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Cost Effective Options for Inclusive Agrifood System Development in Tajikistan

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ABSTRACT

This paper presents a model-based and data-driven analysis of alternative public investment options for Tajikistan's agrifood system based on cost-effectiveness in achieving multiple development outcomes. The study indicates that there is no single intervention that is the most cost-effective across all economic and social outcomes, including agrifood GDP growth, job creation, poverty reduction, lowered undernourishment, and improvement in diet quality. Irrigation infrastructure development, R&D in husbandry, and food loss and waste reduction are the most cost-effective investments in the combined economic outcomes, including growth and jobs. In contrast, irrigation, food loss and waste reduction, and seed systems are more effective in the combined social outcomes, including poverty, undernourishment, and diet. Considering time horizons, extension services are more effective in the short run, while irrigation and R&D deliver greater impact over time. Sector variations in the magnitude of effects are also observed among investment interventions. Overall, comparisons across development outcomes, sectoral focus, and timeframes reveal important synergies and trade-offs, underscoring the need for evidence-based tools to guide effective policy and investment decisions.

Keywords: Investment priorities, agrifood system, economic impact, social impact, Tajikistan

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ACRONYMS

AFS	Agrifood system
AgEMP+	Agrifood system employment
AgGDP+	Agrifood system gross domestic product
ASSADP	Agrifood System and Sustainable Agriculture Development Program
CGE	Computable General Equilibrium
GDP	Gross domestic product
HIC	High-income countries
IFPRI	International Food Policy Research Institute
LIC	Low-income countries
LMIC	Lower-middle-income countries
ReDD	Reference Diet Deprivation Index
R&D	Research and Development
RIAPA	Rural Investment and Policy Analysis Model
SAM	Social Accounting Matrix
TAJSTAT	Agency of Statistics under President of Tajikistan
UMIC	Upper-middle-income countries
US$	US dollars
WDI	World development indicators

1. INTRODUCTION

This paper focuses on the cost-effectiveness of public investment interventions in the agrifood system. The analysis covers a broad range of interventions in the agricultural sector, such as investments in research and development (R&D), extension and advisory services, market and food systems, risk reduction and resilience, and infrastructure. The effectiveness of different investment interventions is measured by their impact on achieving economic and social development outcomes. Economic outcomes are measured by agri-food growth and job creation, while social outcomes include reducing poverty, lowering undernourishment, and improving diet deprivation. We rank investment options according to their impact on individual and combined development outcomes. The data-driven and model-based evidence of such analysis is expected to be useful for policymakers in agrifood system investment prioritization.

Tajikistan's agrifood system (AFS) remains a cornerstone of the national economy, contributing 34.7 percent of GDP, employing 58.1 percent of the labor force, and serving as a key source of livelihood for approximately three-fourths of the rural population. As such, the AFS is expected to play a continued and critical role in the country's broader economic transformation and in achieving inclusive and sustainable development.

Public policy and investment interventions play a decisive role in shaping the magnitude and sustainability of development gains (Christiansen and Martin, 2018; Pham and Riedel, 2019), while public support for the agriculture sector in Tajikistan remains limited (Shtaltovna 2013), and direct support, including to domestic seed sector through budgetary payments, is relatively insignificant (Khakimov et al. 2014b). Moreover, roughly only five percent of farmers cover or use professional extension services (Muminov 2021). In addition, high rates of interest on loans (ranging between 20 and 24 percent) to the agriculture sector by commercial banks constrain access to finance and limit the development of primary and off-farm components of AFS (Khakimov et al. 2024).

There were some recent efforts of the government to support the agricultural sector through sectoral reform and development programs, such as the State Program for Medium-Term Development (MTDP) 2021–2025 and FAO's Investment Plan for Food and Nutrition Security and Sustainable Agricultural Development (NIP) 2021–2030. The MTDP focuses on enhancing agricultural policies, increasing farmer access to inputs, and modernizing infrastructure. The NIP emphasizes sustainable development of natural resources, agrifood systems, and social inclusion (World Bank 2021a). The Agrifood System and Sustainable Agriculture Development Program (ASSADP) for 2023–2030 proposes various support measures, including infrastructure financing, capacity building, and subsidies for sustainable practices

(FAO 2023). Some studies emphasize the importance of multisectoral support to enhance agricultural productivity and resilience as a food systems approach (Kawabata et al. 2020).

However, the World Bank's recent agriculture sector public expenditure review report (World Bank 2021a) indicates that public expenditure on the sector remains relatively small at less than 1 percent of GDP. Moreover, the support of the agriculture sector relies heavily on donor financing (54 percent). While the agricultural public expenditures in Tajikistan grew significantly between 2015 and 2020, most funding came directly from donors. These expenditures are concentrated in irrigation, veterinary services, and agricultural production support, there is a notable underinvestment in R&D, which may generate longer-term impacts on productivity and climate resilience.

Irrigation accounted for nearly 45 percent of total public agricultural spending as a share of total agricultural spending, and public agriculture expenditure was extremely low, ranging from 0.04 percent on inputs distribution to 2.4 percent on advisory and extension services (2.4 percent).[1]

Increasing the level of public investment in agriculture, especially through the government's own financing, is important while improving the effectiveness of the investments through properly allocating the limited public resources is more urgent. This paper focuses on this strategic and timely issue.

The paper is organized as follows. Section 2 introduces a conceptual framework of the AFS and uses it to situate the AFS within Tajikistan's broader economic structure through a snapshot analysis of the current system. Section 3 outlines the modeling approaches used to assess the cost-effectiveness of public investments in the AFS, highlighting the integration of an economywide model with a detailed investment cost-benefit module and household welfare measurement components. Section 4 presents the core model-based analysis, focusing on the cost-effectiveness of various investment options, with results disaggregated by time horizon and agricultural subsector. Section 5 concludes by summarizing key findings and highlighting challenges for the future transformation of Tajikistan's agrifood system.

[1] See Khakimov et al. (2024) and WB study (2021) for the details.

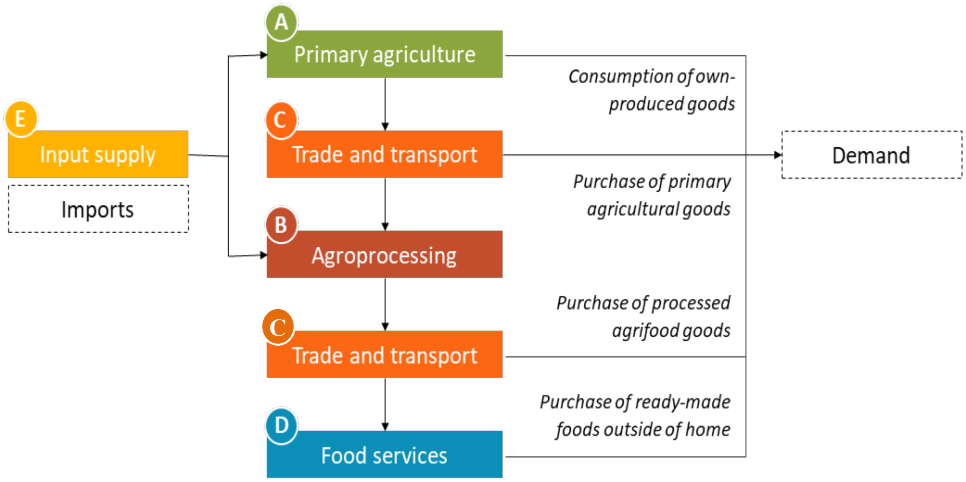
2. CONCEPTUAL FRAMEWORK AND STRUCTURE OF TAJIKISTAN'S AGRIFOOD SYSTEM

AFS involves a complex network of actors linked to each other through their roles in producing, distributing, processing, and consuming primary agricultural and agro-processing products. We measure the AFS from a supply-side perspective, leveraging on national accounts and employment statistics to directly simulate changes in growth and employment over time in investment scenarios. By disaggregating the AFS into distinct value chain groups and mapping interventions that target improving some of their bottlenecks, this approach provides valuable insights into the key drivers of AFS growth impacts in Tajikistan.

