Impacts of an increase in irrigated agricultural land on the Kenyan economy

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Executive summary

- The National Irrigation Service Strategy 2022-2026 (NISS) foresees to increase the irrigated agricultural area by 200,000 ha by 2026.
- We analyze the economy-wide implications of this expansion of irrigated cropland including the investments required.
- We find that the expansion of irrigated cropland has positive multiplier effects throughout the Kenyan economy, results in economic growth and can achieve a pro-poor distribution of welfare effects.
- The distribution of the land property and use-rights under the newly developed irrigation schemes is crucial from a welfare perspective.

Impacts d'une augmentation des terres agricoles irriguées sur l'économie du Kenya

Résumé

- La Stratégie Nationale des Services d'Irrigation 2022-2026 (NISS) prévoit d'augmenter la superficie agricole irriguée de 200 000 ha d'ici 2026.
- Nous avons analysé les implications économiques de cette expansion des terres agricoles irriguées, y compris les investissements nécessaires.
- Nous avons constaté que l'expansion des terres agricoles irriguées a des effets multiplicateurs positifs sur l'ensemble de l'économie kenyane, qu'elle entraîne une croissance économique et qu'elle peut aboutir à une répartition des effets sur le bien-être en faveur des pauvres.
- La répartition de la propriété foncière et des droits d'utilisation dans le cadre des nouveaux programmes d'irrigation est cruciale du point de vue de la distribution du bien-être.

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1. Background

- Irrigated land has a higher productivity compared to rainfed land due to a) higher yields and b) potentially multiple harvests (depending on crop type).
- By 2020, 216,000 ha (2.2% of the total cropland in Kenya) was developed for irrigation.
- Through the National Irrigation Service Strategy 2022-2026 (NISS), the Kenyan government plans to increase the irrigated agricultural area by 200,000 ha over five years (MWSI, 2022, p.91).
- The total irrigation potential for Kenya has been estimated at 1,341,900 ha (MWSI, 2022, p. iii).
- The financing for irrigation development and management will be through public funds, development partners, public-private partnership, private sector financing and beneficiary contribution. (MWSI, 2022, p.87).
- The budget for implementing the NISS is estimated at KES 388.71 Billion over the five-year implementation period. (MWSI, 2022, p.90). It is detailed in Table 1.

Table 1: NISS estimated budget [Billion KES]

No	Strategic Area	Strategic Issue	Cost (KES Billion)
1	Irrigation potential and development	Inadequate mapping of irrigation areas	2.35
		Unexploited irrigation potential	125.6
2	Water for Irrigation	Inadequate water for irrigation	215.55
3	Management of irrigation schemes	Poor management of irrigation schemes	2.07
		Poor management of irrigated enterprises and related value chains	0.77
4	Irrigation service provision	Limited access to quality irrigation services	14.32
5	Policy, legal and institutional framework	Inadequate institutional arrangement for irrigation development	6.9
6	Capacity development	Limited capacity for irrigation development and management	8.4
7	Research, technology and innovations	Limited research and innovation to meet irrigation sector needs	6.05
		Low uptake of irrigation research	3.35
8	Information and knowledge management	Findings and innovations	1.25
9	Cross-cutting issues in irrigation development and management	Limited inclusivity in irrigation planning and development	1
		Environmental concerns and their impact on irrigation development	1.1
10	**Total**		**388.71**

Source: MWSI, 2022, p.91.

2. Methods

2.1 Database

A Social Accounting Matrix (SAM) for Kenya for the year 2019 has been designed at the International Agricultural Trade and Development Group at Humboldt-Universität zu Berlin based on Elnour et al. (2022) and extended with support from the staff of the Kenya National Bureau of Statistics.

The SAM identifies 46 activities producing 49 commodities, of which 20 are agricultural commodities. Additionally, the SAM includes eight production factors: two types of capital (agricultural and not), two land types (irrigated and not) and four labour categories. Labour is classified based on skill level (skilled and unskilled) and gender (male and female). Besides, households are categorised into four groups, depending on location (rural and urban) and income level (poor and non-poor).

