is *mu_nu_l(h)*, which measures the responsiveness of labour productivity to changes in micronutrient intake. The values for these elasticities are derived from the econometric analysis conducted by (Ramos et al., 2022).

3.2. Data

To run the model, three main datasets are needed: the Kenya Household Budget Survey (KIHBS) 2015/2016, the 2017 Kenyan Social Accounting Matrix (SAM), and the Nutritional Conversion Table of Kenya (NCT). The SAM for Kenya was built from the 2015/2016 KIHBS (Jiménez et al. 2021). The Kenyan Nutrition Conversion Table (NCT) includes the nutrient composition of the food items reported in the food composition module of the 2015/2016 KIHBS. It was developed from the 2015/2016 KIHBS and the 2018 Food Composition Table (FCT) of Kenya, although other FCT were also used to complete the information of some food items, such as the USDA Food Database or Tanzania and West Africa FCTs.

The DEMETRA CGE model is based on the 2017 Kenya SAM. Thus, to compute the model, first it is necessary to make a matching between the commodities included in the SAM and the foods items included in the survey and that were considered for building the Nutrient Conversion Table. The SAM included 19 commodities categories: Maize, Wheat and barley, Rice, Other grains, Other roots, Pulses, nuts and oilseeds, Fruits, Vegetables, Beef, Dairy (including eggs and fats), Poultry, Other livestock, Goat, Fishing, Grain milling, Bakery, sugar and confectionary, Other meat, Beverages, and Other food. To be data consistent, the criteria for matching both datasets are the construction of the SAM, which is the same criteria used in Ramos et al. (2022). That is, we include in each category the food items that were considered when the 2015/2016 SAM was updated. The matching between both datasets are available upon request. This classification follows a production perspective, and it is not associated with the nutrient content of each food item. Thus, this matching could get biased results when considering the impact of micronutrients in productivity, as some of them could be overrepresented. For instance, the group Pulses, nuts and oilseeds included three different types of food with different nutrient content, but it is not possible to disaggregate this information if the SAM is not disaggregated too.

The SAM also has aggregates of the Kenya counties. Thus, this matching should be also considered. Particularly, the SAM considered eight different agro zones: Nairobi (NA), Mombasa (MO), High Rainfall zone (HR), Semi-Arid North (MN), Semi-Arid South (MS), Coast (CO), Arid North (AN) and Arid South (AS). It should be noted that Nairobi and Mombasa are disaggregated by income quintile, while the rest of agro zones are differentiated between rural and urban. Both the regional and commodities matching are available upon request.

Besides, to run the new productivity equation, it is necessary to calculate the micronutrient contribution of each food commodity included in the SAM and for each household category considered in the DEMETRA model. That is, households of the eight agro zones differentiated between rural and urban, except in the cases of Nairobi and Mombasa which are divided by income quintiles, as previously stated. To calculate these shares, it is required the nutritional content of the food items that appear in the 2015/2016 KIHBS and the consumption made by each type of household. Thus, with the information from the NCT and the consumption microdata from the KIHBS, the micronutrients are computed (Table A1).

Finally, the elasticities of micronutrients are obtained from the econometric analysis of Ramos et al. (2022). In this work, it is estimated a less square regression in which the dependent variable is the logarithm of the labour earning per adult male equivalent (AME) as proxy of labour productivity, and the independent variables are the micronutrients, also expressed per AME. Other variables included in the regression are the daily caloric intake (DEC), the Food Insecurity Experience Scale (FIES), the level of education and the number of household members with diseases. The results show that all micronutrients were significant in explaining labour productivity, except Vitamin C and Vitamin B12. For this reason, we include in the equation (R1) only the most relevant micronutrients, namely Haem Iron, Zinc, Vitamin C and Vitamin B2. Further, it is worth noting that the values of the coefficients

obtained in Ramos et al. (2022) are low (table A2), meaning that the responsiveness of labour productivity to a change in any micronutrient intake is expected to be modest, although significant. In other words, we anticipate that accounting for micronutrients intake will lead to small increases in total labour productivity as from equation (R1) compared to equation (1).
The estimations presented in Ramos et al. (2022) are replicated for both rural and urban households, as well as for skilled and unskilled labour. Consequently, for the sensitivity analysis, the elasticities in the DEMETRA model can be differentiated across these categories.

3.3. Design of Policy Scenarios

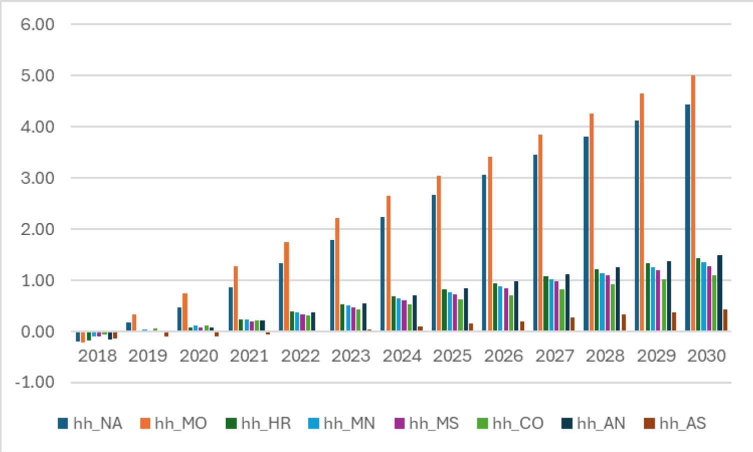
The scenario simulates a subsidy on healthy foods such as fruits, vegetables, fish, or dairy products, which incentivizes consumption (quantity) through a price mechanism. The simulation is conducted using both configurations of the DEMETRA model that is with and without the micronutrients-labour productivity relationship. The comparison of the outcomes of the baseline and the new model configuration highlights how the relationship between micronutrients and labour productivity influences the simulated policy. The policy scenario models the application of a 10% sales subsidy on a set of healthy commodities, including oilseeds, fruits, vegetables, other crops, dairy products, milled grains, and fish. The subsidy is introduced in the base year (2016) and continues until 2030.

4. Results

4.1 Comparison of the baseline without and with micronutrients as labour productivity driver

The primary contribution of this work is the introduction of micronutrients into the productivity equation of the DEMETRA dynamic CGE model. WE illustrate it comparing the original baseline model, where the productivity equation corresponds to the original equation (1), with the baseline that incorporates micronutrients, where equation (1) is replaced by equation (R1). Iron (haem), zinc, vitamins A (RAE) and B2 provided by current food consumption patterns effectively lead to an additional improvement of labour productivity in Kenya (in all agro zones and thus at the national level) since 2020 and with a continuing and increasing effect over the time. Nevertheless, disparities in labour productivity gains appear across households of agro zones, which are influenced by the current regional health, food security, and socio-economic conditions.
Figure 1 displays the additional labour productivity change (in percentage points - p.p.) attributed to micronutrients across different agro zones. The impact is particularly pronounced in the urban centres of Mombasa and Nairobi, the two largest cities in Kenya. In both major cities, the productivity gains are predominantly driven by the poorest quintiles, a trend that is especially evident in Nairobi. This result highlights the importance of the role of micronutrient intakes in improving labour productivity, particularly in poorest households, that comes also coupled with a health and wellbeing improvement - hidden net benefits of nutritional issues, such as the reduction in non-communicable diseases (FAO, 2024). Comparatively, Nairobi and Mombasa offer better access to healthcare, markets, and infrastructure, allowing households, particularly in lower-income brackets, to benefit from improved nutrition.

