Food and Energy Security

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Food and Energy Security Open Access

ORIGINAL ARTICLE OPEN ACCESS

Economic Viability of Scaling Improved Bean Technologies in Burundi and Zimbabwe

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Received: 30 September 2024 | **Revised:** 15 January 2025 | **Accepted:** 17 January 2025

Funding: The study was funded by the Swiss Agency for Development and Cooperation (SDC), in the Federal Administration of Switzerland, and the Federal Department of Foreign Affairs, grant number 81031140.

Keywords: common bean | cost benefit analysis | Sub-Saharan Africa | technologies

ABSTRACT

Scaling improved bean varieties and complementary technologies are important to improve crop productivity incomes and food and nutrition security in Sub-Saharan Africa. In Burundi and Zimbabwe, bean technologies were promoted through a demand-led and public–private partnership model. While econometric approaches have been used to estimate the impact of enhanced technologies on farmers' livelihoods for a long time, no economic feasibility analysis has been done. Most analyses focus on farmers livelihoods, overlooking other value chain actors like traders, processors, and seed producers including community seed multipliers. Thus, this study contributes to the literature by conducting an economic feasibility analysis that includes all actors in the bean value chain and estimates additional investments attracted from public and private stakeholders. We further identified gains or losses on account of the externalities generated through different value chain actors. We find positive net present values (NPV) and a benefit–cost ratio (BCR) greater than one. This implies that the economic benefits of the bean value chain improvement program in the two countries are larger than their costs. Farmers and traders are the main beneficiaries, receiving 99% and 65% of the net economic benefits generated in the bean value chain in Burundi and Zimbabwe, respectively. Finally, we find the intervention sustainable and resilient against economic shocks, making it worth replicating in other countries in sub-Sahara Africa and beyond. Pragmatic and policy options are recommended to inform future interventions of a similar nature.

1 | Introduction

Burundi and Zimbabwe are countries in Sub-Saharan Africa grappling with food and nutrition insecurity, with a significant proportion of the population, particularly those in rural areas, suffering from severe malnutrition. At the national level, 34.5% and 28.9% of women aged between 15 and 49 years old suffer from chronic anemia, while 54.0% and 23.5% of children under 5 years old are stunted in Burundi and Zimbabwe, respectively (UNICEF 2021; USAID 2018a, 2018b, 2022). Common beans with their high protein and micronutrient content, particularly iron and zinc, offer a sustainable solution to the above-mentioned food and nutritional challenges. Investing in common bean value chains could significantly improve the health and well-being of women of reproductive age (15–49 years old) and children under 5 years old, who are the most affected by malnutrition.

Despite the huge contribution of common beans to economic growth, farmers in these countries are experiencing low productivity and farm incomes due to widespread use of low-yielding bean varieties and lack of complementary farming technologies. This has negatively affected other value chain actors that cannot get the quality and quantity of bean grains that they need. These challenges have been exacerbated by unstable macroeconomic and political environments, climate shocks, and related biotic and abiotic stresses experienced by bean value chain actors in the two countries. Common beans could potentially help Burundi and Zimbabwe overcome their socioeconomic challenges. Globally, Burundi has the lowest gross national income (GNI) per capita (US$ 732 in 2021) (UNDP 2022) and is still recovering from the social unrest of the 1993–2005 civil war and political coup in 2015. In contrast, Zimbabwe has a per capita GNI that is five times larger (US$ 3810) than Burundi's.

Between 2015 and 2022, the Pan African Bean Research Alliance (PABRA) embedded in the Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT) together with Institut des Sciences Agronomiques du Burundi (ISABU), Department of Research and Specialist Services (DRSS) and Department of Agricultural, Technical and Extension Services (AGRITEX) in Zimbabwe, implemented a flagship intervention entitled: "Improving food security, nutrition, incomes, and natural resource base and gender equity for better livelihoods of smallholder households in Sub-Saharan Africa"[1] funded by the Swiss Agency for Development and Cooperation (SDC) and Global Affairs Canada (GAC). PABRA facilitated and empowered National Agriculture Research Systems (NARS) members to conduct demand-led research and supported development that addresses the needs of all bean value chain actors. In addition, PABRA developed institutional innovations that catalyze investment in the beans by private sector partners and other partner development organizations involved in the bean subsector.

This paper aims to provide insights into the impacts of the catalytic PABRA-led investment on bean value chain facilitated by NARS in the two countries. This analysis estimates the magnitude of the impact that PABRA has achieved within two challenging national contexts. Despite numerous reports on impacts of adoption of improved common bean varieties and complimentary integrated crop management (ICM) practices, an ex-ante or ex-post economic feasibility analysis has never been done. Rather, econometric approaches have commonly been used to estimate the impact on improving farmers' livelihoods (e.g., Aseete and Katungi 2023; Katungi et al. 2020, 2021; Ochieng et al. 2020; Ogada et al. 2020). We conducted an economic viability analysis after the implementation phase and adopted a value chain approach while similar or related studies concentrated on individual actors, mainly small-scale farmers (Akinyi et al. 2022; Junia Mutenje et al. 2019; Ng'ang'a, Miller, and Girvetz 2021; Ombati Mogaka, Karanja Ng'ang'a, and Kiplangat Bett 2022; Poudel, Thapa, and Mishra 2024; Rosegrant et al. 2023; Smith et al. 2021). However, these studies excluded other value chain actors such as traders, aggregators, processors, seed producers or companies, and seed multipliers from their analysis. Our analysis also goes further, to determine who gains and who loses on account of the externalities generated by the program actors. These include, for example, smallholder farmers—youth, women—traders, processors, seed multipliers, and seed companies. We identify the sources of uncertainty (risk) that the intervention faced. We also tested the significance and impact of the identified critical variables on the intervention outcomes and helped to find the appropriate mitigation measures to reduce the intervention's exposure to risks of failure.