With respect to irrigation, according to the SAM, eight crop types are grown on irrigated land and irrigated land has a higher productivity compared to rainfed land as it a) produces higher yields and b) allows for multiple harvests for most crops and as detailed in Table 2. Irrigated land is owned almost exclusively by private and mostly rural households (compare reference situation in Table 5).

Table 2: Per hectare land productivity ratio between rainfed and irrigated land

	Maize	Wheat	Rice	Other cereals	Roots & tubers	Pulses & oil seeds	Fruits	Veg.& Spices
Productivity ratio due to multiple harvests	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00
Productivity ratio due to yield increase	1.12	1.21	2.21	1.32	1.05	3.01	1.69	1.69
Total productivity factor of irrigated land	2.23	2.42	4.43	2.64	2.10	6.03	1.69	3.38

Source: Authors' compilation based on data produced by Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b) (Frieler et al., 2017; Müller et al., 2022).

2.2 Model and closure rules

We use the computable general equilibrium (CGE) model STAGE (McDonald and Thierfelder 2015). A CGE model combines economic theory and numerical models to establish the impact of shocks in an economy. Real economic data is used to fit a set of equations that replicate the structure of the economy. From this framework, it is possible to simulate the effect of exogenous shocks, such as policy changes, including economy-wide interactions. The following presents a summary of the CGE model used:

- Production is structured by a three-level nest of Constant Elasticity of Substitution (CES) and Leontief production functions. At the top level, aggregate value-added, and intermediate inputs are combined using a CES function. Production factors are aggregated using CES functions at different levels, whereas the intermediate input component is aggregated using a Leontief production function (the second level). Aggregate primary factors (i.e., labour and land) are combined using CES functions (the third level).
- Producers sell their products either in the local or foreign markets, based on relative prices, as determined by a Constant Elasticity of Transformation (CET) function.
- Households supply production factors to productive activities through factor markets in exchange for wages that constitute a significant portion of their incomes. After paying taxes and making savings, households spend their income on purchasing products. Households maximise their utility subject to Stone-Geary utility functions, selecting the optimal mix of commodities and services while considering purchase prices, preferences, and income constraints.

We apply flexible exchange rate regime closure. The model is saving-driven. All production factors are fully employed across all markets and fully mobile across sectors. The model numéraire for the scenarios is the CPI. The government savings are fixed, and the household tax rate is flexible. Therefore, any policy implemented in the model is financed through income tax on households.

We assume a very high substitutability between rainfed and irrigated land for those crops which are grown on both land types. Due to the higher yields and potentially multiple harvests, the productivity of irrigated land is assumed to be much higher compared to rainfed land as detailed in Section 3.2.

2.3 Scenarios

We run three scenarios differentiated according to the time-horizon considered. Results are compared to the reference situation, representing the Kenyan economy of 2019 as depicted in the SAM.

- **Short-run scenario (Invest):** This scenario represents the phase of developing the additional irrigation schemes. In accordance with the NISS (MWSI, 2022), it is assumed that the investment period is 5 years. Further it is assumed that the total costs (Table 1) are distributed equally over the years. The benefits from the additional irrigated area are assumed to only materialize after this period.

  In this simulation, the full costs are borne by the government, which finances the additional expenditure through a uniform, multiplicative increase of the household income tax rates. This way, this scenario allows to capture and single out the economic effects of the investments required for expanding the irrigation capacity as indicated in the NISS (MWSI, 2022).

  The total investment costs are annualized and distributed to the single model-activities as follows: Construction 68.2 BN KES, Public administration 5.5 BN KES, Education 3.8 BN KES and Social work 0.2 BN KES.