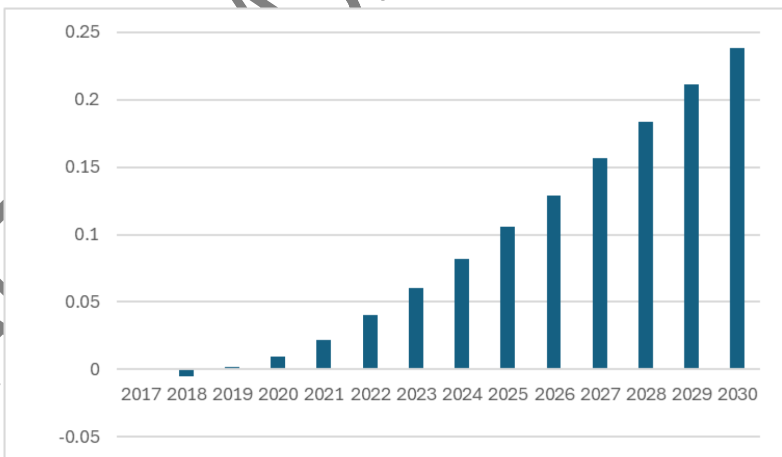
Figure 1: Additional labour productivity change (p.p.) associated with micronutrients by agro zone in Kenya. Baselines comparison.



Source: Own elaboration.

Outside of these key urban areas, productivity gains from micronutrients are also positive but less pronounced in the Arid North, High Rainfall, and Semi-Arid North zones, with urban households in these regions experiencing greater gains than their rural counterparts since urban households may already have relatively better access to nutritious food and healthcare (World Bank, 2016).
This additional labour productivity change also impacts GDP, which serves as a proxy for economic growth (**Figure 2)**. These increases are consistently positive and grow over time. In 2019, additional 0.002 p.p. in GDP growth is due to the improvement in labour productivity through the micronutrient intakes mechanism, while by 2030, the additional growth in GDP reached 0.239 p.p.. This suggests that the economic benefits of a balanced diet manifest as a medium- to long-term process, as indicated in Ogundari and Aromolaran (2017).

Figure 2: Additional increases of GDP (in p.p.) due to micronutrients. Baseline comparison.



Source: Own elaboration.

4.2 Comparison of micronutrient-related policies to improve labour productivity

This section presents the results of applying a sales subsidy to healthy food commodities, which leads to an increase in household consumption, particularly of grain milling products, oils, nuts, pulses, eggs, dairy, and fruits. While the consumption of vegetables, roots, and meat (not benefited by the subsidy for environmental justifications) also rises, the increase is less pronounced (**Table 1**).[3] The changes in micronutrient intake are thus linked to the increased consumption of pulses rich in zinc, dairy, eggs and fruits rich in vitamin A and nuts rich in vitamin B2.

Table 1. Food consumption impact in Kenya under the Subsidy scenario - difference in p.p. between the scenario and the baseline with micronutrient-labour productivity modelling

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
c_bake	-0.02	-0.22	-0.22	-0.13	0.00	0.16	0.25	0.29	0.32	0.40	0.45	0.47	0.50	0.53
c_beef	0.47	-0.31	-0.45	-0.44	-0.21	-0.06	-0.04	-0.14	-0.21	0.58	0.51	0.31	0.16	0.00
c_bevt	0.90	0.28	0.30	0.56	1.08	1.66	2.05	2.24	2.42	2.80	3.00	3.15	3.30	3.44
c_dair	7.66	7.76	8.43	9.39	10.63	12.01	13.43	14.81	16.27	18.06	19.74	21.38	23.11	24.90
c_fish	1.57	1.56	1.66	1.80	2.02	2.26	2.44	2.61	2.78	2.99	3.19	3.39	3.60	3.81
c_frui	7.72	7.63	8.07	8.79	9.89	10.99	11.88	12.65	13.41	14.45	15.33	16.15	16.97	17.79
c_gmil	18.35	18.85	19.89	21.34	23.13	25.04	26.59	28.04	29.45	31.14	32.77	34.29	35.81	37.32
c_goat	0.23	-0.04	-0.07	-0.04	0.06	0.15	0.21	0.22	0.24	0.49	0.52	0.48	0.48	0.47
c_maiz	-0.33	-0.91	-0.93	-0.76	-0.30	0.10	0.32	0.46	0.58	0.80	0.96	1.05	1.17	1.29
c_meat	1.08	0.29	0.29	0.52	1.03	1.57	1.89	2.04	2.23	3.14	3.35	3.46	3.60	3.74
c_ogrn	-0.38	-0.47	-0.49	-0.48	-0.44	-0.42	-0.41	-0.40	-0.40	-0.39	-0.39	-0.39	-0.39	-0.39
c_oils	17.64	17.55	18.32	19.59	21.39	23.17	24.66	25.95	27.20	28.84	30.27	31.57	32.89	34.19
c_oliv	0.14	0.08	0.07	0.09	0.12	0.13	0.15	0.15	0.15	0.23	0.23	0.22	0.22	0.21
c_omfd	-0.21	-0.34	-0.35	-0.32	-0.25	-0.16	-0.12	-0.11	-0.10	-0.04	-0.02	-0.02	-0.01	0.00
c_poul	0.15	0.01	0.00	0.00	0.05	0.11	0.15	0.16	0.17	0.29	0.30	0.28	0.27	0.26
c_rice	-0.15	-0.22	-0.23	-0.23	-0.20	-0.17	-0.17	-0.17	-0.18	-0.17	-0.17	-0.18	-0.19	-0.19
c_root	3.12	2.74	2.98	3.48	4.32	5.13	5.73	6.23	6.71	7.43	8.01	8.50	9.03	9.55
c_vege	5.98	5.88	6.20	6.73	7.50	8.27	8.91	9.46	9.99	10.73	11.35	11.87	12.42	12.96
c_watr	-0.05	-0.12	-0.11	-0.09	-0.05	0.01	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15
c_whea	-0.07	-0.09	-0.09	-0.09	-0.09	-0.10	-0.10	-0.10	-0.11	-0.11	-0.12	-0.12	-0.13	-0.13

Source: Own elaboration.