In Figure 2.1, a country's AFS is made up of five components, A to E (see Thurlow et al. 2023). *Primary agriculture* (A) comprises the supply and demand of all agricultural products, including crops, livestock, fisheries, and forestry products. *Agro-processing* (B) is part of the manufacturing sector and includes those subsectors that process agriculture-related food or non-food products. *Trade and transport services* (C) include those services associated with the transporting, wholesaling, and retailing of agrifood products between farms, firms, and final points of sale. *Food services* (D) include services such as meals prepared at restaurants, food stalls, or hotels. Finally, *input supply* (E) is the portion of domestically produced intermediate inputs (seeds, fertilizers, and financial services) used directly in agricultural and agro-processing production.

Using this conceptual framework, it is possible to measure the size and structure of a country's AFS economywide. Following the definitions of Thurlow et al. (2023), AFS GDP (or AgGDP+) is the sum of the GDP contributions of these five components (A to E), while AFS employment (or AgEMP+) is the total number of jobs across those components. As a country's economy grows and transforms over time, there will be changes in the relative contributions of the various on-farm and off-farm components of the AFS to total AgGDP+ or AgEMP+. A transforming economy, for example, will typically be characterized by more rapid growth in the off-farm activities of the AFS; hence, there will be an increased contribution by off-farm components to AgGDP+ and AgEMP+ as well as a relative decline in the contribution of primary agriculture. By disaggregating AgGDP+ and AgEMP+ into specific agricultural value chain groups, we can further assess the contribution of each individual value chain to AFS growth and transformation.

FIGURE 2.1. A SIMPLE CONCEPTUAL FRAMEWORK OF THE AGRIFOOD SYSTEM



Source: Thurlow et al. (2023).

We apply this framework to Tajikistan's data drawn primarily from the national accounts and employment information published by Tajikistan National Statistical Agency (TAJSTAT). In 2022, the AFS in Tajikistan contributes over 34.7 percent of gross domestic product (GDP) and 58.1 percent of employment. Primary agriculture alone contributed one-quarter of total GDP and 54.9 percent of employment, while the four off-farm components of the AFS contributed about 10 percent of GDP and 3.2 percent of employment. The share of employment in primary agriculture in total employment in AFS (AgEmp+) is huge, 94 percent. The current structure of Tajikistan's AFS is represented by 14 groups of value chains; two (cotton, and fruits and nuts) exportable, six internationally less-traded (pulses, roots, vegetables, cattle and dairy, poultry, and small ruminants), and six importable value chains (wheat, maize and rice, oilseeds, other crops, fish, forestry) (Diao et al., 2025).

Tajikistan faces a significant deficit in its agrifood commodity trade balance, with the value of agrifood imports more than double that of exports. Notably, 90.6 percent of agrifood imports consist of processed products, whereas 91.1 percent of agrifood exports are primary agricultural commodities. The agrifood system's import-to-consumption ratio stands at 24.7 percent—more than twice the export-to-output ratio of 11.3 percent—highlighting the underdevelopment of off-farm components within the agrifood system.

Household demand for processed agrifood products–most of which are imported–accounts for 42.7 percent of total agrifood demand, despite the associated domestic production sectors accounting for only 18.6 percent of AFS GDP (AgGDP+). The amount of processed food imports ($1.19 billion) is greater than by 17 times the amount of processed food exports ($0.07 billion), while primary agricultural products export exceeds by 1.5 times primary agricultural products – $0.53 billion versus $0.36 billion, respectively (Diao et al., 2025; Khakimov, et al. 2024). Agrifood imports also grew more rapidly, increasing by a multiple of

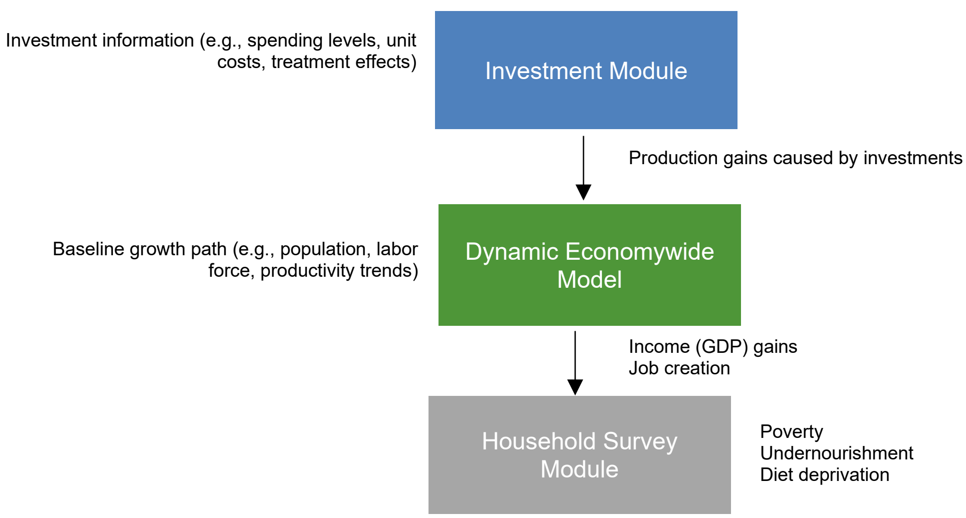
16 between 2000 and 2023, while exports only doubled over the same period (Khakimov et al. 2025a). The AFS in detail is structured in Tajikistan 2022 Social Accounting Matrix (SAM), which is the main dataset to calibrate the model used in this study. The structure of the SAM is further elaborated in section 3.2.

3. METHODS OF ANALYSIS

3.1. Modeling framework

This study adopts IFPRI's Rural Investment and Policy Analysis (RIAPA) modeling system (IFPRI 2023). The RIAPA modeling system has been widely applied to evaluate the economywide impacts of various public expenditure options across different contexts (Thurlow et al. 2007; Pauw and Thurlow 2015; Benfica et al. 2019; Aragie et al. 2024). RIAPA integrates an investment module and household survey-based microsimulation modules into an economywide CGE model uniquely and innovatively. The investment module uses disaggregated investment data and translates a country's public investment into changes in productivity across agricultural, agrifood, and other relevant non-agricultural subsectors. The microsimulation modules focus on detailed household spending and consumption patterns, linking survey-based household data to the economywide CGE model to assess poverty, undernourishment, and diet deprivation (Figure 3.1). As such, the integrated RIAPA model allows us to conduct a comprehensive evaluation of public investment impacts on Tajikistan's economic and social development outcomes.

FIGURE 3.1. AN INTEGRATED RIAPA MODEL FOR AGRIFOOD SYSTEM INVESTMENT AND OUTCOMES ANALYSIS



Source: Author's compilation

3.2. The RIAPA-CGE model

At the core of the integrated RIAPA framework is IFPRI's standard, recursive-dynamic computable general equilibrium (CGE) model. CGE models are widely utilized for economic policy formulation and analysis (Dixon and Parmenter, 1996; Devarajan and Robinson, 2010). They capture the inter-linkages between sectors, households, and rural-urban economies, making them well-suited for assessing the economywide effects of public policies.