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- **Medium-run scenario (IrrigMed):** This scenario shows the effects resulting from the additional irrigated cropland on the Kenyan economy, under the following assumptions.
  - The additional land is sourced from previously used rainfed land.
  - The ownership of the newly irrigated land is distributed among private households only and according to their shares of irrigated landownership in the base situation (Figure 1).
  - The expenditure for the additional water required when expanding irrigated crop production is captured by adjusting the intermediate input consumption of the respective cropping activities, increasing the share of water expenditure in total intermediate consumption at the same rate as the increase in irrigated land. This reflects the assumption that the farmers benefitting from the irrigated land will be in charge of maintaining the irrigation scheme once it is established.
- **Long-run scenario (IrrigLong):** As a potential assessment, we additionally run a long run scenario going beyond the current planning horizon in which the irrigated area is expanded to 1,116,720 ha (80% of the total irrigation potential).

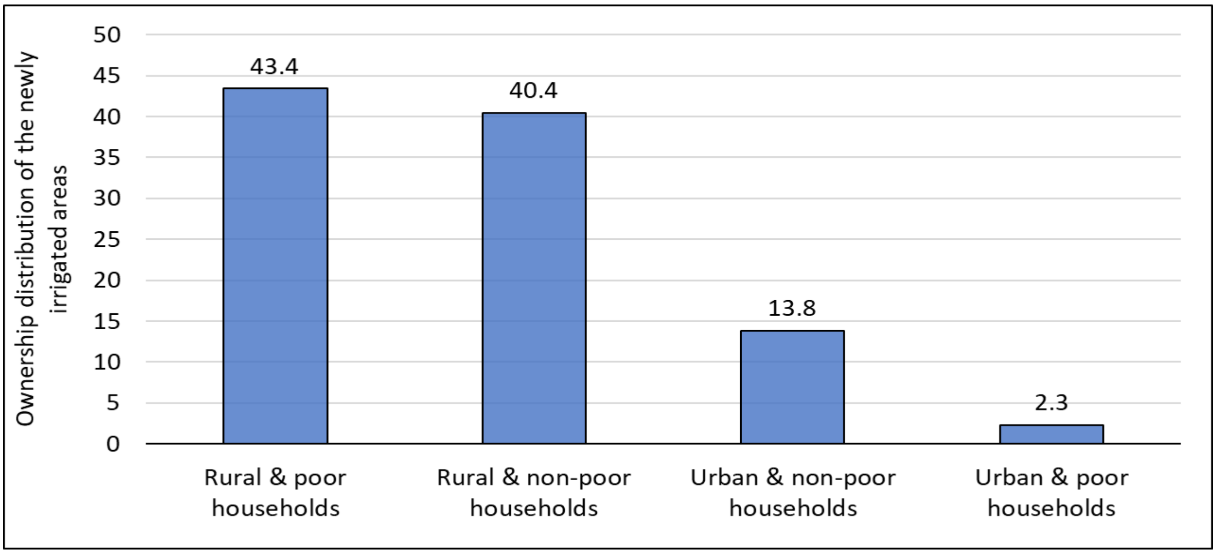

Figure 1: Ownership distribution of the newly irrigated areas

Source: Authors' calculations based on Elnour et al., 2022.

Land availability and ownership

While the irrigated land supply in the medium and long run scenarios strongly increases, this means that only 2% and 9% of the originally rainfed land are converted, respectively (Table 3), due to the small share of irrigated land in the reference situation (2%).

Table 3: Percentage change in land availability

Land type	Invest	IrrigMed	IrrigLong
Irrigated	0.0	92.6	417.0
Rainfed	0.0	-2.1	-9.3

Source: Authors' calculations.

Under the assumption that all the newly developed land will be owned by private households according to their original land-ownership shares, this would mean that all households in the medium run would own 93% more irrigated land than in the reference situation and even 5 times as much in the long-run (compare Table 4Table 4).