Our study contributes to the literature and fills the identified knowledge gap by performing a cost–benefit analysis (CBA) that considers all the actors in the crop value chain. We did this by first: (1) estimating the additional investments that the intervention attracted from public and private stakeholders; (2) conducting a CBA of the investment program; (3) identifying who gains or losses on account of the externalities generated through different value chains actors; (4) conducting sensitivity analysis to determine how risks affect the intervention outcomes; and (5) providing lessons learnt and appropriate mitigation measures needed to address challenges of similar interventions in future.

The paper is organized as follows. The next section provides the country's context and intervention. Section 3 introduces the materials and methods, detailing data sources and analysis, and the analytical approach used. Section 4 discusses the results of the economic analysis and intervention impacts. Finally, Section 5 presents the conclusions, programmatic, and policy implications.

2 | Country Context and Intervention

2.1 | Country Context

2.1.1 | Burundi

The country experienced political instability between 1993 and 2010, which significantly reduced the average per capita agricultural production to less than half due to conflicts, recurrent drought, torrential rains, pests and diseases, and deteriorating soil fertility levels. The latter (decreasing soil fertility) is compounded by shrinking farm sizes, compelling people to clear forested land and reclaim the wetlands for settlement and agricultural production. These worrying trends in poverty and malnutrition among women and children have been worsened by the volatile macroeconomic and political environment in the country.

This means that the common bean, which is predominantly considered a major food and cash crop, supports the livelihoods of more than 90% of small-scale farmers. The crop has the potential to contribute to the agenda of existing National Agricultural Strategy (SAN) and National Food Security Programme (NFSP). Bean consumption in Burundi is the highest in the world (41 kg annually per person) Food Agriculture Organization (FAO 2023), providing 50% of daily protein and 20% of caloric intake (USAID 2022).

Therefore, investing in bean value chains is crucial since it has a multiplier effect on smallholder farmers and transforms their livelihoods. The bean seed system in the country is underdeveloped, and seeds are often sold by traders in open-air markets; thus, the quality of such seeds is not guaranteed. This has partly contributed to the low productivity of beans of about 700 kg per hectare in 2014 among small-scale farmers, who are the majority in the country (Republique du Burundi [RDB] 2018).

2.1.2 | Zimbabwe

Like Burundi, Zimbabwe experienced political and economic instability for more than two decades caused by implementing a land reform policy. This policy led to the government taking over the land of large-scale farmers and redistributing it to small-scale farmers. This action contributed to a decline in agricultural production to less than half of the national production levels despite agriculture being the cornerstone of the country's economy, contributing 15%–17% of the national Gross Domestic Product (GDP) (Anseeuw et al. 2012). The unstable economic situation and climate-related shocks have further exposed Zimbabwe to food and nutrition insecurity, with a large proportion of the population chronically malnourished.

Common beans are important in the diets of many Zimbabwean households, but their contribution declines with a decrease in the food and nutrition security of the households (Katungi et al. 2017). This could be due to the low level of bean consumption (12 kg per capita and per year). Production, nutrition, and consumption-focused initiatives are required to reverse this trend. Farmers who are the main producers experience challenges such as limited access to appropriate varieties, appropriate complementary crop management technologies, adequate knowledge, and skills to grow the bean crop. This was compounded by several biotic and abiotic stresses such as recurrent drought, torrential rains, pests and diseases, and deteriorating soil fertility, contributing to reduced agricultural productivity.

Common beans are among the top five crops providing high income to small-scale farmers and traders and are commonly traded in informal markets and supermarkets in the country. However, productivity has been low due to weak seed systems and bean producers' limited use of modern farm technologies. The seed system in Zimbabwe has been weak and cannot sustainably supply high-quality germplasm, and available improved seeds (breeder, basic, and certified improved seeds), as well as associated agronomic practices are expensive.

2.2 | Background Information on the Intervention

The Pan-Africa Bean Research Alliance (PABRA)[2] program of the Alliance of Bioversity and the International Center for Tropical Agriculture implemented the investment intervention on "Improving food security, nutrition, incomes, natural resource base and gender equity for better livelihoods of smallholder households in Sub-Saharan Africa," between 2015 and 2021 in Zimbabwe and Burundi. The intervention was financed by the Swiss Agency for Development and Cooperation (SDC) and Global Affairs Canada (GAC) with complementary financing from the governments of Burundi and Zimbabwe and other development partners. The objective was to improve food security, nutrition, incomes, and gender equity of smallholder farmers through improved bean productivity and consumption in the two countries. The farming communities that are extremely vulnerable to external shocks, such as climatic, political, and economic challenges were targeted. To achieve this, the intervention focused on:

- Developing and disseminating high-yielding bean varieties and ICM technologies in diverse agro-ecologies to raise productivity at farm level and bridge the yield gap.
- Strengthening seed production and delivery systems, engaging both public and private sector partners and using various seed delivery options, and promotion of released high Iron and Zn bean varieties for wider dissemination.
- Promoting consumption of bio-fortified bean varieties and enhanced nutrition education.
- Increasing women's access to production resources and basic nutrition skills.
- Strengthening the capacity of researchers, development partners, value chain actors, and farmers to enhance relevant skills.

Moreover, the 7-year investment was intended to build and support the work of PABRA to revitalize the capacity among National Agricultural Research Systems (NARS) to respond to the bean value chain actors' demands and create more opportunities for more investments by other partners. The initiative achieved considerable success, such as "rebooting" bean production and upgrading the bean value chain, supporting bean systems and enterprise creation for all value chain actors, smallholder farmers, traders, seed merchants, agro-dealers, and research institutions.