The RIAPA-CGE model is calibrated to Tajikistan's economy using the 2022 Social Accounting Matrix (SAM). Specifically, the SAM represents the Tajikistan economy in 2022 with 69 economic production sectors and 72 commodities. Among the 69 economywide sectors, there are 22 primary agricultural sectors that directly map to component A of the AFS framework, and 14 food processing sectors (component B of the AFS). Part of the three service sectors form components C and D, while component E of the AFS relies on the data for input-output relationship in the SAM between the AFS sectors and the rest of the economy that provide intermediate inputs to the AFS sectors (see IFPRI (2024a) and Diao et al. (2025) for more detailed discussions of the SAM).

With the 2022 SAM, the RIAPA CGE model first produces a baseline that runs between 2022 and 2045, following the historical trends of economic and sectoral growth, population and labor force growth, and levels of government spending. The investment scenarios are designed and then compared against this baseline as a "business-as-usual" to assess impacts over time.

3.3. The investment module

The investment module synthesizes numerous datasets to construct a detailed empirical basis for evaluating agricultural and rural investments. Using this foundation—and combining it with information on unit costs, adoption rates, and marginal effects—the module estimates productivity gains at the subsector level, attributing them to each unit of public spending across a wide range of interventions. The version of the investment module used in this study is a newly updated framework and its previous applications in various contexts include Aragie et al. (2022); Pauw and Thurlow (2015); Benfica et al. (2019). The early version is elaborated in Aragie et al. (2024).

In the updated module, the agrifood system investments are organized into multiple layers or stages, reflecting their position within the investment system: upstream investments in knowledge generation (e.g., R&D), midstream investment for innovation dissemination (e.g., seed system), and downstream investment for on-farm adoption (e.g., the application of modern seed by farmers). The updated investment module tracks 15 individual interventions, each of which may target up to six distinct groups of agricultural subsectors.

For each of the 15 individual interventions, the investment module estimates productivity gains within the agrifood system using a structured and highly disaggregated approach. This process relies on data for investment costs—including total and unit costs—across various intervention types and technologies (e.g., R&D on drought-resistant seeds). It also incorporates adoption rates and impact coefficients (i.e., marginal effects) specific to each targeted agricultural subsector. These inputs—spending data, adoption rates, and marginal effects—yield the productivity gains that form the module's outputs (see Annex Table A2 for selected input data).

Unit costs are measured per unit of farmland or per head of livestock, while adoption rates represent the extent of technology uptake at the subsector level, expressed as a percentage of total crop area (e.g., maize) or livestock population (e.g., cattle). The resulting productivity improvements are a critical link between the investment module and the CGE model within the RIAPA framework. The CGE model then endogenously adjusts productivity in the targeted subsectors and simultaneously updates all other variables to reach a new macroeconomic equilibrium. Through both direct and indirect linkages, these investments influence not only productivity but also income, prices, employment, and other key economic indicators across the broader economy.

Data used in the investment module comes from various sources. Unit costs are usually retrieved from the country's government or development partner's investment project planning (such as irrigation master plans), evaluation documents, expert estimate, or from a broad literature review to fill the gap (see Annex Table A2 on sources of unit cost data). The baseline adoption rates and/or coverage levels are often obtained from farm or household surveys that report the number of farmers with access to certain technologies and practices or the cropland covered by those technologies and practices. Likewise, impact coefficients–which provide a measure of the change in productivity due to the adoption of a certain technology or practice–can be estimated based on survey data or can otherwise be obtained from the literature. Alternatively, crop models, which simulate how crops interact with their environment and respond to various factors, can provide usable estimates for a fair number of crops against different interventions. With these fundamental features of sector-investment combinations, the final productivity gains for each sector rely on the level of spending on each intervention. Whereas a hypothetical equal amount of spending is considered for each intervention area in this analysis for cost-benefit comparison, an actual budget allocation pattern can also be evaluated using spending data from the country's government ministries, such as the Ministry of Agriculture or the Ministry of Finance.

3.4. The household survey modules

Through the integration of the investment module with the CGE model in the RIAPA framework, economic outcome indicators—such as changes in economic growth and job creation—are directly generated. Assessing changes in social outcome indicators requires detailed information at the household level, necessitating survey-based microsimulation modules. To this end, the RIAPA-CGE model is linked top-down with household survey-based microsimulation modules to measure changes in poverty, the prevalence of undernourishment, and diet deprivation. All households in the microsimulation modules are individually linked to their corresponding income groups of households in the RIAPA-CGE model. Changes in incomes for different household groups in the CGE model influence household-level consumption patterns and calorie intake across various food items, reflecting differences in income levels and preferences. These shifts translate into measurable changes in social outcome indicators.

Specifically, changes in poverty are calculated by linking a poverty microsimulation module to the variables of the RIAPA-CGE model following the methodology of Arndt et al. (2012). Incomes and commodity consumption for fifteen representative household groups by income level and rural and urban locations are endogenous variables in the RIAPA-CGE model, and households in the microsimulation module track the changes of their corresponding household groups in the CGE model. The new poverty status is then computed for each of the sampled households in the microsimulation model. Likewise, the measure of undernourishment uses the same set of households and focuses on the change in the share of the population below a minimum dietary energy requirement in kcal per capita per day.

The process for estimating changes in diet deprivation using the microsimulation module is similar to that for poverty, and households are linked to their respective representative household groups in the CGE model. In this instance, however, modeled changes in food consumption across six food groups are used to compute changes in the Reference Diet Deprivation (ReDD) index (Pauw et al. 2023), which serves as a multidimensional indicator of a household's diet quality. ReDD index, which is a deprivation gap measure, quantifies shortfalls in consumption relative to a recommended consumption threshold. A decline in the deprivation gap indicates improvement in overall diet quality.

4. COST-EFFECTIVE INVESTMENT OPTIONS FOR INCLUSIVE AND SUSTAINABLE TRANSFORMATION

4.1. Scenario design

In this study, we focus on the impact of 15 different investment areas. For comparability, we assume a $25 million increase in public spending for each of the 15 investment areas yearly for over five years and evaluate their respective impacts on selected economic and social outcomes. This spending level is chosen to generate an economywide impact that is of relevant magnitude to compare the investments. Some investments influence development outcomes only in the year they are made, while others have impacts that persist over a longer period. To capture these differences, we assume a maximum impact duration of 20 years and assess changes in key development outcome indicators through 2045 for all investments. For interventions with one-year effects, outcome indicators stop changing after the investment year. In contrast, investments with multi-year effects continue to influence the indicators until the impact naturally tapers off.

The 15 investment areas are grouped into five broad types of interventions: (i) research and development (R&D), (ii) extension and advisory services, (iii) markets and food systems, (iv) risk reduction and resilience, and (v) infrastructure. Annex Table A1 includes a detailed list of interventions and their corresponding groups. In short, the interventions include the following:

- R&D investments contribute to the development of improved seed varieties, productive agronomic practices, animal breeds, and animal husbandry.
- Extension and advisory services promote the adoption of improved seeds, agronomic practices, livestock inputs (e.g., feed and vaccines), and climate-smart agricultural practices.
- Markets and food system investments are designed to strengthen seed systems through access to finance and training, and reduce food loss and waste, or improve access to credit.
- Risk reduction and resilience interventions support better decision-making by agrifood system actors by providing early warning information and climate forecasting.
- Infrastructure investments raise overall value chain productivity through expanding irrigation schemes or feeder roads that connect farmers to input and product markets.