Table 4: Distribution of irrigated land ownership [ha]

		Reference	IrrigMed	IrrigLong
Irrigated land	Rural & poor households	93,789	180,675	485,087
	Rural & non-poor households	87,153	167,891	450,763
	Urban & poor households	5,065	9,758	26,199
	Urban & non-poor households	29,884	57,568	154,562
	Enterprises	109	109	109
	TOTAL	**216,000**	**416,000**	**1,116,720**
Rainfed land	Rural & poor households	4,174,520	4,087,630	3,783,220
	Rural & non-poor households	3,879,810	3,799,080	3,516,200
	Urban & poor households	236,032	231,339	214,898
	Urban & non-poor households	1,372,340	1,344,660	1,247,670
	Enterprises	3,357	3,357	3,357
	TOTAL	**9,666,070**	**9,466,070**	**8,765,350**

Source: Authors' calculations.

3. Results

3.1 Factor prices

In the short-run, during the construction of the irrigation schemes (Invest-scenario), factor prices remain largely constant. The labour wages increase slightly (Figure 2). This is caused by the expansion of those sectors which experience an increased demand due to the irrigation investment (construction and service sectors) and which are relatively labour intensive. As the construction sector employs more male labour, male wages increase slightly more than female wages.

In the medium run, all labour wages and agricultural capital rents slightly increase due to the expansion of crop production, which benefits female labour slightly more. Rents of non-agricultural capital are positively affected by positive multiplier effects due to the general expansion of the economy. With the expansion of highly productive cropland, land rents decrease especially for irrigated land but also for rainfed land, due to the assumed high substitutability between land types.

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In the long-run the effects of the medium term are similar in direction but amplified, due to the much larger increase in irrigated land.

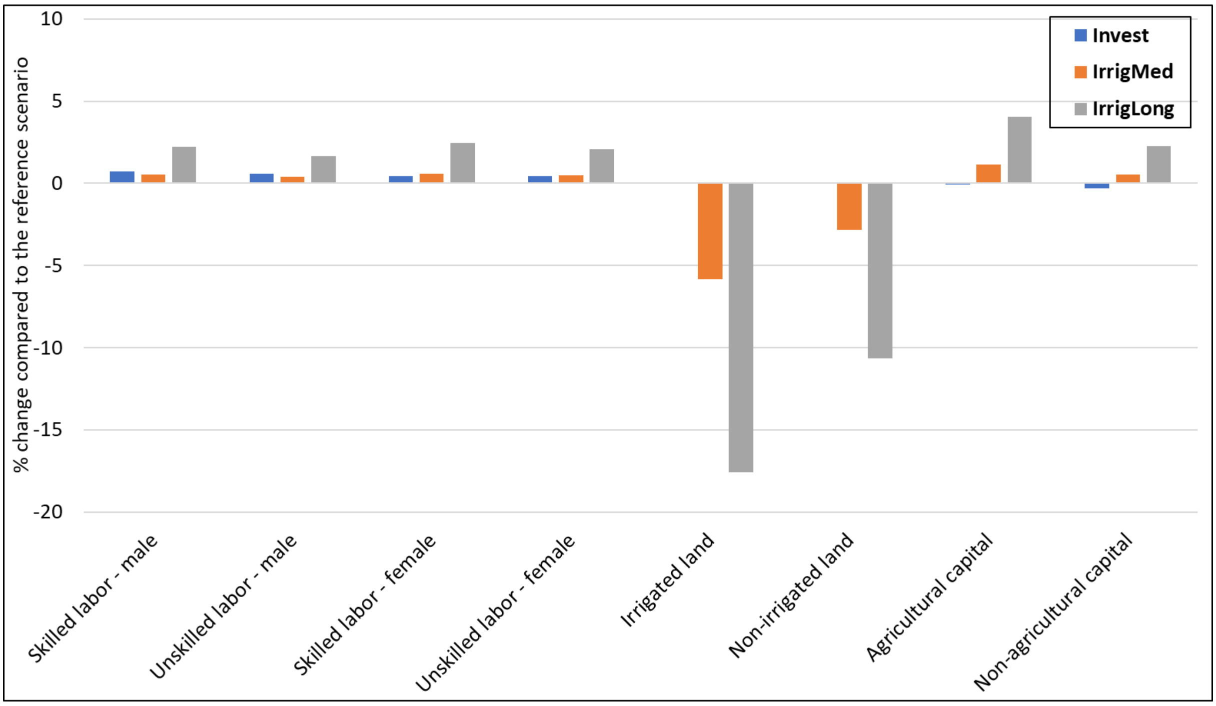

Figure 2: Effects on factor prices, % change compared to the reference scenario

Source: Authors' calculations based on simulation results.