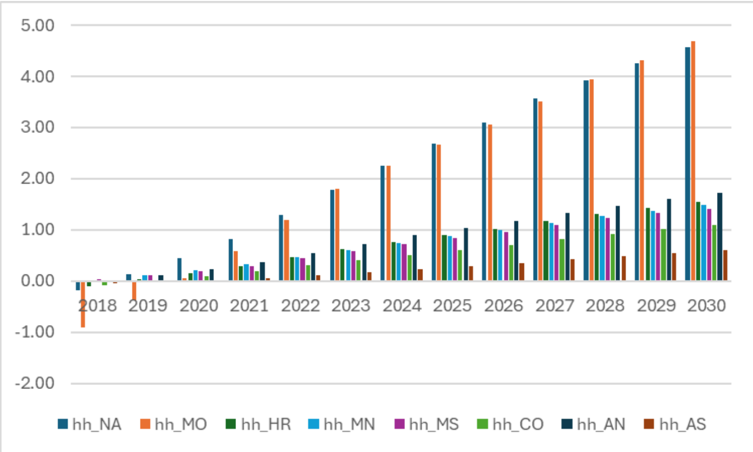
The improvement in a better nutrition through zinc, vitamins A and B2 intakes leads to labour productivity increases in Kenya following a quite similar regional pattern of impacts as described for the dynamic baseline's results with micronutrient as a labour productivity driver.

Figure 3 illustrates the additional labour productivity change resulting from the introduction of micronutrients when the subsidy is applied. As the subsidy leads to a global increase in consumption, particularly of grain milling products, oils, dairy, and fruits, there is also an increase in micronutrient intake. Consequently, the productivity change under the subsidy is more significant when micronutrients are incorporated into the model. This effect is particularly pronounced in Nairobi and Mombasa, as observed in the dynamic baseline (Figure 1). However, in this case, the impact is more pronounced in Nairobi than in Mombasa. In both cities, the productivity gains are primarily driven by changes in the households' productivity within the lowest socioeconomic quintiles. Micronutrient-related productivity gains are also notable in the Arid North, High Rainfall, and Semi-Arid North and

[3] "Other crops" commodities also benefit from the subsidy, although Kenyan households do not directly consume this good.

South counties, with urban households seeing slightly higher benefits than rural ones. However, the impact is lowest in the Arid South.

Figure 3: Additional productivity change (in p.p.) isolating micronutrients mechanisms by agro zone - Subsidy scenario.



Source: Own elaboration.

The higher impact of food subsidies in large cities like Nairobi and Mombasa, compared to urban areas in the Arid and High rainfall zones, can be explained by several factors. These cities have higher population densities, with a significant portion of the population living in poverty. The demand for affordable, nutritious food is more pronounced, and the subsidy mechanism is more effective in addressing food insecurity in these areas which do not produce their own food such as in rural areas. In contrast, urban areas in the Arid and High rainfall zones may have smaller populations or lower overall demand for subsidized foods, reducing the subsidy's impact (World Bank, 2016).

Economic disparities and informal employment in Nairobi and Mombasa further amplify the need for subsidies. A large proportion of the population in these cities works in informal sectors with unstable income, making it difficult to afford nutritious foods (IFPRI, 2017). The subsidies directly address this issue by improving affordability, whereas urban areas in the Arid and High rainfall zones may have more stable living conditions or different economic structures, resulting in less demand for subsidized food. Moreover, the impact seen in Nairobi and Mombasa is mainly driven by the poorer quintiles, consistent with the fact that urban poor populations are more likely to alter their diets in response to subsidies, shifting from calorie-dense, nutrient-poor foods to more balanced, micronutrient-rich diets when healthier options become more affordable (Holdsworth et al., 2020).

Better infrastructure in large cities allows for efficient distribution of subsidized foods, ensuring they reach the target populations quickly. In contrast, urban areas in remote regions like the arid and high rainfall zones face logistical challenges in food distribution, limiting the subsidy's effectiveness (Pinstrup-Andersen, 1988).

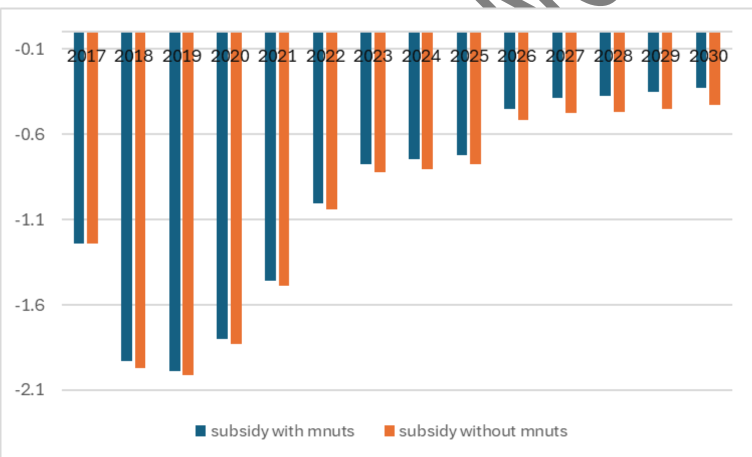
The diversity of food markets in Nairobi and Mombasa also makes the effect of food subsidies more noticeable. Residents in these cities have access to a wide variety of food items, and subsidies can encourage a shift from nutrient-poor staples to more micronutrient-rich foods (Westbury et al., 2021). In contrast, urban markets in the arid and high rainfall zones may not offer the same variety, making it harder for subsidies to significantly alter consumption patterns (Milner et al., 2022).

Lastly, urban populations in large cities are more vulnerable to price fluctuations, which makes them more sensitive to price changes when subsidies are introduced (Cohen and Garrett, 2009). In the arid and high rainfall zones, urban populations may rely less on market foods or have access to locally sourced, more affordable alternatives that are less affected by market prices, diminishing the subsidy's impact.

Even when the sales subsidy of healthy food improves micronutrients intakes and thus labour productivity in Kenya, this kind of measure has broader economic impacts since it is not costless for the government budget and for economic growth.

Introducing a subsidy implies an additional distortion in the markets that can induce a misallocation of resources and thus efficiency costs. Furthermore, while both labour productivity and GDP decline, the decrease is less pronounced when the impact of micronutrients is taken into account (**Figure 4)**. The increase in the amount of the subsidy puts pressure on the government budget, causing spending on public education and health to be reduced (-11% on average over the entire period of analysis) in order to keep the public budget result constant (model closure). Since labour productivity in the DEMETRA dynamic model is driven by the change in per capita education and health expenditures, this reduction in government spending contributes to a decline in labour productivity, and consequently, on the GDP. Figure 4 shows the change in GDP under the sales subsidy on healthy food commodities that concerns all CGE pathways.

Figure 4: GDP change (in p.p.) due to sales subsidy to healthy food commodities - Base and Subsidy scenario.

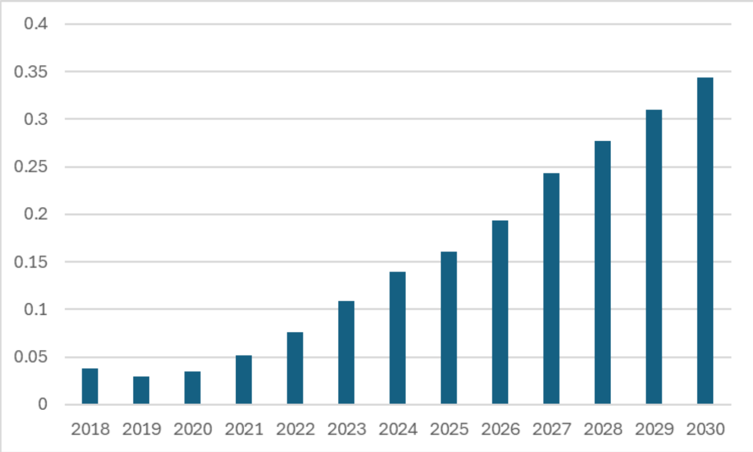


Source: Own elaboration.