Calibration of the investment module requires a range of data inputs for each of the 15 investment areas. These include adoption rates (or coverage rates), which specify the number of farmers that use a specific technology or service, or the area of land on which a technology is applied, as well as yield gains from utilizing those technologies or services. Baseline rates of technology adoption and service coverage rates were obtained from USAID/IFPRI household survey (USAID/IFPRI PBS 2023). Baseline rates of relevant extension services are retrieved from literature (Khakimov 2019), while access to finance data is obtained from Implementation Completion and Results Reports of the World Bank Agriculture Commercialization Project (World Bank 2022). Productivity impacts of the respective interventions across the targeted sectors are derived from crop and livestock models (IFPRI 2024b), boldly assuming estimates from Bangladesh hold for Tajikistan due to lack of Tajikistan-specific estimates in the crop and livestock models.[2] Tajikistan's USAID/IFPRI PBS (2023) survey and World Bank financed project (World Bank, SRAS Project 2021b) are specifically used to estimate adoption and coverage rates for the various technologies and practices modeled in this analysis. The USAID/IFPRI PBS survey shows a generally low rate of input coverage, showing a potential for rapid increase in yield through targeted interventions. IFPRI's crop model (IFPRI, 2024b) is used to estimate yield gains from adopting different farm practices. For Tajikistan, the model reveals stronger cereal yield effects from irrigation infrastructure, followed by information on planting windows and the adoption of improved seeds. These investment module parameters, alongside measures such as value-added and output prices, are important determinants of the returns on investments in different technologies or services.

Investment unit costs measure the financial cost of expanding input coverage (e.g., increasing irrigated land by one hectare). These are primarily sourced from impact evaluation studies, sector development plans, and existing literature. A key enhancement in this version of the investment module, compared to its most recent predecessor described in Aragie et al. (2024), is its ability to track the time lag between investment spending and its eventual impact (e.g., for rural roads or irrigation projects that take several years to materialize) as well as the duration of that impact (this accounts for depreciation or time-bound interventions). This distinction is crucial, as some investments yield one-time effects, while others generate sustained benefits over multiple years.

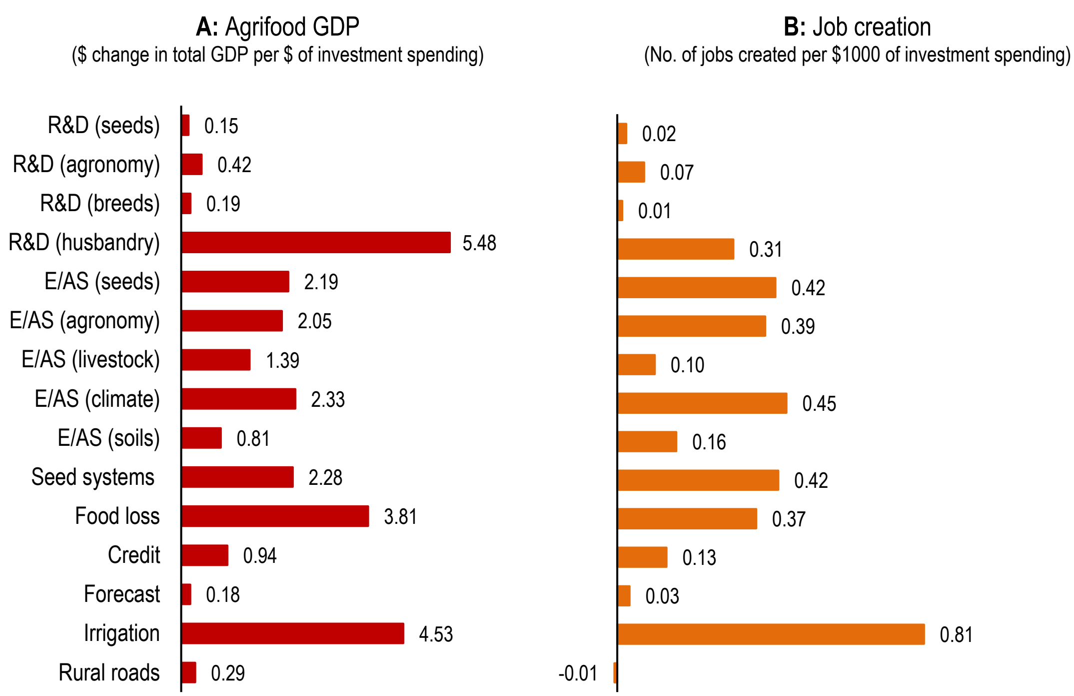
Tajikistan is historically exposed to weather-related shocks on agricultural production that can reduce the efficiency of technologies and practices. An alternative situation of a permanent decline in yield gain from a 1-in-25-year drought is also considered to test how the rankings of interventions change by 2045 when the system is faced with high-magnitude climatic shocks.

[2] We recognize that Tajikistan and Bangladesh are distinct geographically and climatically, but share several similarities in their agriculture, primarily due to their economic development levels, reliance on agriculture for livelihoods, and certain structural challenges. Both countries have predominantly small-scale, subsistence-oriented farming, where farmers working on fragmented plots. They face irrigation inefficiencies and water-related risks (shortages, flooding, poor infrastructure).

4.2. Comparing investments impacts

We begin our comparison of investments by examining their impact on two key economic outcomes: agrifood system growth and job creation. Investments in R&D for livestock husbandry, irrigation, food loss and waste reduction, and improved seed systems demonstrate particularly strong growth effects. Farmer-focused interventions—such as extension and advisory services on climate, seeds, and agronomy—also rank among the most cost-effective in terms of their contribution to agrifood system GDP. Specifically, each additional dollar invested in R&D for husbandry yields an estimated $5.48 in agrifood system GDP. Irrigation investments follow closely, generating approximately $4.53 per dollar—still a highly favorable return. Similarly, investments in food loss and waste reduction return nearly four times their cost. Spending on improved seed systems and advisory services offers economywide returns of about two dollars per dollar invested. By contrast, several other interventions are associated with significantly lower GDP gains per unit of investment (see Figure 4.1).