3.2 Domestic production

In the construction period (Invest), due to the increased demand for construction by the government, especially this sector expands (Figure 3:). As construction consumes 96% of the forestry and 79% of the mining sectors outputs, these sectors grow accordingly. Due to the competition for production factors and the declining demand from non-poor households (see section 4.4) especially private services are contracting.

With the establishment of the irrigation schemes (IrrigMed), especially the production of tea expands, although tea is not grown on irrigated cropland. Instead, this activity profits more indirectly from a) the drop in the price of rainfed land (see section 4.1) and b) from a stable producer price, being not much affected by declining domestic prices with expansion of supply. This is because of the high export share of tea. 65% of its total production are exported, which is the highest export share of all activities in the Kenyan economy. This allows this sector to expand production while producer prices drop relatively little. The general expansion of crop production also results in positive multiplier effects in upstream (food processing) and downstream (water) activities. With increasing household income (section 4.3), also the demand for and hence provision of services is slightly increasing.

Long-run impacts are similar in terms of direction as the medium run effects (IrrigMed), yet at a much higher magnitude. For representational reasons, they are not depicted in Figure 3.

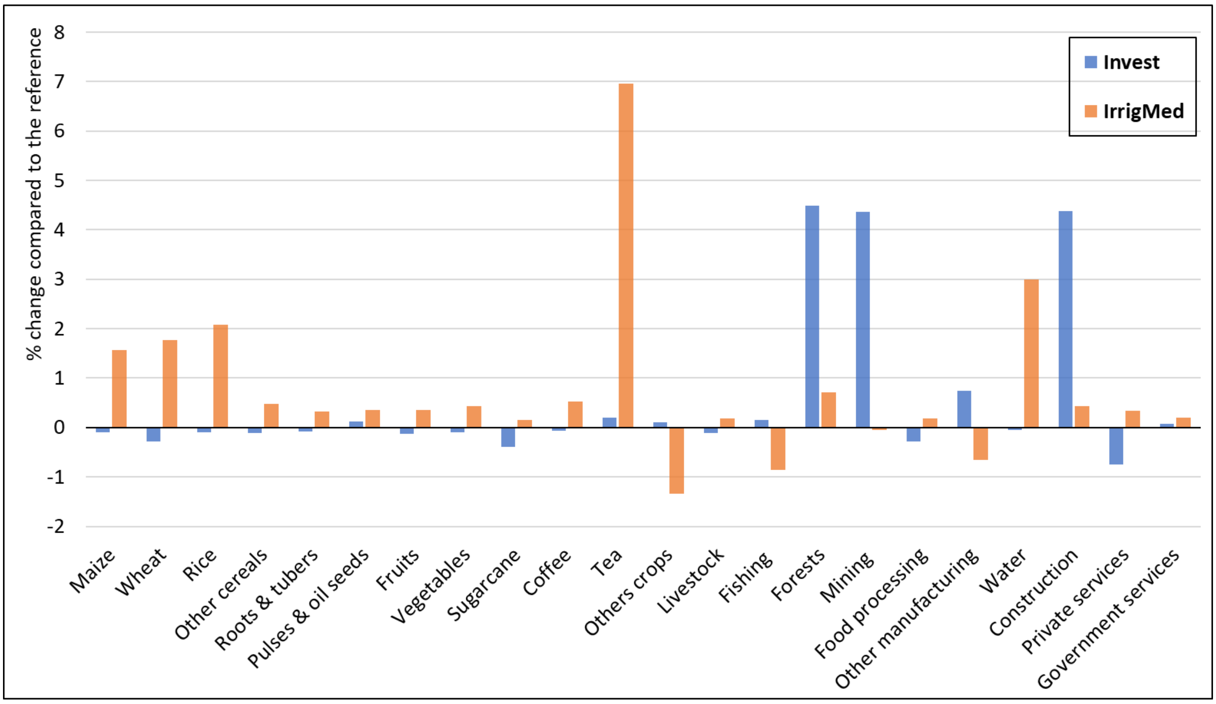

Figure 3: Effects on quantities of domestic production, % change compared to the reference scenario, partially aggregated sectors

Source: Authors' calculations based on simulation results.

3.3 Household welfare