The intervention significantly influenced bean production, increased utilization of improved bean varieties and ICM technologies, and enhanced household welfare in both countries (Katungi et al. 2020, 2021; PABRA 2021). Specifically, it promoted climbing and common bean improved varieties and ICM technologies or practices and disseminated already released high Fe (iron) and Zn (zinc) beans and facilitated seed production and built capacity of researchers, development partners, value chain actors, and farmers to enhance relevant skills. This intervention was critical since past studies, including recent ones, demonstrated that combining the use of improved legume varieties with ICM (e.g., intercropping with cereals, application of phosphorous fertilizer, inoculants, farm yard manure, minimum tillage, crop rotations, etc.) increase grain and biomass yield (Kihara et al. 2022; Muoni et al. 2022; Ochieng et al. 2016). For instance, the intervention aimed to reach 750,000 smallholder farming households with high-quality seed of improved varieties, and ICM options but reached 945,000 farmers within a period of 3 years between 2015 and 2018 in Burundi and 1,464,100 by 2021 in Zimbabwe (PABRA 2021). Similarly, new partnerships with seed merchants and companies were created, existing ones were strengthened, and objectives aligned with government policies in Zimbabwe and Burundi (Katungi et al. 2020, 2021; Nduwarugira et al. 2023).

3 | Materials and Methods

3.1 | Data Sources

We employed a mixed-method approach that utilizes quantitative and qualitative data to ensure greater validity, information richness, coherence, and insights (Creswell and Creswell 2017). First, we used secondary data obtained from literature reviews from the program design documents, baseline, midline, and endline evaluations, annual reports, and monitoring data. Data requirements included the number of farmer beneficiaries, number of actors involved, baseline conditions before the program including yield, land sizes, seasons, marketing, and prices, and annual changes in the baseline conditions. The analysis used on the baseline data before the program, but in situations where this was not available, we used information from secondary sources.

Primary data sources were mainly provided through key informant interviews (KIIs) and focus group discussions (FGDs) with stakeholders, which included online interviews and face-to-face meetings. The farm-level yield data between 2015 and 2022 were obtained from the intervention reports and publications (Katungi et al. 2020, 2021; PABRA 2021, 2022). Farm-level yield data were obtained from the (FAO 2023) and Burundi Institute of Statistics and Economic Studies (ISTEEBU) (2021; RDB 2018) for robustness check (Table A1 in Appendix 1).

The data from the two sources were extrapolated to 2035, taking a 20-year period commonly employed in economic feasibility studies. In Burundi, we assumed that closing efficiency yield gaps through intensification of capacity-building initiatives increases bean yield by 47% (Katungi et al. 2020). FGDs were done with farmer representatives selected based on their production capacities (high, medium, and low) to ensure inclusivity in the sample. Each FGD is comprised of 3–10 members. Through FGDs and KIIs, production costs and benefits of beans, challenges of production, source and prices of inputs, and prices were established. The selected farmers represented most farmers in the intervention areas, and data were validated by local experts during stakeholder workshops.

All FGDs were organized by country teams at an accessible point, preferably within or near the NARs facilities or the project regions. The data were then validated during national stakeholder workshops held in each country. In Burundi, 10 KIIs and 4 FGDs were conducted, while Zimbabwe had 39 KIIs and 3 FGDs (Table 1). The workshops held in each country targeted bean multipliers, agro-dealers, bean processors, traders, seed merchants, producer representatives, and researchers. Gender implications and other socioeconomic benefits, such as job creation, enterprise development, and the distribution of economic benefits to the value chain actors, were also analyzed and presented. The data and information from the interviews and literature review were entered directly into a CBA Excel tool for analysis.

3.2 | Analytical Approach

We applied an *ex*-post cost-benefit analysis (CBA) model to estimate the impact of the intervention. The model can indicate whether an intervention is more sustainable and efficient than a business-as-usual (BAU) scenario. Thus, we evaluated the costs vis-a-vis the benefits associated with the intervention among various value chain actors (farmers, traders/off-takers, processors, and seed producers) in Burundi and Zimbabwe. To do this, we used three main assessment criteria for the CBA, namely, benefit–cost ratio (BCR), net present value (NPV), and internal rate of return (IRR). We performed an annual analysis for a 20-year duration beginning from 2015 and ending in 2035, using inflation indexes to program future annual incomes by value chain actors. Our evaluation used a discounted measures approach to determine the performance of the intervention while looking at both the implementation phase

TABLE 1 | KIIs and FGDs conducted in Burundi and Zimbabwe.

	Data collection method			
	Burundi		Zimbabwe	
Respondents' category	**KII**	**FGD**	**KII**	**FGD**
ISABU, DRSS and AGRITEX staff	4 (4 M)	—	7 (5 M; 2 F)	—
Seed merchants	2 (2 M)	1 (9 M)	—	1 (5 M)
Seed multipliers	—	1 (8 members (4 F; 4 M)	12 (6 F; 6 M)	1 (8 members (4F; 4M)
Farmers	—	1 (10 members (4 M; 6 F)	18 (18 members (9 F; 9 M)	1 (8 members (6 F; 2 M)
Bean traders	—	1 (3 M	1 (1 M)	
Bean processors	3 (3 M)	—	1 (1 M)	
NGOs	1 (1 M)	—	—	1 (2 M)
Total KII and FGD	10	4	39	3
Total interviewed	40 (30 M; 10 F)		62 (33 M; 29 F)	

Abbreviations: AGRITEX, Department of Agricultural, Technical and Extension Services; DRSS, Department of Research and Specialist Services, Zimbabwe; F, females; FGD, Focus Group Discussions; ISABU, Institut des Sciences Agronomiques du Burundi; KIIs, Key Informant Interviews; M, males.