FIGURE 4.1. COMPARISON OF INVESTMENTS BASED ON THEIR COST-EFFECTIVENESS ON ECONOMIC OUTCOMES

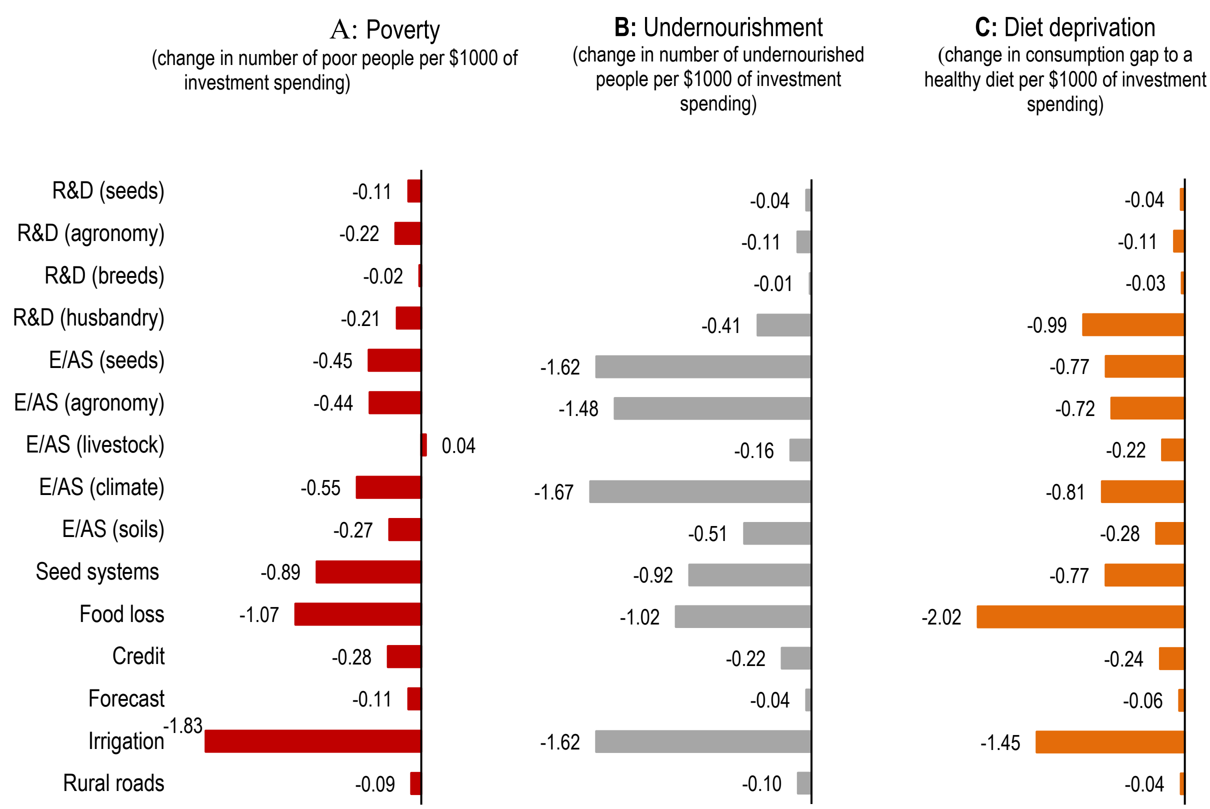


Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

Job creation remains an important development challenge for most low- and middle-income economies, including Tajikistan, especially given the continued rapid increase in the working-age population. Notably, model results highlight irrigation interventions as most effective, generating 0.81 additional jobs per $1000 invested due to their stronger backward and forward linkages across the economy. Investing in extension and advisory services related to climate, seeds, and agronomy, and revitalizing the seed system also emerge as a more effective investment area for job creation. However, most other interventions offer limited employment effects. This is because productivity gains from most investments enable higher output with fewer labor inputs, potentially reducing labor demand expansion in certain sectors (Figure 4.1).

This analysis also considers three key social outcomes: the poverty headcount, the prevalence of undernourishment, and the quality of household diets. These indicators are derived from household survey–based microsimulation models integrated into the RIAPA framework. The results indicate that different investment areas vary significantly in their effectiveness at influencing these social outcomes (see Figure 4.2).

FIGURE 4.2. COMPARISON OF INVESTMENTS BASED ON THEIR COST-EFFECTIVENESS ON SOCIAL OUTCOMES



Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

Investment in irrigation has the largest impact on poverty and undernourishment, which is partly explained by the strong GDP and employment effects of this intervention that especially benefits lower income quintile households. Food loss and waste reduction and improved seed systems are also more effective for reducing poverty and undernourishment, while farmer-facing interventions including extension and advisory services related to climate, agronomy, and seeds have particularly stronger effects to reduce prevalence of undernourishment. Likewise, to their effects on poverty and undernourishment, irrigation infrastructure development and food loss and waste reduction rank the highest on their impact on diet diversity. Food loss and waste reduction increase the access of low-income households to those food items with higher loss and waste rates, such as horticulture, to which they have relatively large consumption gaps. Unlike the results discussed earlier, spending on R&D in husbandry ranks among the highest on diet impacts since this intervention improves access and availability of animal source food to which many households experience a consumption gap (Figure 4.2).

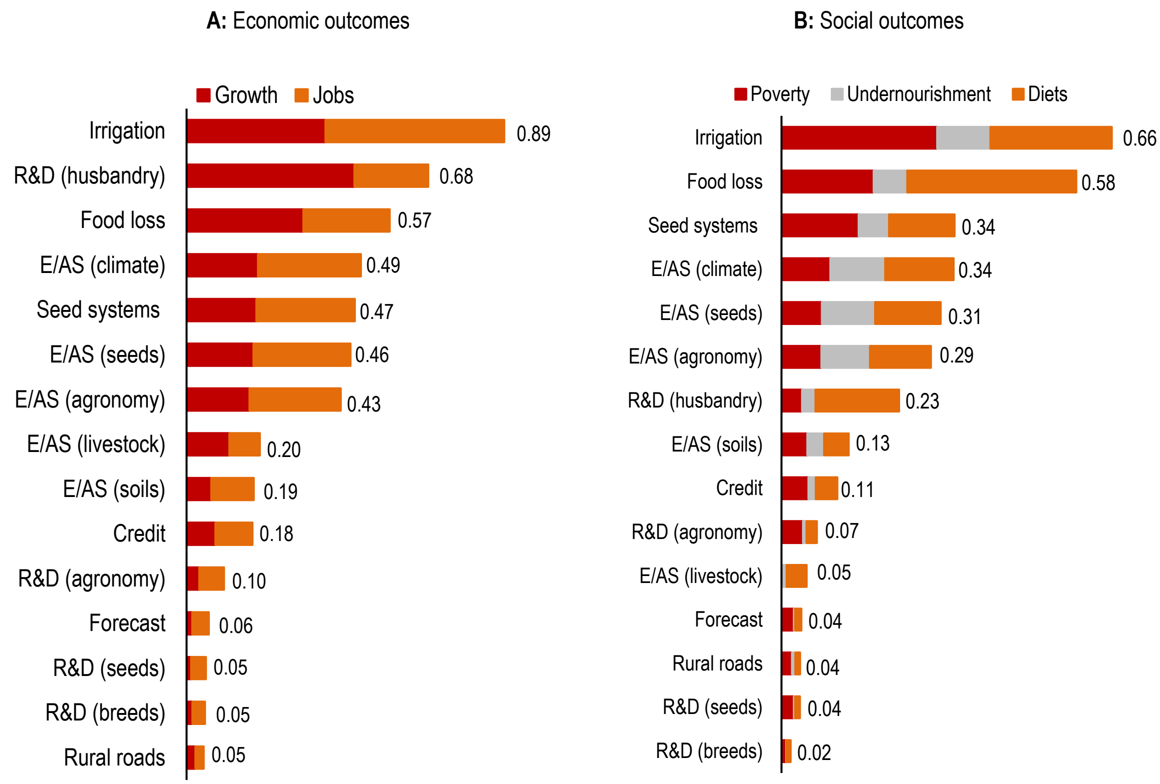
4.3. Composite score of investments by their impact on selected outcome indicators

As outlined in the preceding section, investments were ranked based on their impact across a wide range of outcomes, categorized into economic and social dimensions. The results revealed that there is no single intervention consistently ranked highest across all outcomes, highlighting the existence of potential tradeoffs among indicators. Furthermore, we construct composite scores for each intervention based on their impact within each outcome group. The process involves several distinct steps. First, we normalize the intervention scores by assigning a value of 1 to the most cost-effective intervention and 0 to the least cost-effective for each outcome. Second, for each intervention, we apply equal weights to its normalized outcome scores within the same outcome dimension. Third, we sum up the weighted scores for each intervention and rank them accordingly.

For example, when constructing the composite score for economic outcomes, we assign equal weights—50 percent each—to growth and job creation, reflecting an assumption of equal policymaker preference for both outcomes. We then sum up the weighted scores for growth and job creation to derive an overall economic impact score for individual interventions. These scores are subsequently used to identify the most and least effective interventions in overall economic outcomes. The same procedure is applied to determine composite scores for the social outcomes.

Figure 4.3 shows that investing in irrigation is the most cost-effective option for achieving economic outcomes, with job creation playing a major role in its high ranking. R&D in husbandry and food loss and waste reduction are also among the more cost-effective investments, primarily due to their significant contributions to AFS GDP growth. In contrast, job creation is the main driver of cost-effectiveness for farmer-facing interventions—such as extension and advisory services on climate, agronomy, and seeds—placing them among the top-performing investments in Panel A.