Although the subsidy has a negative effect on the economy, the inclusion of micronutrient intakes as labour productivity drivers mitigates this impact.

Figure 5 shows the additional GDP growth resulting from the inclusion of micronutrients in the productivity change equation. This additional growth is positive and increases over time, as observed in the baseline scenario. In the initial years, it is approximately 0.05 percentage points (pp), but by 2029 and 2030, it exceeds 0.3pp. Although the subsidy continues to have a negative effect even when micronutrients are included, in the later years, the productivity gains from micronutrients partially offset the subsidy's negative impact on education and health expenditures.

Figure 5: Additional increases of GDP associated with micronutrients (in p.p.) - Subsidy scenario.



Source: Own elaboration.

The sensitivity of these results will be tested for the micronutrients-labour productivity elasticities. The described results considered national elasticities, but Ramos et at. (2022) also differentiate by rural/urban and skilled/unskilled labour. These differentiated elasticities will be considered for the sensitivity analysis. As mentioned in the description of results, the current consumption patterns and their micronutrient contents (initial structural situation) also condition the policy results.

5. Future lines of research in micronutrients

Building upon the results of the subsidy scenario, future research will explore additional strategies to improve micronutrient intake and assess their broader economic and health impacts. While fiscal policies such as subsidies are effective in influencing consumer behaviour, food fortification—whether traditional or biofortification—offers a complementary approach to directly enhancing the nutritional content of staple foods. Studies have examined the economic impacts of fortification programs using a variety of evaluation methods, mostly relying on observational methodologies such as ecological studies, repeat cross-sectional surveys, and cohort designs (Mannar and Hurrell, 2018). However, there is also a growing body of evidence from studies employing higher-quality methodologies, such as randomized controlled trials (RCTs) and quasi-experimental designs, which offer greater capacity to discern causal impacts. For instance, RCTs like those conducted by (Nogueira Arcanjo et al., 2012) or (Perignon et al., 2016) and quasi-experimental studies by (Hoddinott et al., 2012) have provided robust evidence on the health and economic benefits of fortification. These methods complement observational approaches by controlling for confounding factors and enabling more precise estimations of the impact of fortification initiatives.

Despite these findings, the integration of fortification's economic impacts into broader macroeconomic models remains limited. By contrast, such models have been more extensively applied to biofortification, which involves breeding crops to enhance their micronutrient content. Computable General Equilibrium (CGE) models and other macroeconomic frameworks have been used to predict the impacts of biofortification on food systems, health outcomes, and economic growth, particularly in agricultural economies (Lividini et al., 2018). Studies such as (Meenakshi et al., 2010) and (De Moura et al., 2024) have evaluated the potential of biofortified crops like vitamin A-enriched cassava or zinc-enriched rice, showing promising economic and health returns. Incorporating fortification into similar macroeconomic models could provide valuable insights into its systemic impacts and offer a comparative understanding of how these two complementary approaches contribute to economic and social development. The modelling and simulation of food fortification and/or biofortification, and its impact on the consumption of more nutritious food, as well as its effects on labour productivity and economic growth, would be an extension of the work presented in this report.

6. Conclusions

Although there have been improvements in addressing malnutrition and food insecurity in Kenya in recent years, micronutrient deficiencies, such as anaemia, remain widespread. Additionally, high rates of malnutrition and food insecurity persist in certain regions and among specific population groups. These nutritional challenges not only affect the health and well-being of the population but also have significant economic consequences, particularly in terms of labour productivity, as demonstrated by previous studies.

To capture this effect, the micronutrients intake is included in the productivity change equation of the DEMETRA single-country CGE model. Productivity change, initially defined as the sum of the change of education and health expenses per capita, is snow summing the micronutrients intake change per capita. The DEMETRA model considers four key micronutrients Haem Iron, Zinc, Vitamin B2 and Vitamin A. We introduce this modification defining the contribution of each food commodity and household type to micronutrient intake. Additionalys, elasticities are derived from the econometric estimation of Ramos et al., (2022).

To analyse the effect of introducing micronutrients into the model, a 10% subsidy on health foods, one of the most common policies aimed at improving diet, is simulated. The results suggest that this subsidy has a negative effect on the economy, leading to a reduction of education and health expenditures, and consequently, a decrease in labour productivity and GDP. However, the impact of micronutrient intake, driven by changes in the consumption of certain food products, partially mitigates these negative effects.

The results of this study align with the objectives set forth in the Kenya Nutrition Action Plan (KNAP) 2018-2022 and the Kenya Agri-Nutrition Implementation Strategy (KANIS) 2020-2025, which emphasize the importance of improving the production and consumption of diverse, safe, and nutrient-dense foods (KANIS) and increasing dietary diversity (KNAP). The model also underscores the relevance of urban food subsidies, already incorporated into the social protection component of the KNAP, and the Market System Development Initiative within the KANIS. These initiatives aim to improve food accessibility, particularly in urban areas, while promoting broader dietary improvements, and the findings suggest that such strategies can significantly enhance labour productivity and contribute to overall economic growth.

Food and nutrition-related policies should be viewed not only as tools for improving public health and well-being but also as strategies for fostering economic growth. Future research could explore the potential impact of additional nutritional policies using the DEMETRA model. In line with national strategies, fortification and biofortification present promising approaches to improving diets and addressing nutritional challenges. Modelling and simulating these policies, and assessing their economic impact, would serve as an extension of the work presented in this report. Furthermore, this study underscores the importance of explicitly considering the nutritional-economic synergies and hidden economic benefits (and potential costs) of policies aimed at improving nutrition. Kenya should focus on leveraging the broader economic outcomes of its nutrition programs, such as the Kenya Nutrition Action Plan 2018-2022 and the Kenya Agri-Nutrition Implementation Strategy 2020-2025, as these initiatives can play a crucial role in stimulating long-term economic growth.

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Table A1. Shares of micronutrients by commodity and household (new worksheet “micronutrients” located in data_Kenya_v1.xlsx).