(2015–2021) and forward to 2035. These discount measures (NPV, IRR, and B/C ratio) are appropriate to show whether the intervention is worthwhile or not (Akinyi et al. 2022; Junia Mutenje et al. 2019; Ng'ang'a, Miller, and Girvetz 2021; Ombati Mogaka, Karanja Ng'ang'a, and Kiplangat Bett 2022; Rosegrant et al. 2023).

The profitability was assessed with incremental benefits measured by increased productivity (yield multiplied by the output price) compared to the counterfactual or business as usual (BAU) the value chain actors' practice. The counterfactual hypothesizes what would have happened if PABRA had not promoted improved bean varieties and complementary technologies, resulting in the continued use of previous bean technologies by producers. The difference in the estimated benefits between the two scenarios is assumed to be the incremental benefit generated by the intervention. The incremental costs of the intervention were measured by multiplying the changes in the units of inputs (e.g., fertilizers, seeds, etc.) and labor used by their corresponding unit costs.

3.2.1 | The Net Present Value (NPV)

The net annual value of benefits was calculated by subtracting annual costs from annual benefits and discounted using a discount factor and then summated to form the net present value. The NPV was calculated using the following formula.

$$\mathrm{NPV} = \frac{R_t}{(1+i)^t} \text{ or } \mathrm{NPV} = \sum_{t-1}^{n} \frac{C_t}{(1+y)^t} - I_{o.}$$

where NPV = net present value, R_t (or C_t) = net cash flow at time t, I (r) = discount rate, and t = time of the cash flow and I_o is the initial investment value.

For an intervention to be viable, the NPV ought to be zero or positive. A positive NPV indicates that the benefits outweigh the costs, which means that the capital invested in the program could be paid back plus interest (discount rate). A discount rate of 12% is generally accepted for agricultural projects to reflect the opportunity costs of capital and is commonly used in Burundi (WorldBank 2017) and Zimbabwe (Lachaud et al. 2018; USAID 2018b). A negative NPV means that the program is financially or economically loss-making and not viable.

3.2.2 | The Internal Rate of Return (IRR)

IRR for financial analysis and the economic rate of return (ERR) for economic analysis is the discount rate at which a program returns a zero NPV; thus, a break-even discount rate. It shows the return on the investment for every dollar spent. For an intervention to be viable, the IRR must be equal to or bigger than the discount rate used for the program. The IRR is determined as follows:

$$\mathrm{NPV} = \sum_{t-1}^{n} \frac{C_t}{(1+y)^t} - I_o = 0$$

where n = the program/investment's duration in years.

3.2.3 | The Benefit-to-Cost Ratio (BCR)

The BCR is the ratio of discounted benefits relative to its discounted costs. Because it is a ratio, the BCR is appropriate for comparing alternatives (or programs) with different NPVs. For a program to be viable, the BCR must be equal to or larger than 1.

3.3 | Data Used in the Model

Costs: We split the costs used in the CBA model into two categories: investment costs and operation and maintenance costs (O&M) for value chain actors. Investment costs include installation costs such as processing equipment, storage, processing, warehousing, and so on. Maintenance costs are incurred for recurrent operations during the project period 2015–2021 (e.g., for farmers include weeding, fertilizer application, etc.) while operation expenses (OPEX) occurred due to introducing new technology or practice such as transportation, insurance, licenses, bills-water, electricity, telephone. Estimating the business costs for value chain actors such as traders, seed merchants, seed multipliers, and processors entailed doing gross margins analysis for each actor. The variables used in the CBA are presented in Table 2.

Benefits: The benefits were anticipated as a result of the increased adoption of improved bean varieties and ICM practices, which ultimately boosted productivity and enhanced incomes for stakeholders across the bean value chain. The benefits were estimated for each actor as the gross income from the business or the farm.

The net benefits for each actor were calculated as the difference between the total annual benefits and the total annual costs. While the net incremental economic benefits were estimated by deducting the "counterfactual/business as usual (BAU)" net benefits from the "with intervention" net benefits for each value chain actor and for all actors along the bean value chain.

We compared the findings with similar studies in Africa and beyond to ensure reliability, consistency, and robustness. Estimates of the costs, benefits, NPVs, BCR, and incremental benefits were compared with the averages from the BAU scenarios.

3.4 | Sensitivity Analysis and Robustness Check

As explained in above, most analyses have singly used deterministic CBA to estimate NPV, IRR, and BCR. However, this approach often underestimates or overlooks uncertainties (risks) the value chain actors take when using a new technology or practice (Oberndorfer, Sander, and Fuchs 2020) and poses a challenge in measuring unintended outcomes (Smith et al. 2021). To address this, we further conducted sensitivity analysis to identify the sources of uncertainty (risks) and their impacts on the intervention outcomes to inform appropriate mitigation measures to reduce the exposure. Some of the risks include changes in market price, changes in production levels,

TABLE 2 | Data used in the cost–benefit analysis (CBA) and their sources.