FIGURE 4.3. COMPOSITE SCORES ON EACH ECONOMIC AND SOCIAL OUTCOME COMPONENTS BY INVESTMENT AREA: EQUAL WEIGHT

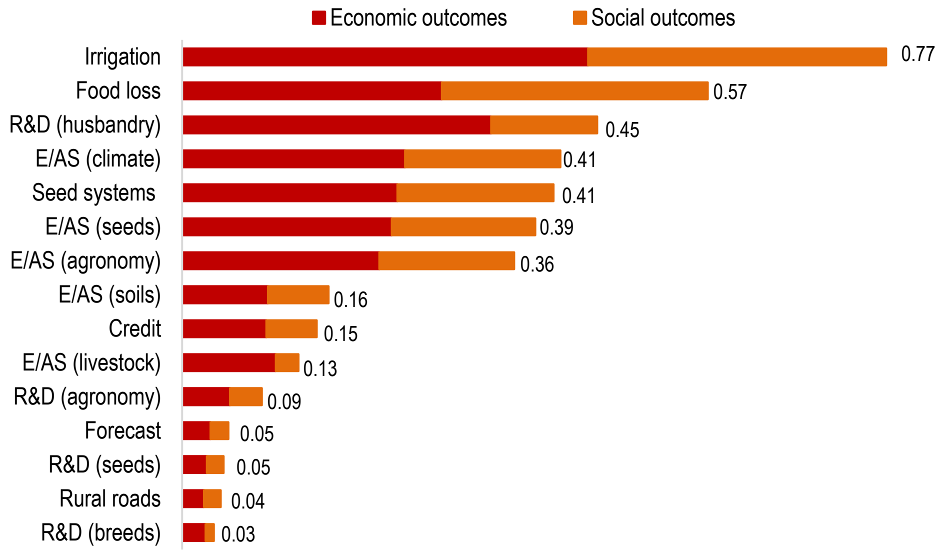


Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

Panel B of Figure 4.3 reports composite scores of interventions based on their overall impacts on social outcomes, summarizing their effects on poverty headcount, prevalence of undernourishment, and diet deprivation. The overall impact is constructed by summing together the three indicators' normalized scores, each with the same weight of one-third. Like the economic outcome ranking, investing in irrigation ranks as the most cost-effective option for achieving sound effects in overall social outcomes, with specifically stronger effects on poverty reduction and improvement in diet quality. Similarly, systemic interventions, such as food loss reduction and seed systems, rank highly in social outcomes. Three extension and advisory-related interventions also rank relatively high. By contrast, upstream investments, including R&D in seeds, agronomy and breeding systems, are less cost-effective both in their overall economic and social impacts.

Policy decisions are often made by jointly considering economic and social outcomes. To help determine the overall cost-effectiveness of the investments analyzed, these two dimensions are further combined, attaching 50 percent weight to each. The combined scores are reported in Figure 4.4 and clearly illustrate synergies and potential trade-offs across investments between these two types of outcomes.

FIGURE 4.4. COMPOSITE SCORES ON ECONOMIC AND SOCIAL OUTCOMES BY INVESTMENT AREA: EQUAL WEIGHTS



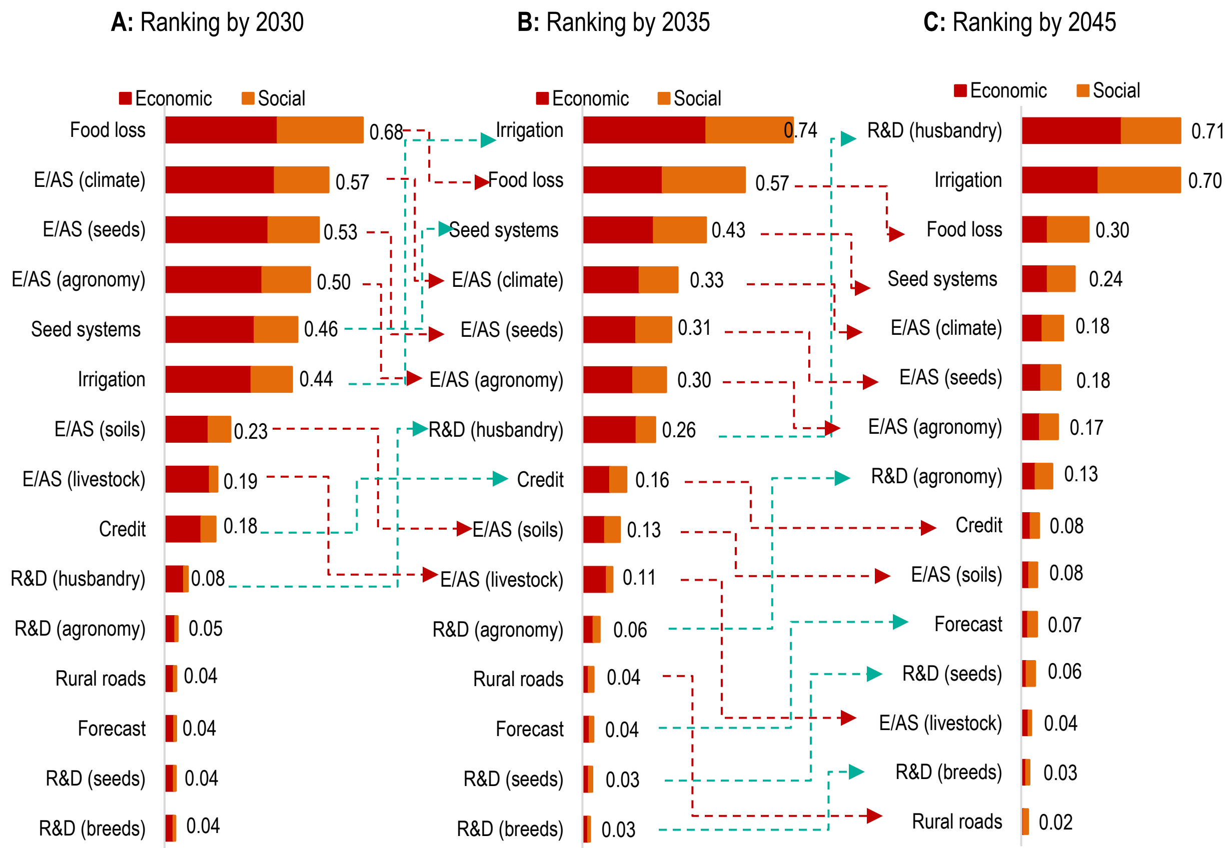
Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

As expected, irrigation is at the top in the overall ranking, while its impact on economic outcomes is larger than its social impact. The intervention on food loss and waste reduction stays at the second in the overall ranking with similar impacts on both economic and social outcomes. Among other interventions, the impacts on economic outcomes are generally larger than their impacts on social outcomes, and R&D in husbandry, seed systems, and farmer-facing interventions such as extension and advisory services on climate, seeds, and agronomy are also relatively more cost-effective in their overall economic and social impacts.