Sector name	Household type	Fe	Zinc	VitB2	VitA
bake	hh_AN_RU	0.000000	0.004765	0.014585	0.002958
beef	hh_AN_RU	0.314631	0.069231	0.045142	0.014062
bevt	hh_AN_RU	0.000000	0.000440	0.001652	0.000090
dair	hh_AN_RU	0.099330	0.53451	0.272630	0.207091
fish	hh_AN_RU	0.138078	0.069347	0.033363	0.097729
frui	hh_AN_RU	0.000000	0.094288	0.017200	0.036599
maiz	hh_AN_RU	0.000000	0.189841	0.120801	0.033344
meat	hh_AN_RU	0.252276	0.079003	0.058763	0.009379
ogrn	hh_AN_RU	0.000000	0.100128	0.068839	0.009101
oils	hh_AN_RU	0.000000	0.062009	0.053761	0.105386
omfd	hh_AN_RU	0.006490	0.002966	0.006976	0.212489
poul	hh_AN_RU	0.189196	0.022805	0.035837	0.095294
rice	hh_AN_RU	0.000000	0.092539	0.051304	0.012254
root	hh_AN_RU	0.000000	0.018644	0.026356	0.038579
vege	hh_AN_RU	0.000000	0.006534	0.019643	0.064401
whea	hh_AN_RU	0.000000	0.134009	0.173147	0.061245
bake	hh_AN_UR	0.000000	0.010419	0.028326	0.006470
beef	hh_AN_UR	0.233641	0.054713	0.035376	0.012167
bevt	hh_AN_UR	0.000000	0.001041	0.002811	0.002324
dair	hh_AN_UR	0.071459	0.052904	0.268112	0.208989
fish	hh_AN_UR	0.165360	0.088308	0.040638	0.133107
frui	hh_AN_UR	0.000000	0.099539	0.014627	0.026830
maiz	hh_AN_UR	0.000000	0.158525	0.105310	0.049365
meat	hh_AN_UR	0.300875	0.084640	0.064865	0.018232
ogrn	hh_AN_UR	0.000000	0.074026	0.067410	0.016967
oils	hh_AN_UR	0.000000	0.057025	0.048602	0.078611
omfd	hh_AN_UR	0.011880	0.003966	0.007222	0.128583
poul	hh_AN_UR	0.216784	0.027809	0.043335	0.127231
rice	hh_AN_UR	0.000000	0.119645	0.062485	0.014675
root	hh_AN_UR	0.000000	0.015655	0.021805	0.040024
vege	hh_AN_UR	0.000000	0.005662	0.015651	0.075503
whea	hh_AN_UR	0.000000	0.146124	0.173425	0.060922
bake	hh_AS_RU	0.000000	0.005625	0.004026	0.001466
bevt	hh_AS_RU	0.000000	0.000396	0.001058	0.000669
dair	hh_AS_RU	0.179812	0.078325	0.334720	0.256281
fish	hh_AS_RU	0.137431	0.026326	0.019699	0.085395
frui	hh_AS_RU	0.000000	0.100993	0.009757	0.063115
maiz	hh_AS_RU	0.000000	0.308479	0.198383	0.167629
meat	hh_AS_RU	0.456640	0.079795	0.050258	0.011394
ogrn	hh_AS_RU	0.000000	0.061174	0.053044	0.024704
oils	hh_AS_RU	0.000000	0.052352	0.037910	0.052372
omfd	hh_AS_RU	0.005651	0.002207	0.003896	0.115484
poul	hh_AS_RU	0.220466	0.016258	0.021580	0.065492
rice	hh_AS_RU	0.000000	0.109518	0.058854	0.020438
root	hh_AS_RU	0.000000	0.009865	0.011848	0.006823

vege	hh_AS_RU	0.000000	0.005099	0.013532	0.044566
whea	hh_AS_RU	0.000000	0.143588	0.181437	0.084172
bake	hh_AS_UR	0.000000	0.010917	0.008319	0.005974
beef	hh_AS_UR	0.117698	0.021510	0.011245	0.004172
bevt	hh_AS_UR	0.000000	0.000907	0.001395	0.001165
dair	hh_AS_UR	0.121663	0.041404	0.167414	0.131514
fish	hh_AS_UR	0.099598	0.050998	0.022987	0.060445
frui	hh_AS_UR	0.000000	0.109957	0.011439	0.038439
maiz	hh_AS_UR	0.000000	0.245206	0.149094	0.128839
meat	hh_AS_UR	0.374339	0.084028	0.054991	0.008870
ogrn	hh_AS_UR	0.000000	0.042295	0.045130	0.024674
oils	hh_AS_UR	0.000000	0.063877	0.043774	0.046534
omfd	hh_AS_UR	0.014344	0.004500	0.006823	0.121211
poul	hh_AS_UR	0.272358	0.027268	0.034353	0.108798
rice	hh_AS_UR	0.000000	0.144821	0.073913	0.013450
root	hh_AS_UR	0.000000	0.019848	0.023111	0.007804
vege	hh_AS_UR	0.000000	0.005146	0.011797	0.058922
whea	hh_AS_UR	0.000000	0.127319	0.334214	0.239188
bake	hh_CO_RU	0.000000	0.008483	0.008187	0.014723
beef	hh_CO_RU	0.437828	0.089856	0.052438	0.019014
bevt	hh_CO_RU	0.000000	0.000436	0.000950	0.000933
dair	hh_CO_RU	0.024162	0.030864	0.141906	0.130864
fish	hh_CO_RU	0.062446	0.027978	0.015757	0.055574
frui	hh_CO_RU	0.000000	0.042029	0.069702	0.050677
maiz	hh_CO_RU	0.000000	0.465160	0.306429	0.234153
meat	hh_CO_RU	0.302211	0.069179	0.044869	0.013982
ogrn	hh_CO_RU	0.000000	0.046187	0.035531	0.013485
oils	hh_CO_RU	0.000000	0.049858	0.033885	0.039254
omfd	hh_CO_RU	0.003409	0.002230	0.003778	0.072357
poul	hh_CO_RU	0.169944	0.019106	0.026872	0.083177
rice	hh_CO_RU	0.000000	0.058760	0.033463	0.007434
root	hh_CO_RU	0.000000	0.012949	0.012415	0.100132
vege	hh_CO_RU	0.000000	0.005936	0.021311	0.031948
whea	hh_CO_RU	0.000000	0.070988	0.192507	0.132292
bake	hh_CO_UR	0.000000	0.011918	0.027697	0.015716
beef	hh_CO_UR	0.407444	0.095273	0.054015	0.017767
bevt	hh_CO_UR	0.000000	0.000912	0.003221	0.001322
dair	hh_CO_UR	0.023698	0.027481	0.125276	0.097589
fish	hh_CO_UR	0.048835	0.023700	0.016263	0.054702
frui	hh_CO_UR	0.000000	0.076585	0.042493	0.044941
maiz	hh_CO_UR	0.000000	0.425930	0.282387	0.230631
meat	hh_CO_UR	0.371616	0.089741	0.052129	0.029171
ogrn	hh_CO_UR	0.000000	0.063413	0.045822	0.015413
oils	hh_CO_UR	0.000000	0.039455	0.027893	0.073918
omfd	hh_CO_UR	0.003511	0.002109	0.004143	0.101207
poul	hh_CO_UR	0.144897	0.018560	0.025360	0.071208
rice	hh_CO_UR	0.000000	0.055613	0.030754	0.004346
root	hh_CO_UR	0.000000	0.010365	0.010527	0.040515
vege	hh_CO_UR	0.000000	0.005138	0.015634	0.037188
whea	hh_CO_UR	0.000000	0.053805	0.236385	0.164365
bake	hh_HR_RU	0.000000	0.007653	0.014103	0.006392