Value chain actors	Data	Data sources
Bean producers	• Years of bean production • Varieties of commonly produced beans • Average land sizes (total in hectares) • Average land sizes under bean production • Costs of bean production (inputs, materials, services, and labor) • Average production volumes/acre (yield) in tonnes • Average bean price per kilogram • Value of production—total per acre/ha • Gross margins per hectare	Stakeholder workshops with farmer representatives Literature reviews and reports FGDs with selected bean farmers/farms KIIs with program staff
Bean seed merchants	• Total value of capital expenditure (CAPEX) investments between 2015 and 2021 • Operation expenses (OPEX) of doing business—bills, rates, licenses, fees, and so on • Quantity handled monthly in a season • Prices of bean products (seeds) sold • Total number of customers • Value of sales per year	KIIs—including online interviews with seed merchants FGDs and national workshops
Bean agro-dealers/suppliers	• Type of seeds sold—certified, quality declared, or uncertified • Total value of CAPEX investments for bean agro-dealers • Major business operation expenses (OPEX)—bills, rates, licenses, fees, and so on • Quantity handled monthly in a season in tonnes • Prices of bean products (seeds) sold • Value of sales per year	KIIs—including online interviews with bean agro-dealers/seed distributors Learning stakeholder workshop with the value chain actors
Bean aggregators, traders, and Processors	• Sources of bean markets/type of suppliers • Purchase prices per variety • CAPEX for business investments • Major business operational expenses (OPEX) (collection/aggregation, storage, transportation, insurance, licenses, water, electricity, telephone) • Average monthly volume of sales in tonnes • Average monthly value of sales • Gross margins per hectare	KIIs—including online interviews with bean off-takers/traders Learning stakeholder workshop with off-takers/traders
National Research Institutions (NARS)	• Major bean varieties developed and released in the last 5 years • Average bean program/unit annual research budget • Value of funds donated/provided by PABRA in the last 5 years	KIIs with bean researchers/program/NARs staff Literature reviews
Pan African Bean Research Alliance (PABRA)	• Total program budgets • Number of investees supported (seed merchants, traders/off-takers, processors) • Number of agro-dealers/seed businesses reached out/benefitted • Number of farmers (male, female, youth) benefitting • Other program impacts (nonmonetary)	Literature reviews KIIs with program staff

and so on. The percentage of change was based on the historical trend, especially during the implementation phase (2015–2021). As used in most CBA studies, our sensitivity analysis assumed changes of 10% on costs and benefits, or both, to create a worst-case and best-case scenario (Akinyi et al. 2022). The optimistic scenario assigns the most favorable values to the variables, while the pessimistic scenario assigns the least favorable values (Commonwealth of Australia 2006). The pessimistic scenario included a 10% increase in the cost and a decrease in benefits, while the contrary was applied to the optimistic scenario.

4 | Results and Discussion

4.1 | Investments

As elaborated in the Methods section, we calculated the additional investments from both public and private sources attracted by the initial PABRA investments in Burundi and Zimbabwe. Between 2015 and 2022, PABRA invested US$1.47 million in Burundi and US$1.78 million in Zimbabwe. Investment in beans functioned as an effective catalyst in generating significant additional funding and follow-on financing from various private and public stakeholders. In Burundi, an estimated US$249 million investments by farmers, processors, traders, and other public and private stakeholders were made during the project period with farmers and traders investing more than 96% (Table 3).

In Zimbabwe, additional investors contributed about US$732 million, with more than 95% being invested by farmers, traders, and processors during the same period (Table 3). These benefits have been achieved due to the increased adoption of improved varieties and ICM technologies, especially among women farmers who are the majority in Burundi (Nchanji et al. 2023) and Zimbabwe (Katungi et al. 2021). For instance, the increased use of improved varieties and complementary technologies has led to the expansion of land under bean production and currently, beans occupy 45% of the total cropped area in Burundi (Katungi et al. 2020). This demonstrates that bean is an important crop in Burundi, where it significantly contributes to the national GDP. However, if investment continued up to 2035, other value chain actors, including farmers and traders, would invest approximately US$5 billion in Burundi and US$5.5 billion in Zimbabwe, showing the potential contribution of the bean subsector to the economy.

4.2 | Economic Benefits

This section presents the results of the economic analysis. Between 2015 and 2022, bean yields in Burundi increased by 70%, while in Zimbabwe, they nearly doubled (see Table A1 in the Appendix 1). This remarkable growth resulted from the widespread adoption of improved seed varieties and enhanced crop management practices, particularly among women, who represent more than 60% of bean farmers in both countries. Investments from PABRA and from various value chain actors—ranging from traders and seed merchants to seed multipliers, farmers, and processors played a pivotal role, generating significant economic benefits.

The catalytic intervention attracted additional investments by farmers, public, and private bean value chain actors presented in Section 4.1. For instance, in Burundi, a total of US$310 million (NPV) and net incremental economic benefits of US$263 million were generated between 2015 and 2022, with a benefit-to-cost ratio (BCR) of 2.05[3] (Table 4). The incremental NPVs were calculated by subtracting the NPVs for the business as usual (BAU) or counterfactual from the total NPVs for the intervention. The investments in Zimbabwe generated an estimated net economic benefit of US$283 million from 2015 to 2022, with a BCR of 1.4. If the project or investment continues to 2035, net incremental economic benefits are estimated at US$3.2 billion in Burundi (BCR: 2.46) and US$1.44 billion (BCR: 1.51) in Zimbabwe.

The BCR is greater than one (2.05 and 2.46 in Burundi and 1.51 and 1.64 in Zimbabwe) which means that every dollar invested generated US$2.05 in Burundi and US$1.51 in Zimbabwe (Table 4). The positive NPV and BCR greater than one implies that the economic benefits of bean value chain improvement projects in the two countries are larger than their costs. Thus, the project is sustainable and can be replicated in other Sub-Saharan African and Asia countries.