As the required irrigation investments are financed through an income tax increase, levied equiproportionally on all households, tax rates during the investment period need to be increased by about 20%, which translates to a maximum increase of 1.4 percentage points for urban non-poor households, who face the highest tax rate in the reference situation (Table 5). Once the irrigation schemes are established (IrrigMed/Long), the taxes can be reduced to reference rates again (even a bit more, as due to the growing economy, the government has higher income from other sources).

Table 5: Income tax rates [%]

	Reference	Invest	IrrigMed	IrrigLong
Rural & poor households	0.8%	0.9%	0.8%	0.8%
Rural & non-poor households	3.0%	3.6%	3.0%	3.0%
Urban & poor households	0.5%	0.6%	0.5%	0.5%
Urban & non-poor households	7.3%	8.7%	7.2%	7.1%

Source: Authors' calculations based on simulation results.

As can be seen in Figure 4, during the construction period especially urban non-poor households experience welfare losses. This is because they contribute most to the financing of the irrigation investment. For urban poor households, skilled labour has a higher share in total income than for other household groups. Due to the low average tax rate (or low tax base) of this household group, the benefits from higher wages (compare Section 4.1) outweigh the losses of net-income due to the tax increase.

With the irrigation-expansion established (IrrigMed), all households benefit. Rural poor households experience the highest welfare gains, followed by urban poor households. This effect is enhanced with a larger irrigation expansion (IrrigLong). The positive effects are mainly driven by increasing household income, which in turn is caused by higher factor income from the additional irrigated land (which in relative terms contributes most to household income of rural households) and the fall in crop prices, benefitting mainly poor households with a high food expenditure share.