beef	hh_HR_RU	0.327161	0.080152	0.046164	0.013334
bevt	hh_HR_RU	0.000000	0.000929	0.002310	0.000363
dair	hh_HR_RU	0.038081	0.068424	0.305891	0.217160
fish	hh_HR_RU	0.140491	0.096465	0.034373	0.068571
frui	hh_HR_RU	0.000000	0.064734	0.020556	0.029531
maiz	hh_HR_RU	0.000000	0.257189	0.141928	0.021318
meat	hh_HR_RU	0.270294	0.073663	0.045255	0.016101
ogrn	hh_HR_RU	0.000000	0.067176	0.042952	0.010037
oils	hh_HR_RU	0.000000	0.063529	0.046545	0.116322
omfd	hh_HR_RU	0.003982	0.002401	0.003699	0.094593
poul	hh_HR_RU	0.219990	0.029525	0.040982	0.101048
rice	hh_HR_RU	0.000000	0.053341	0.029948	0.007353
root	hh_HR_RU	0.000000	0.033069	0.039416	0.134903
vege	hh_HR_RU	0.000000	0.010665	0.032228	0.092858
whea	hh_HR_RU	0.000000	0.091086	0.153651	0.070117
bake	hh_HR_UR	0.000000	0.013299	0.052915	0.006573
beef	hh_HR_UR	0.328640	0.085487	0.051186	0.013755
bevt	hh_HR_UR	0.000000	0.001232	0.002903	0.000940
dair	hh_HR_UR	0.034282	0.057454	0.269548	0.177218
fish	hh_HR_UR	0.126755	0.091200	0.034968	0.064699
frui	hh_HR_UR	0.000000	0.149143	0.015892	0.025106
maiz	hh_HR_UR	0.000000	0.217334	0.130846	0.035263
meat	hh_HR_UR	0.320135	0.089001	0.056103	0.039853
ogrn	hh_HR_UR	0.000000	0.043498	0.038190	0.011019
oils	hh_HR_UR	0.000000	0.042416	0.032404	0.088110
omfd	hh_HR_UR	0.008415	0.003853	0.008392	0.210094
poul	hh_HR_UR	0.181773	0.025902	0.037377	0.085742
rice	hh_HR_UR	0.000000	0.059318	0.034578	0.005742
root	hh_HR_UR	0.000000	0.022816	0.028897	0.068533
vege	hh_HR_UR	0.000000	0.008932	0.025611	0.085408
whea	hh_HR_UR	0.000000	0.089112	0.180189	0.081944
bake	hh_MN_RU	0.000000	0.008165	0.021338	0.004325
beef	hh_MN_RU	0.436477	0.118982	0.063949	0.017581
bevt	hh_MN_RU	0.000000	0.000690	0.001710	0.000283
dair	hh_MN_RU	0.040106	0.073087	0.306791	0.202651
fish	hh_MN_RU	0.081672	0.057878	0.029267	0.056023
frui	hh_MN_RU	0.000000	0.103914	0.017986	0.028343
maiz	hh_MN_RU	0.000000	0.201813	0.108865	0.033579
meat	hh_MN_RU	0.236217	0.081835	0.049621	0.039528
ogrn	hh_MN_RU	0.000000	0.066560	0.039985	0.010657
oils	hh_MN_RU	0.000000	0.070947	0.047763	0.093811
omfd	hh_MN_RU	0.006623	0.002689	0.006560	0.195239
poul	hh_MN_RU	0.198906	0.029703	0.038474	0.090292
rice	hh_MN_RU	0.000000	0.059245	0.031008	0.006750
root	hh_MN_RU	0.000000	0.032125	0.035900	0.038907
vege	hh_MN_RU	0.000000	0.010270	0.025365	0.093574
whea	hh_MN_RU	0.000000	0.082099	0.175417	0.088457
bake	hh_MN_UR	0.000000	0.014742	0.081018	0.005135
beef	hh_MN_UR	0.311865	0.076141	0.040618	0.010661
bevt	hh_MN_UR	0.000000	0.001201	0.002551	0.001112
dair	hh_MN_UR	0.051243	0.073144	0.303555	0.187751

fish	hh_MN_UR	0.115645	0.064438	0.034442	0.076033
frui	hh_MN_UR	0.000000	0.196483	0.015623	0.031877
maiz	hh_MN_UR	0.000000	0.182238	0.106094	0.054235
meat	hh_MN_UR	0.300036	0.085874	0.051566	0.083671
ogrn	hh_MN_UR	0.000000	0.046195	0.040484	0.015646
oils	hh_MN_UR	0.000000	0.056756	0.037651	0.073530
omfd	hh_MN_UR	0.006022	0.002505	0.005591	0.151965
poul	hh_MN_UR	0.215189	0.028780	0.037002	0.082901
rice	hh_MN_UR	0.000000	0.059923	0.031175	0.006291
root	hh_MN_UR	0.000000	0.028384	0.031201	0.044450
vege	hh_MN_UR	0.000000	0.012283	0.023614	0.098453
whea	hh_MN_UR	0.000000	0.070913	0.157815	0.076290
bake	hh_MO_Q1	0.000000	0.010541	0.015619	0.000746
bevt	hh_MO_Q1	0.000000	0.001350	0.002078	0.003307
dair	hh_MO_Q1	0.044298	0.038709	0.204884	0.213628
fish	hh_MO_Q1	0.244478	0.129182	0.058335	0.127060
frui	hh_MO_Q1	0.000000	0.077851	0.038602	0.036538
maiz	hh_MO_Q1	0.000000	0.301511	0.207398	0.111018
meat	hh_MO_Q1	0.547856	0.090382	0.059107	0.024514
ogrn	hh_MO_Q1	0.000000	0.034594	0.047400	0.039047
oils	hh_MO_Q1	0.000000	0.055715	0.048063	0.046948
omfd	hh_MO_Q1	0.003763	0.005017	0.003498	0.005640
poul	hh_MO_Q1	0.159605	0.014424	0.022734	0.080485
rice	hh_MO_Q1	0.000000	0.088626	0.056587	0.025563
root	hh_MO_Q1	0.000000	0.012161	0.017033	0.074318
vege	hh_MO_Q1	0.000000	0.007481	0.023740	0.107509
whea	hh_MO_Q1	0.000000	0.132456	0.194922	0.103678
bake	hh_MO_Q2	0.000000	0.013503	0.011981	0.001571
beef	hh_MO_Q2	0.345435	0.078525	0.054441	0.015967
bevt	hh_MO_Q2	0.000000	0.001179	0.002172	0.001286
dair	hh_MO_Q2	0.029133	0.035487	0.201849	0.131300
fish	hh_MO_Q2	0.120407	0.073331	0.042787	0.090282
frui	hh_MO_Q2	0.000000	0.140043	0.030298	0.031401
maiz	hh_MO_Q2	0.000000	0.247598	0.182426	0.071240
meat	hh_MO_Q2	0.398789	0.091309	0.065136	0.062145
ogrn	hh_MO_Q2	0.000000	0.053711	0.062180	0.026707
oils	hh_MO_Q2	0.000000	0.044980	0.039014	0.052586
omfd	hh_MO_Q2	0.006535	0.004221	0.010381	0.253956
poul	hh_MO_Q2	0.099702	0.012416	0.020745	0.051938
rice	hh_MO_Q2	0.000000	0.079901	0.054084	0.012947
root	hh_MO_Q2	0.000000	0.010492	0.014034	0.044860
vege	hh_MO_Q2	0.000000	0.006565	0.021316	0.073518
whea	hh_MO_Q2	0.000000	0.106741	0.187154	0.078299
bake	hh_MO_Q3	0.000000	0.015590	0.102246	0.003357
beef	hh_MO_Q3	0.421890	0.122917	0.078954	0.019685
bevt	hh_MO_Q3	0.000000	0.001488	0.002049	0.001374
dair	hh_MO_Q3	0.025281	0.036363	0.190582	0.107004
fish	hh_MO_Q3	0.093464	0.073540	0.043649	0.076133
frui	hh_MO_Q3	0.000000	0.161710	0.028069	0.027915
maiz	hh_MO_Q3	0.000000	0.200343	0.133832	0.037583
meat	hh_MO_Q3	0.326303	0.098429	0.065602	0.052391