4.3 | Distribution of the Economic Benefits by Value Chain Actors

Grain traders and bean farmers benefited the most in Burundi, earning over 99% of the net incremental benefits (traders' 22.5% and farmers 77%) (Table 5). The remainder of the benefits were earned by seed merchants (0.04%), seed multipliers (0.7%), and bean processors (0.04%). In Zimbabwe, producers, traders, and processors were the main beneficiaries, accounting for 41%, 24%, and 23% of the benefits, respectively, while the balance was shared amongst seed houses (8%) and seed multipliers (2.8%). Farmers and traders are the main beneficiaries, taking up 99% and 65% of the generated net benefits accrued in the bean value chain in Burundi and Zimbabwe, respectively. This investment in benefited large and vulnerable small traders, mostly women and youth in both countries. Processors, seed merchants, and multipliers in Zimbabwe earned higher net economic benefits than their counterparts in Burundi. This implies that Zimbabwe's food processing and seed system sectors are better established than Burundi's.

TABLE 3 | Investments by value chain actors between 2015–2022 and 2015–2035.

	Project period 2015–2022				Projection 2015–2035			
	Burundi		Zimbabwe		Burundi		Zimbabwe	
Value chain actors	US$ "000"	Percent	US$ "000"	Percent	US$ "000"	Percent	US$ "000"	Percent
Seed merchants	5403	2	16,592	2	39,022	0.8	74,582	1.4
Seed multipliers	3937	2	12,715	2	23,589	0.5	66,132	1.2
Farmers	80,169	32	324,722	44	1,446,238	28.6	2,674,394	48.6
Traders	158,370	64	188,859	26	3,531,092	69.9	1,918,119	34.8
Processors	1374	1	189,491	26	8729	0.2	774,282	14.1
Total	249,253	100	732,377	100	5,048,669	100	5,507,509	100

Note: 1US$ =3000 Burundi Francs (BIF), In Zimbabwe, US$ dollars was used.

TABLE 4 | Economic NPVs of the BAU case and intervention at 12% discount rate.

Period	Country	Business as usual (BAU) or counterfactual (US$)	With intervention (US$)	Net incremental benefit (US$)	Benefit–cost ratio (BCR)[a]
2015–2022	Burundi	46,404,626	310,091,349	263,686,723	2.05
	Zimbabwe	82,874,117	366,744,785	283,870,669	1.39
2015–2035	Burundi	259,601,601	3,465,048,623	3,205,447,022	2.46
	Zimbabwe	288,541,883	1,729,342,911	1,440,802,027	1.51

[a]IRR > discount rate.

TABLE 5 | Net incremental economic benefits per value chain actor discounted at 12%, 2015–2035.

	Zimbabwe			Burundi		
Actors	NPV	BCR	Percent	NPV	BCR[a]	Percent
Seed houses or merchants	104,829,907	1.9	7.7	1,356,372	1.1	0.04
Seed multipliers	62,624,594	2.7	4.6	2,173,978	1.2	0.07
Farmers	386,810,896	1.3	28.3	2,478,728,004	4.9	77.27
Traders/aggregators	274,531,231	1.3	20.1	724,155,706	1.5	22.58
Processors	537,930,205	2.2	39.4	1,346,495	1.3	0.04
Total	1,366,726,833		100	3,207,760,555		100

[a]IRR > discount rate.

4.4 | Gender and Other Socioeconomic Benefits

As presented in Table 5 above, farmers and traders benefited the most taking up 99% of the economic benefits in Burundi while farmers and processors earned 87% of the economic benefits in Zimbabwe. To better understand the distribution of the economic benefits, we further disaggregated the economic gains by gender of the farmer and by the size of businesses for traders and processors, in order to identify the groups that benefit the most (Table 6).

In Burundi, approximately 60% of the benefits generated by farmers were accrued to women totaling around US$ 1.4 billion. In Zimbabwe, among farmers, women earned 40% of the benefits while youth received 10%. In Burundi, 50% of the net benefits went to village-based small traders, while 20% and 30% accrued to large and medium traders, respectively. These results demonstrate that investment in bean value chains benefits both large and vulnerable small traders in both countries who are mostly women and youth. These results challenge the common criticisms that development efforts in Sub-Saharan Africa typically prioritize the needs of large commercial producers, traders, and merchants, rather than fostering the needs and participation of women, rural and less commercial traders (Siri, Nchanji, and Tchouamo 2020). More women bean producers benefited from improved bean value chains as they were more likely to adopt nonpurchased ICM technologies such as organic soil fertility management practices and good agronomic practices (GAPs) than their male counterparts (Katungi et al. 2021).

The investment equally created more job opportunities and private enterprises. In Burundi, four processors, namely, Totahara, Safina Industry Company (SAICO), Kaflobe, and Rengerubuzima, created at least 145 new product outlets or enterprises that includes 142 traders and three cooperatives. During the project, the number of small and medium seed enterprises (SMSEs) increased from 15 producing 10 tons in 2014, to 315 (55% of them women-led) producing 1595 tons of certified and quality declared seed (QDS) by 2021 (Eric Nduwarugira et al. 2022). An estimated 1,969 traders benefitted from increased production, which resulted in greater harvests being available for sale. These enterprises created employment opportunities for at least 1,162 people, 51% of whom are women (PABRA 2021). This includes much more casual labor and other indirect employment opportunities.

In Zimbabwe, the project supported the creation of 15 new seed enterprises, more than 50% led and owned by women, while indirectly supporting many more individuals and seed enterprises. These provided more than 10,000 direct employment opportunities (56% female) and many more indirect employment opportunities for women and youth (Figure 1). The percentage of women employed in seed companies and aggregator or trader businesses grew from 10% in 2014 to 38% in 2021, while the number of processors increased from five in 2015 to 15 in 2022, which significantly increased the investment in the bean value chain in Zimbabwe.