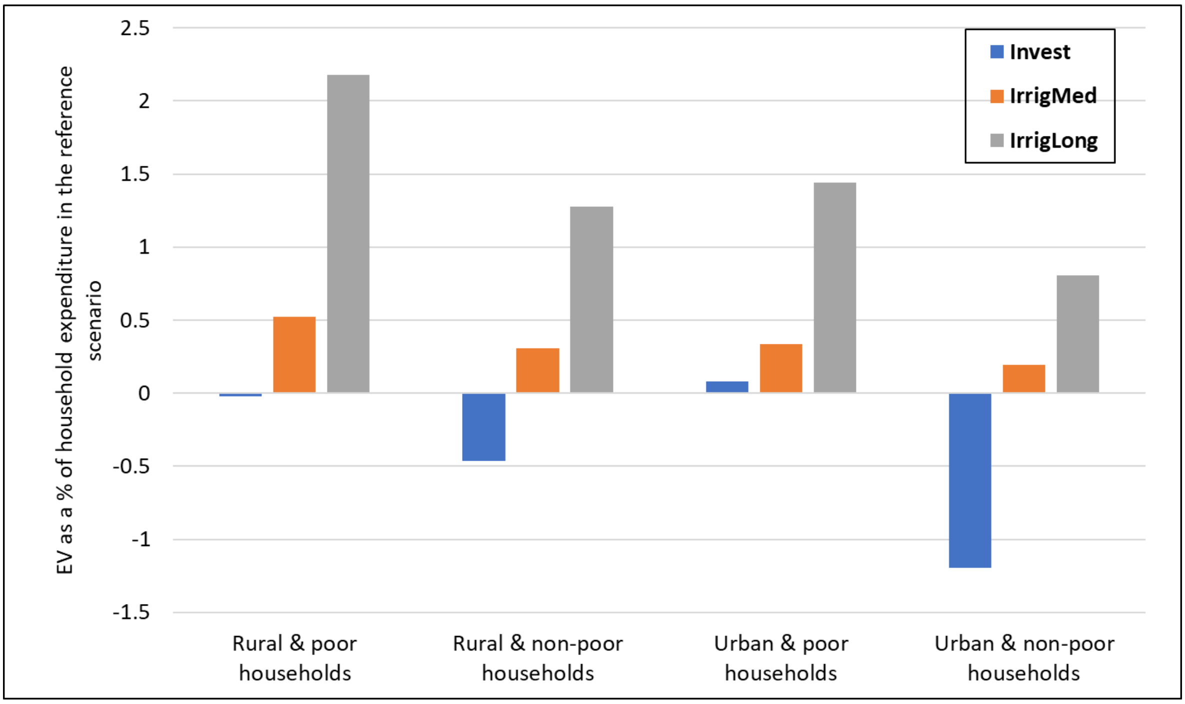

Figure 4: Effects on household welfare, Equivalent Variation (EV) as a share of household expenditure in the reference scenario[1]

Source: Authors' calculations based on simulation results.

3.4 Macroeconomic effects

In the investment period government consumption demand is increasing caused by the additional outlays for building the irrigation schemes. As these expenses are financed through increasing income taxes on households, household consumption and savings drop accordingly, causing total investment to drop as well (Figure 5).

After the establishment of the irrigation schemes, with government demand falling back to the reference situation, household demand is increasing, due to the raised household income and reduced consumer prices of crops. Also, exports expand, mainly driven by the increased exports of tea, allowing to finance more imports, mainly petrol, chemicals and manufactured goods.

[1] Equivalent variation (EV) refers to a change in income that would have an equivalent effect on utility as all price and income changes combined.

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Altogether, this leads to a positive impact on gross domestic product, increasing by about 0.4% (about 32 Billion KES) in the medium term (IrrigMed) and even by 1.6% with the further expansion of irrigated cropland to 80% of the potential, in the longer run (IrrigLong).