ogrn	hh_MO_Q3	0.000000	0.056883	0.054208	0.017419
oils	hh_MO_Q3	0.000000	0.037576	0.031953	0.057571
omfd	hh_MO_Q3	0.009976	0.005987	0.019545	0.369048
poul	hh_MO_Q3	0.123086	0.019645	0.030411	0.064724
rice	hh_MO_Q3	0.000000	0.066631	0.041787	0.006309
root	hh_MO_Q3	0.000000	0.014580	0.019542	0.050359
vege	hh_MO_Q3	0.000000	0.006940	0.021752	0.060389
whea	hh_MO_Q3	0.000000	0.081379	0.135819	0.048740
bake	hh_MO_Q4	0.000000	0.013149	0.012316	0.003266
beef	hh_MO_Q4	0.373377	0.107493	0.069105	0.016252
bevt	hh_MO_Q4	0.000000	0.001701	0.003112	0.002838
dair	hh_MO_Q4	0.027849	0.034620	0.181198	0.096138
fish	hh_MO_Q4	0.092557	0.074182	0.042321	0.067600
frui	hh_MO_Q4	0.000000	0.148269	0.025962	0.025233
maiz	hh_MO_Q4	0.000000	0.199316	0.137997	0.051609
meat	hh_MO_Q4	0.413167	0.123164	0.083160	0.076459
ogrn	hh_MO_Q4	0.000000	0.056146	0.100865	0.037894
oils	hh_MO_Q4	0.000000	0.034043	0.028444	0.050075
omfd	hh_MO_Q4	0.013958	0.006652	0.020128	0.359285
poul	hh_MO_Q4	0.079092	0.012474	0.019326	0.038797
rice	hh_MO_Q4	0.000000	0.077967	0.048937	0.004335
root	hh_MO_Q4	0.000000	0.012822	0.017120	0.026222
vege	hh_MO_Q4	0.000000	0.007197	0.022075	0.071583
whea	hh_MO_Q4	0.000000	0.090806	0.187933	0.072414
bake	hh_MO_Q5	0.000000	0.016195	0.029378	0.004227
beef	hh_MO_Q5	0.408029	0.117282	0.071588	0.019208
bevt	hh_MO_Q5	0.000000	0.001904	0.005737	0.003408
dair	hh_MO_Q5	0.028419	0.039326	0.196049	0.136031
fish	hh_MO_Q5	0.052449	0.028875	0.025670	0.059708
frui	hh_MO_Q5	0.000000	0.215386	0.032918	0.027953
maiz	hh_MO_Q5	0.000000	0.198178	0.133367	0.066793
meat	hh_MO_Q5	0.363109	0.105453	0.073054	0.162511
ogrn	hh_MO_Q5	0.000000	0.030681	0.074516	0.015903
oils	hh_MO_Q5	0.000000	0.037196	0.029333	0.045233
omfd	hh_MO_Q5	0.004938	0.004855	0.009290	0.175306
poul	hh_MO_Q5	0.143057	0.022525	0.033136	0.075896
rice	hh_MO_Q5	0.000000	0.087386	0.052077	0.004139
root	hh_MO_Q5	0.000000	0.014912	0.018908	0.040687
vege	hh_MO_Q5	0.000000	0.006906	0.019371	0.065455
whea	hh_MO_Q5	0.000000	0.072939	0.195608	0.097542
bake	hh_MS_RU	0.000000	0.006831	0.011386	0.003361
beef	hh_MS_RU	0.463647	0.111918	0.068589	0.023620
bevt	hh_MS_RU	0.000000	0.000644	0.001819	0.000520
dair	hh_MS_RU	0.030723	0.055346	0.267329	0.226698
fish	hh_MS_RU	0.113040	0.081307	0.032074	0.065752
frui	hh_MS_RU	0.000000	0.111486	0.016475	0.046386
maiz	hh_MS_RU	0.000000	0.231662	0.140409	0.049466
meat	hh_MS_RU	0.216090	0.063338	0.041941	0.016531
ogrn	hh_MS_RU	0.000000	0.085746	0.053075	0.014139
oils	hh_MS_RU	0.000000	0.079666	0.055230	0.109435
omfd	hh_MS_RU	0.001923	0.001761	0.001896	0.046835