4.4. Do the rankings change over time?

The previous section compares investment impacts by the end of the simulation period (2045) across different investments. Investments vary in their time of functionality, with some—such as irrigation infrastructure or research and development—requiring several years before they begin delivering their intended services or benefits. It is therefore useful to assess whether the investment ranking changes when impacts are measured over different time horizons. In particular, government officials often operate within shorter political cycles, typically 4–5 years, which may favor investments with more immediate returns. By contrast, many infrastructure and long-term R&D investments require planning and evaluation over much longer horizons to fully realize their impacts. The RIAPA framework explicitly accounts for time delays between the year an investment begins and the year it becomes fully functional in delivering outcomes. For example, an irrigation investment might begin construction in 2025, start delivering water to farmland in 2030, reach its full design capacity in 2035, and continue to operate for decades thereafter with minimal maintenance costs. These technical and operational characteristics imply that economic and social outcomes vary not only by investment type, but also by the time frame over which they are assessed. In this section, we report the composite scores and rankings of investment areas for 2030, 2035, and 2045 to examine how time horizons affect the relative performance of investments (Figure 4.5).[3]

FIGURE 4.5. CHANGES IN RANKINGS WITHIN DIFFERENT TIME HORIZONS



Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

The assessment reveals significant temporal shifts in the cost-effectiveness of interventions. A general pattern emerges. Interventions of a recurrent nature, such as extension and advisory services, tend to rank more highly in the short term, as their impacts are realized quickly. In contrast, long-term investments—such as irrigation, seed systems, and research and development (R&D)—gain prominence in later years as their benefits accumulate. Notably, climate- and seed-related extension services are among the top-ranked interventions in 2030 but fall to mid-ranking position by 2045, when the impacts of larger, one-off

[3] The selected time horizons—five years (to 2030), ten years (to 2035), and twenty years (to 2045)—are appropriate for illustrating the short-, medium-, and long-term impacts of investments. While alternative timeframes can be considered, they are more likely to reflect transitional phases to the time horizons considered in this study.

investments begin to take effect. Irrigation investment, which ranks sixth in 2030, climbs to first place by 2035. Similarly, R&D in husbandry rises nine positions to become the most cost-effective intervention by 2045.

4.5. Unpacking priorities by sub-sectors

In the previous subsections, we presented the cost-benefit rankings across various intervention areas. Each investment typically targets specific agrifood value chains or subsectors. For instance, food loss reduction efforts primarily focus on the value chains of cereals, cash crops, and root crops. In contrast, other interventions—such as those related to climate information systems and rural roads—tend to have broader, systemwide effects, influencing a wide range of agrifood value chains. In this section, we conduct a more detailed analysis by ranking interventions based on the specific value chains or subsectors they target. To this end, we construct 57 unique sector-investment combinations and develop a single impact score for each. These impact scores are normalized composite indices, similar to those presented in Figure 4.4. For each combination, we generate two separate normalized composite scores: one for economic outcomes and another for social outcomes. These are then aggregated with equal weights (50% each) to form the final impact score. The comparative results across all 57 combinations are summarized in Table 4.1.

The blue-shaded cells in Table 4.1 identify value chains or subsectors where impacts of a given intervention exceed the overall average impact score of this intervention's cross-cutting score. For instance, the composite score for the cross-cutting investment of R&D in improved seeds is very low (0.02), where the intervention's impact is evaluated systemwide across all sectors. However, its impact on specific sectors differs, and the impact on pulses and oilseeds is well above this cross-cutting average, 0.29. Meanwhile, the green-shaded cells denote sector–investment combinations ranked among the top five in the sector-specific impact score. These sector-investment combinations indicate potential priority areas where investments could substantially enhance the overall performance of agri-food system interventions. As such, although R&D investments in improved seeds for pulses and oilseeds show above-average impacts relative to the cross-cutting score of R&D in seeds, these do not fall within the top five intervention areas, mainly due to their smaller overall impacts measured system-wide across value chains. Conversely, extension and advisory services for "other cash crops" not only exceed the average impact score of the intervention system-wide across all sectors but also is among the top five crop-specific investment areas. Furthermore, Table 4.1 suggests that combining extension and advisory services on agronomic practices for "other cash crops", food loss and waste reduction efforts on roots and horticulture and expanding irrigation access to "other cash crops" would significantly improve the effectiveness of the overall agrifood system investments in Tajikistan. Better market opportunities—both domestic and export—and the relative cost-effectiveness of the corresponding investments contribute to the higher scores observed for these top-performing investment-sector combinations. Note that extension and advisory services targeting animal husbandry remains moderately cost-effective non-crop specific investment option.

As illustrated by the impact scores of investment-sector combinations, Table 4.1 further highlights significant variations in the relative cost-effectiveness of investments across sectors. For example, food loss reduction interventions targeting horticulture and root crops rank among the top three most cost-effective options out of 57 investment-sector scenarios, while similar interventions targeting cereals and cash crops are among the least promising in terms of intended impact. These findings underscore the need for in-depth analysis of each investment option to identify where the highest socio-economic returns per dollar spent can be achieved. A logical extension of this analysis would be to explore budget allocation patterns that could maximize overall impact.

TABLE 4.1. COMPOSITE SCORES BY INVESTMENT AREA AND CROP SECTOR

			Cross-cutting	Cereals	Root crops	Pulses and oilseeds	Horti-culture	Cotton	Other cash crops
R&D	1	R&D (improved seeds)	0.02	0.04	0.14	0.29	0.02	0.02	0.01
	2	R&D (agronomy)	0.03	0.11	0.34	0.33	0.03	0.04	0.02
	3	R&D (animal breeds)	0.02						
	4	R&D (animal husbandry)	0.18						
Extension / advisory services	5	E/AS (improved seeds)	0.12	0.02	0.19	0.22	0.26	0.09	0.53
	6	E/AS (agronomic practices)	0.11	0.02	0.19	0.11	0.24	0.09	0.52
	7	E/AS (livestock)	0.05						
	8	E/AS (climate information)	0.12						
	9	E/AS (climate smart agriculture)	0.05	0.02	0.08	0.05	0.10	0.04	0.25
Markets and food systems	10	Seed systems	0.12						
	11	Food loss and waste	0.19	0.02	0.59	0.23	0.67	0.01	0.01
	12	Credit access (financial inclusion)	0.05						
Risk reduction and resilience	13	Seasonal forecast (early warning)	0.02						
Infrastructure	14	Irrigation infrastructure	0.22	0.07	0.32	0.14	0.46	0.19	0.84
	15	Rural roads	0.02						

Source: RIAPA modeling system
Note: E/AS = extension and advisory services; R&D = research and development.

5. CONCLUSION

The transformation of Tajikistan's agrifood system is crucial for advances in economic growth, employment creation, and household welfare, particularly in rural areas. This is also increasingly important for environmental sustainability. Achieving this requires both increased levels of public support for agriculture and allied sectors, and improved efficiency of such support economically, socially, and environmentally. Currently, the government of Tajikistan supports the agrifood system through a VAT exemption for imported agricultural inputs (feed, machinery, seeds) and a seasonal electricity discount for water pumping stations for irrigation. Investment in agrifood R&D, extension and advisory services, markets and food systems, infrastructure, risk reduction, and resilience are crucial to ensure sustainable development, although most such interventions received limited financial support. In 2021, roughly 5 percent of farms and nearly 14 percent of arable land used professional extension services. The government's fiscal space also restricted the level and sustainability of support for such investments.

In this study, we systematically assessed a range of agrifood system investment options using IFPRI's RIAPA model to tailor to Tajikistan's public investment data and many other economic and social development datasets. Investment options were ranked based on their cost-effectiveness in delivering multiple economic and social development outcomes, including agrifood GDP growth, agrifood job creation, poverty reduction, undernourishment reduction, and improvements in diet deprivation.