4.5 | Sensitivity Analysis and Robustness Check

The performance of the project in the base scenario (2015–2022) is considered robust to economic shocks within best- and worst-case scenarios during the project period and projected to the future up to 2035[4]. Table 7 presents the annual sensitivity analysis indicating base, best-, and worst-case scenarios during implementation phase

TABLE 6 | Distribution of economic benefits by gender and size of the business.

Actor		Burundi		Zimbabwe	
Farmers	Net benefits earned (US$)	2,478,728,004		386,810,896	
		Share %	**in US$**	**Share %**	**in US$**
	Male	60	1,487,236,802	50	193,405,448
	Female	40	991,491,202	40	154,724,358
	Youth	—	—	10	38,681,089
Traders	Net benefits earned (US$)	724,155,706		274,531,231	
		Share %	**in US$**	**Share %**	**in US$**
	Small	50	362,077,853	40	109,812,492
	Medium	30	217,246,712	30	82,359,369
	Large	20	144,831,141	30	82,359,369
Processors	Net benefits earned (US$)	1,346,495		537,930,205	
		Share %	**in US$**	**Share %**	**in US$**
	Small	70	942,547	20	107,586,041
	Medium	30	403,949	30	161,379,062
	Large	—	—	50	268,965,103

Note: Traders: Small—≤100 Metric tonnes per year; Medium—≥100; Large—≥300. Processors: Small—=≤500 Metric tonnes per year; Medium—≥500; Large—≥1500.

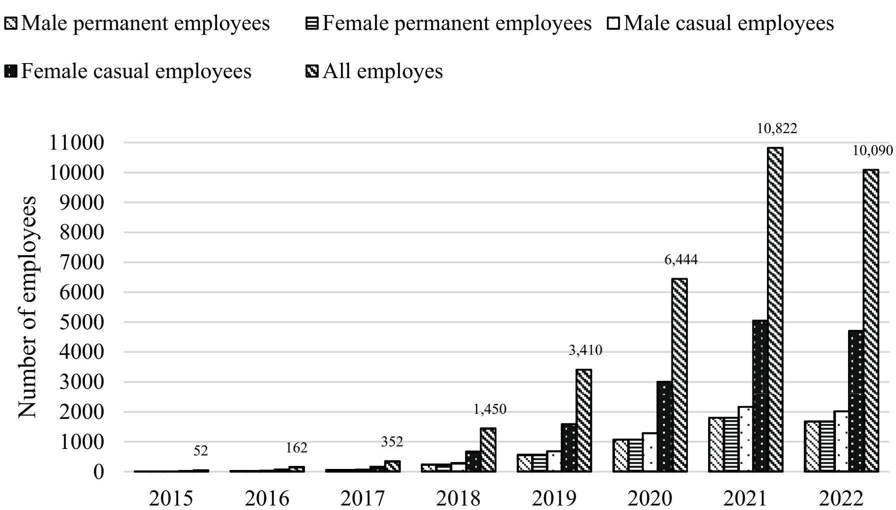

FIGURE 1 | Number of employment opportunities created.

and projections for 20-year period. In the best-case scenario, the BCR increases to 3.01 from the base scenario of 2.46, while it drops to 2.02 in the worst-case scenario. The NPV remains positive, and the BCR still remains greater than 1 even in the pessimistic scenario (worst case). This clearly indicates that such interventions are sustainable and can address the food and nutrition security challenges and enhance incomes through increased bean production, distribution, processing, and consumption.

The robustness check results indicate that the economic benefits are still positive even if FAO and ISTEEBU data are used in the analysis (Table 8). Net present values (NPVs) are positive and benefit–cost ratios (BCR) are greater than one in both worst- and best-case scenarios making the intervention sustainable to address food, nutrition, and income challenges in the two countries.

4.6 | Influence on Policy and Programming

The project also influenced government policy and programming by ensuring recognition of high iron bean (HIB) varieties within the government's agricultural input support program. In Burundi, the government integrated HIB and bean-based products in the school feeding program to improve the nutrition of school learners. The World Food Program (WFP), World Vision International, and other partners supported the integration of bio-fortified beans in the school feeding program. Bio-fortified beans have also become one of the major value chains promoted by Burundi's First Lady's Foundation, known as the Good Action Foundation "Umugiraneza." In Zimbabwe, the promulgation of a mandatory food fortification policy resulted in increased demand for bio-fortified crops such as beans, and processors have begun to commercialize bio-fortified beans. Additionally, the project influenced the government to support the bean subsector by recognizing beans as a strategic crop and including it in the Pvumvudza Presidential Conservation Farming Program launched in 2021[5]. The program distributed small packs of seeds of new varieties in partnership with the Department of Research and Specialist Services (DRSS) and the Ministry of Health. These achievements demonstrate that beans have been recognized as an important crop with potential for improving food and nutrition security, economic opportunities, and agroecosystems in Burundi and Zimbabwe.

5 | Conclusion and Recommendations

Several studies have evaluated the economic impacts of food and nutrition security interventions in Sub-Saharan Africa. However, only a few have comprehensively considered the costs and benefits (both financial and economic) of all the actors, including farmers, seed multipliers, seed companies, traders or aggregators, and processors in a crop value chain. This study, therefore, fills this gap by using common beans as an example. The project's economic benefits exceed the costs, as demonstrated by positive net present values (NPVs) and benefit–cost ratio (BCR) greater than one. The results

TABLE 7 | Sensitivity analysis using the pessimistic (worst case)–optimistic (best case) scenarios, discounted at 12%.