poul	hh_MS_RU	0.174577	0.023085	0.034096	0.100229
rice	hh_MS_RU	0.000000	0.049965	0.029810	0.010546
root	hh_MS_RU	0.000000	0.019933	0.025828	0.071120
vege	hh_MS_RU	0.000000	0.007556	0.023763	0.086297
whea	hh_MS_RU	0.000000	0.069755	0.196278	0.129067
bake	hh_MS_UR	0.000000	0.014838	0.093051	0.006873
beef	hh_MS_UR	0.467787	0.129969	0.079176	0.024098
bevt	hh_MS_UR	0.000000	0.001211	0.002880	0.001324
dair	hh_MS_UR	0.030133	0.052626	0.252278	0.174220
fish	hh_MS_UR	0.091026	0.070979	0.031828	0.064523
frui	hh_MS_UR	0.000000	0.175279	0.015038	0.036806
maiz	hh_MS_UR	0.000000	0.190289	0.120717	0.052042
meat	hh_MS_UR	0.263470	0.079260	0.051777	0.069767
ogrn	hh_MS_UR	0.000000	0.043728	0.047079	0.013437
oils	hh_MS_UR	0.000000	0.051983	0.037336	0.077680
omfd	hh_MS_UR	0.004617	0.002651	0.006023	0.172010
poul	hh_MS_UR	0.142968	0.021760	0.031947	0.083003
rice	hh_MS_UR	0.000000	0.063353	0.037671	0.007268
root	hh_MS_UR	0.000000	0.014814	0.018464	0.044817
vege	hh_MS_UR	0.000000	0.006992	0.019391	0.093255
whea	hh_MS_UR	0.000000	0.080268	0.155344	0.078876
bake	hh_NA_Q1	0.000000	0.017236	0.029348	0.012920
bevt	hh_NA_Q1	0.000000	0.001360	0.002570	0.001255
dair	hh_NA_Q1	0.060106	0.054455	0.250465	0.109106
fish	hh_NA_Q1	0.217602	0.094375	0.034268	0.051346
frui	hh_NA_Q1	0.000000	0.134646	0.014587	0.018316
maiz	hh_NA_Q1	0.000000	0.278038	0.175234	0.057994
meat	hh_NA_Q1	0.544452	0.092086	0.055466	0.021248
ogrn	hh_NA_Q1	0.000000	0.042689	0.034057	0.008680
oils	hh_NA_Q1	0.000000	0.027228	0.020976	0.110269
omfd	hh_NA_Q1	0.024147	0.004999	0.016191	0.349929
poul	hh_NA_Q1	0.153692	0.013889	0.019512	0.032297
rice	hh_NA_Q1	0.000000	0.077898	0.044237	0.002528
root	hh_NA_Q1	0.000000	0.019915	0.024955	0.059652
vege	hh_NA_Q1	0.000000	0.011347	0.030796	0.085460
whea	hh_NA_Q1	0.000000	0.129840	0.247339	0.078999
bake	hh_NA_Q2	0.000000	0.019480	0.031079	0.010966
beef	hh_NA_Q2	0.478761	0.138834	0.089183	0.016612
bevt	hh_NA_Q2	0.000000	0.001259	0.003428	0.000523
dair	hh_NA_Q2	0.030175	0.046631	0.239970	0.103123
fish	hh_NA_Q2	0.139964	0.105067	0.039242	0.057031
frui	hh_NA_Q2	0.000000	0.101401	0.016328	0.012388
maiz	hh_NA_Q2	0.000000	0.226872	0.159072	0.054062
meat	hh_NA_Q2	0.239943	0.073174	0.054678	0.116334
ogrn	hh_NA_Q2	0.000000	0.028038	0.034731	0.009329
oils	hh_NA_Q2	0.000000	0.028152	0.022856	0.074883
omfd	hh_NA_Q2	0.012600	0.005346	0.016028	0.302433
poul	hh_NA_Q2	0.098558	0.015656	0.024238	0.038541
rice	hh_NA_Q2	0.000000	0.070042	0.043928	0.004554
root	hh_NA_Q2	0.000000	0.022110	0.028501	0.066035
vege	hh_NA_Q2	0.000000	0.011398	0.034073	0.092120

whea	hh_NA_Q2	0.000000	0.106539	0.162665	0.041067
bake	hh_NA_Q3	0.000000	0.018485	0.036888	0.007457
beef	hh_NA_Q3	0.434153	0.138789	0.088164	0.015355
bevt	hh_NA_Q3	0.000000	0.001493	0.003462	0.001408
dair	hh_NA_Q3	0.029466	0.046436	0.236214	0.094991
fish	hh_NA_Q3	0.117131	0.098061	0.038050	0.051752
frui	hh_NA_Q3	0.000000	0.159314	0.014366	0.012846
maiz	hh_NA_Q3	0.000000	0.200294	0.142054	0.050630
meat	hh_NA_Q3	0.278866	0.092616	0.063804	0.067113
ogrn	hh_NA_Q3	0.000000	0.021551	0.038411	0.010058
oils	hh_NA_Q3	0.000000	0.022079	0.017591	0.063777
omfd	hh_NA_Q3	0.014804	0.006173	0.022568	0.412658
poul	hh_NA_Q3	0.125580	0.021992	0.033668	0.050056
rice	hh_NA_Q3	0.000000	0.067611	0.041304	0.001054
root	hh_NA_Q3	0.000000	0.020783	0.026292	0.036412
vege	hh_NA_Q3	0.000000	0.010410	0.029534	0.074140
whea	hh_NA_Q3	0.000000	0.073913	0.167631	0.050294
bake	hh_NA_Q4	0.000000	0.020516	0.224863	0.013535
beef	hh_NA_Q4	0.325625	0.086429	0.042364	0.011380
bevt	hh_NA_Q4	0.000000	0.001571	0.002068	0.001627
dair	hh_NA_Q4	0.036692	0.043307	0.170751	0.112655
fish	hh_NA_Q4	0.133697	0.080268	0.026233	0.069453
frui	hh_NA_Q4	0.000000	0.157342	0.013928	0.017452
maiz	hh_NA_Q4	0.000000	0.229035	0.129201	0.082081
meat	hh_NA_Q4	0.361745	0.106018	0.055964	0.046200
ogrn	hh_NA_Q4	0.000000	0.023542	0.038511	0.012304
oils	hh_NA_Q4	0.000000	0.027773	0.016648	0.071007
omfd	hh_NA_Q4	0.008539	0.004056	0.010702	0.226208
poul	hh_NA_Q4	0.133702	0.019440	0.022965	0.052660
rice	hh_NA_Q4	0.000000	0.085256	0.039685	0.001050
root	hh_NA_Q4	0.000000	0.030122	0.028953	0.105354
vege	hh_NA_Q4	0.000000	0.010603	0.022796	0.099534
whea	hh_NA_Q4	0.000000	0.074721	0.154366	0.077499
bake	hh_NA_Q5	0.000000	0.019737	0.212997	0.006908
beef	hh_NA_Q5	0.391118	0.116226	0.055737	0.012037
bevt	hh_NA_Q5	0.000000	0.001923	0.004783	0.002631
dair	hh_NA_Q5	0.034029	0.047427	0.185907	0.101572
fish	hh_NA_Q5	0.092176	0.044315	0.013196	0.046030
frui	hh_NA_Q5	0.000000	0.174905	0.015114	0.017568
maiz	hh_NA_Q5	0.000000	0.211428	0.117671	0.064288
meat	hh_NA_Q5	0.323214	0.109450	0.067689	0.241007
ogrn	hh_NA_Q5	0.000000	0.024838	0.052396	0.007763
oils	hh_NA_Q5	0.000000	0.027993	0.015323	0.048366
omfd	hh_NA_Q5	0.008411	0.004493	0.010822	0.206809
poul	hh_NA_Q5	0.151053	0.024590	0.028419	0.052391
rice	hh_NA_Q5	0.000000	0.090287	0.041903	0.000230
root	hh_NA_Q5	0.000000	0.022600	0.022080	0.046770
vege	hh_NA_Q5	0.000000	0.012627	0.024799	0.093463
whea	hh_NA_Q5	0.000000	0.067160	0.131162	0.052167

Table A2. Responsiveness of labor productivity to changes in micronutrients intake, by household (from Ramos et al., 2022). New worksheet "micronutelas" located in experiment_Kenya.xlsx.

	Fe	Zinc	VitB2	VitA
all HH in the Kenya SAM	0.0735	0.00313	0.0465	0.00004