The RIAPA model simulation analysis shows that there is no single intervention that is most cost-effective in achieving all economic and social outcomes. In terms of overall economic outcomes, which include impacts on agrifood GDP growth and job creation, irrigation infrastructure development, R&D in husbandry, and food loss and waste reduction rank highly as the three top cost-effective investment interventions. Extension and advisory services such as climate, seeds, and agronomy as well as improvements in functional seed systems also have stronger overall effects on agrifood GDP and jobs. Greater social outcomes—poverty reduction, decreased rates of undernourishment, and improved diet diversity—are associated with investments in irrigation, food loss and waste reduction, and seed systems. Farmer-facing investments, such as extension and advisory services focused on climate, seeds, and agronomy, which primarily target the crop sector are also relatively cost-effective in improving social outcomes.

Further, the analysis reveals significant temporal shifts in the cost-effectiveness of interventions over time. Interventions with a recurrent nature, such as extension and advisory services, rank highest in the year invested, with their benefits being materialized in the short run quickly, while investments in irrigation, seed systems, and R&D gain prominence in a longer time horizon with their delayed nature in investment that endures accumulated impact over time.

Investment options are also evaluated across different value chains using sector–intervention combinations. Notably, investments in extension and advisory services that promote improved seeds and agronomic practices for the "other cash crops" value chain, in food loss and waste reduction efforts targeting root crops and horticulture, and in expanding irrigation access for "other cash crops" stand out. These targeted interventions have the potential to significantly enhance the overall effectiveness of agrifood system investments.

The investment option assessment based on the cost-effectiveness of different investments and various development outcomes highlights the existence of synergies and trade-offs among investment interventions, which could affect the prioritization process for policy decisions in investment interventions. This study further demonstrated the importance of evidence-based research that integrates data and proper tools in providing insights to policymakers for policy and investment prioritization. Thus, improvement in data quality and accessibility is important for supporting such evidence-based policymaking.

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APPENDIX

TABLE A1. LIST OF INVESTMENT SCENARIOS CONSIDERED

Broad category	Number	Scenario	Description
Research and development (R&D)	1	R&D (improved seeds)	R&D into improved seed development
	2	R&D (agronomic practices)	R&D into improved agronomic practices
	3	R&D (animal breeds)	R&D into improving breeds
	4	R&D (animal husbandry)	R&D into improved husbandry practices
Extension / advisory services	5	E/AS (improved seeds)	Advising improved seed use
	6	E/AS (agronomic practices)	Advising improved agronomic practices
	7	E/AS (livestock)	Advising improved livestock handling
	8	E/AS (climate information)	Providing climate information system
	9	E/AS (climate smart agriculture)	Advising on climate smart practices
Markets and food systems	10	Seed systems	Extended seed system
	11	Food loss and waste	Food storage and transport
	12	Credit access (financial inclusion)	Micro-credit access for farmers
Risk reduction and resilience	13	Seasonal forecast (early warning)	Seasonal weather forecast
Infrastructure	14	Irrigation infrastructure	Small and medium scale irrigation
	15	Rural roads	Unpaved feeder roads

Source: Authors compilation.

TABLE A2. PARAMETERS USED TO CALIBRATE THE INVESTMENT MODULE

	Cross-cutting	Cereals	Roots	Pulses & oilseeds	Horticulture	Cotton	Other crops	Livestock	Source
Efficacy of practices									
Improved seeds		31.7%	21.4%	31.8%	18.6%	18.8%	18.8%		IFPRI crop model based on Bangladesh estimates
Chemical fertilizers		18.7%	12.6%	5.8%	10.7%	10.6%	10.6%		IFPRI crop model based on Bangladesh estimates
Irrigation		115.8%	77.6%	31.4%	66.6%	66.6%	66.6%		IFPRI crop model based on Bangladesh estimates
Planting window		37.3%	25.1%	12.8%	21.9%	22.1%	22.1%		IFPRI crop model based on Bangladesh estimates
Planting density		7.0%	4.7%	5.1%	4.0%	4.0%	4.0%		IFPRI crop model based on Bangladesh estimates
Manure use		7.1%	4.8%	5.0%	4.1%	4.1%	4.1%		IFPRI crop model based on Bangladesh estimates
Residue management		18.1%	12.2%	8.1%	10.6%	10.7%	10.7%		IFPRI crop model based on Bangladesh estimates
Vaccines for animals								17.0%	IFPRI crop model based on Bangladesh estimates
Artificial insemination								23.5%	IFPRI crop model based on Bangladesh estimates
Improved feed for animals								30.5%	IFPRI crop model based on Bangladesh estimates
Reduced food loss and waste		1.0%	9.8%	4.6%	6.0%				TAJSTAT. Agriculture statistics annual book 2022, pp. 17-19. Assuming a 50% reduction in loss.
Unit cost per farmer (USD)									
R&D - Seeds	5.0								Own estimates based on “World Bank. 2021b. Tajikistan Strengthening Resilience of the Agriculture Sector Project (2022-2027). World Bank, Washington, DC.”
R&D - Agronomy	5.0								
R&D - Breeds	5.0								
R&D - Husbandry	5.0								
R&D - Forecast	5.0								
Seed systems	50.0								Own estimates based on “World Bank. 2021b. Tajikistan Strengthening Resilience of the Agriculture Sector Project (2022-2027). World Bank, Washington, DC.”

Table A3. Parameters used to calibrate the investment module (continued)

	Cross-cutting	Cereals	Roots	Pulses & oilseeds	Horticulture	Cotton	Other crops	Livestock	Source
Unit cost per farmer (USD)									
Extension - Seeds	35.0								Khakimov, P. 2019. Climate Change in Afghanistan, Kyrgyzstan and Tajikistan: Trends and Adaptation Policies Conducive to Innovation. Working Paper #55. University of Central Asia, Graduate School of Development, Institute of Public Policy and Administration. https://ucentralasia.org/media/gijd5apb/uca-ippa-wp55eng.pdf
Extension - Agronomy	35.0								
Extension - CSA	35.0								
Extension - Livestock	35.0								
Extension - Climate info	35.0								
Irrigation infrastructure	2000.0								National Investment Plan for Food and Nutrition Security and Sustainable Agriculture (NIP) 2021-2030
Financial services	60.0								World Bank. Tajikistan. 2022 - Agriculture Commercialization Project (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099925001192329460
Food loss - post-harvest	20.0								Food loss and waste estimate from TAJSTAT 2022 and cost-benefit assumption of $1.
Road infrastructure	8000.0								Adjusted from ADB. 2009. Republic of Tajikistan: Road Rehabilitation Project
Baseline coverage (%)									
Extension - Seeds		31.0%	31.0%	31.0%	31.0%	31.0%	31.0%		Khakimov, P. 2019. Climate Change in Afghanistan, Kyrgyzstan and Tajikistan: Trends and Adaptation Policies Conducive to Innovation. Working Paper #55. University of Central Asia, Graduate School of Development, Institute of Public Policy and Administration. https://ucentralasia.org/media/gijd5apb/uca-ippa-wp55eng.pdf
Extension - Agronomy		31.0%	31.0%	31.0%	31.0%	31.0%	31.0%		
Extension - CSA		31.0%	31.0%	31.0%	31.0%	31.0%	31.0%		
Extension - Livestock								31.0%	
Extension - Climate info		90.0%	90.0%	90.0%	90.0%	90.0%	90.0%		
Irrigation infrastructure		70.8%	70.8%	70.8%	70.8%	70.8%	70.8%		FAO. 2021. National Investment Plan for Food and Nutrition Security and Sustainable Agriculture (NIP) 2021-2030
Financial services		10.0%	10.0%	10.0%	10.0%	10.0%	10.0%		Tajikistan - Agriculture Commercialization Project (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099925001192329460
Food loss - post-harvest		60.0%	60.0%	60.0%	60.0%	60.0%	60.0%		

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