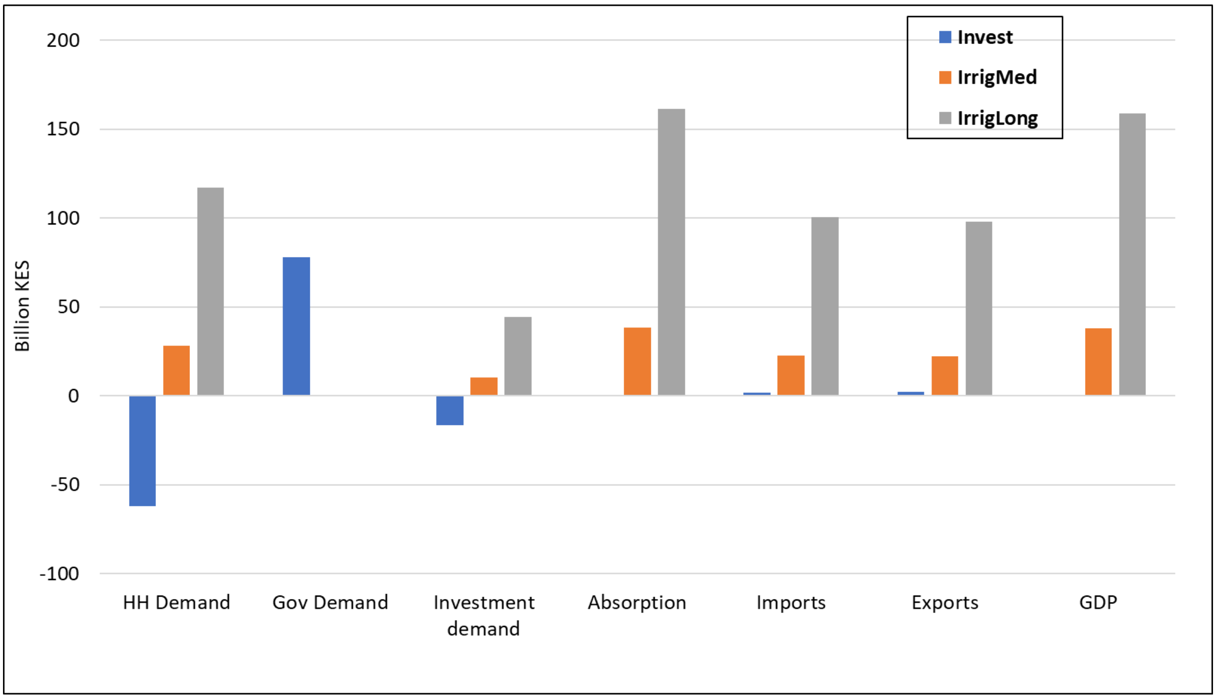

Figure 5: Change in macroeconomic indicators compared to the reference situation in Billion KES

Source: Authors' calculations based on simulation results.

4. Conclusions

This analysis shows that the expansion of irrigated agriculture in Kenya has positive impacts on the economy and on the welfare of households once the additional irrigation schemes are established.

The financing of the irrigation schemes in this analysis is to 100% sourced from domestic households. As shown, this results in losses of household welfare during the investment period, especially to those households which contribute most to the funding (in this analysis, with an equiproportional increase in direct tax rates, these are the urban non-poor households).

It is shown that the expansion of irrigated agriculture can result in a pro-poor distribution of welfare gains, however, a crucial factor for the distribution of welfare gains is the allocation of the additional irrigated land among private households and other institutions.

The benefits of developing additional irrigation schemes do not only stem from the expansion of irrigated agriculture, but also from rainfed agriculture, benefiting indirectly from the increased availability of highly productive irrigated land. Also, multiplier effects in downstream and upstream sectors as well as an increased household demand for services and other commodities contribute to the overall positive economic effects. A sectoral analysis would miss these implications.

With respect to gender, women may benefit slightly more than men, as more women are employed in crop production (especially in tea harvesting), where the demand for labour and hence wages increase. However, more crucial in this respect will be how the ownership of the newly irrigated land is to be distributed among sexes.

Potential adverse environmental implications of increasing the agricultural area, e.g. on water resources are not considered in this study. If, different from what is anticipated, larger areas of savanna-land are converted into irrigated crop land, negative implications in terms of carbon release, biodiversity loss and ecosystem services would need to be studied in more detail. In fact, it has been estimated that up to 248 tons of CO2 are emitted from turning one hectare of African savanna-land into crop land (West et al., 2010; Searchinger et al., 2015). Yet, authors also found that turning sparsely vegetated areas into irrigated croplands could also result in more carbon storage (West et al, 2010).

5. Policy implications

First of all, developing irrigation schemes seems a useful government investment for pro-poor rural development. That being said, the government can strengthen pro-poor effects by putting in place mechanisms to let poor households having overproportionally access to the newly irrigated land. Before the implementation of new irrigation schemes thorough analyses on the environmental effects should be carried out and potential negative externalities should be considered in the design of the implementation of irrigation schemes.

Raising some of the funds needed for financing the irrigation schemes from international organizations/donors and the private sector (enterprises), as foreseen in the NISS (MWSI, 2022), would reduce the negative impacts on household welfare in the construction period. The invest-scenario thus can be interpreted as an upper limit of the negative effects due to the need for raising funds for the irrigation expansion. In order to build more irrigation schemes as simulated in the IrrigMed-Scenario, the investment period would need to be prolonged.

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