	Zimbabwe "US$"		Burundi "US$"	
	2015–2035	**2015–2022**	**2015–2035**	**2015–2022**
Best case				
PV benefits	5,418,554,500	1,294,932,062	5,932,896,987	563,932,450
PV costs	(2,700,389,136)	(703,619,129)	(1,970,862,770)	(225,216,481)
NPV	2,717,165,363	591,312,934	3,962,034,217	338,715,969
BCR[a]	2.01	1.84	3.01	2.50
Worst case				
PV benefits	4,432,544,591	1,059,489,869	4,854,188,444	461,399,277
PV costs	(3,300,475,611)	(859,978,935)	(2,408,832,275)	(275,264,588)
NPV	1,132,068,980	199,510,935	2,445,356,169	186,134,689
BCR	1.34	1.23	2.02	1.68
Base case (BAU)				
PV benefits	4,246,906,898	1,016,249,321	5,393,542,716	512,665,864
PV costs	(2,806,104,871)	(732,378,652)	(2,189,847,523)	(250,240,535)
NPV	1,440,802,027	283,870,669	3,203,695,193	262,425,329
BCR	1.51	1.39	2.46	2.05

[a]IRR > discount rate.

TABLE 8 | Robustness checks using different yield data sets at 12% discount rate.

	Zimbabwe "US$"		Burundi "US$"	
Data source	**2015–2035**	**2015–2022**	**2015–2035**	**2015–2022**
Source: On-farm yield data				
NPV	1,924,617,172	395,411,934	3,203,695,193	262,425,329
BCR[a]	1.64	1.51	2.46	2.05
Source: FAO and ISTEEBU data				
NPV	1,123,950,417	222,407,008	3,205,447,022	333,483,164
BCR	1.43	1.32	2.58	2.29

[a]IRR > discount rate.

are similar even when the Food and Agriculture Organization (FAO) and Burundi Institute of Statistics and Economic Studies (ISTEEBU) productivity data are used. This implies that the intervention is effective in increasing incomes and addressing food and nutrition challenges, as well as sustainable and robust to economic shocks and risks, making it worth replicating in other countries in sub-Sahara Africa and beyond.

Farmers and traders are the primary beneficiaries, receiving 99% and 65% of the net benefits generated in the bean value chain in Burundi and Zimbabwe, respectively. The initiative had a notable impact on women and rural based, less commercial small traders who are mostly women and youth by providing them with significant economic opportunities. Furthermore, common beans have been incorporated into the national policies in Burundi where beans are now integrated into school feeding programs to improve the nutrition of school meals for learners. Similarly, in Zimbabwe, high iron beans (HIBs) were included as a strategic crop under the national program called Pvumvudza Presidential Conservation Farming Program launched in 2021. The intervention has also fostered inclusivity and equity, with women and small traders emerging as key beneficiaries within the bean value chain, ensuring broader access to the benefits for enhanced livelihoods.

Nevertheless, based on this paper, there is still room for improvements or investments for improving livelihoods through increasing food and nutrition security, employment opportunities, and incomes, especially with respect to the following: (1) strengthening demand-driven bean breeding programs, including developing climate resilient and consumer and farmer-preferred varieties including bio-fortified ones; (2) deepening and commercialization of seed systems to attract more investments along the bean value chains; (3) increasing and diversifying the consumption of bio-fortified beans at the household level, and (4) developing and optimizing convenient, highly nutritious bean-based products while fostering women and youth entrepreneurs and creating employment opportunities for enhanced sustainable resilience.

Author Contributions

Ochieng Justus, Joel Maina, Doug White, Jean Claude Rubyogo, Enid Katungi; Eliud Birachi, Eric Nduwarugira, Bararyenya Astère, and Andrew Chiwawa conceived the idea for the manuscript. Ochieng Justus, Joel Maina, and Ruth Chipchirchir performed literature search and data collection and wrote the initial draft with support from Jean Claude Rubyogo and Doug White, Andrew Chiwawa, Enid Katungi; Eric Nduwarugira; Bararyenya Astère; Mercy Mutua and Blaise Ndabashinze; Nepomuscene Ntukamazina and Shylet Tsekenedza. All authors read, reviewed, and approved the final manuscript.

Acknowledgments

The study was funded by the Swiss Agency for Development and Cooperation (SDC), in the Federal Administration of Switzerland, and the Federal Department of Foreign Affairs, grant number 81031140. This analysis relied on input from many organizations, including National Agricultural Research Organizations (NARs), farmer groups, and individuals who contributed to this research. Besides, we recognize the invaluable information provided by different bean value chain actors such as seed companies and merchants, seed multipliers, farmers representatives, bean grain traders, bean processors, government and NGO stakeholders that collaborated in the PABRA program in Burundi and Zimbabwe between 2015 and 2022.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data are available upon reasonable request.

Endnotes

[1] Details of the intervention is provided in Section 2.

[2] Detailed information about PABRA is available at https://www.pabra-africa.org/.

[3] IRR is a discount rate that makes the net present value (NPV) of all cash flows equal to zero.

[4] Sensitivity analysis for the project assumed changes in 10% on costs and on project benefits, or both to create a worst-case (pessimistic) scenario and best-case (optimistic) scenario.

[5] More information about the program is available through the link: https://www.future-agricultures.org/blog/can-the-pfumvudza-conservation-agriculture-programme-deliver-food-security-in-zimbabwe/.

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Appendix 1

TABLE A1 | Yield data used in the cost–benefit analysis (CBA) model in Burundi and Zimbabwe.

Year	Burundi						Zimbabwe	
	Total production (tonnes)	Area under production (hectares)	Yield (kg/ha)	On-farm data (kg/ha)				
		FAO 2023	Calculated	Bush	Climber	Average (B&C)	Yield (kg/ha)	On-farm (kg/ha)
2015	282,978	355,685	796	557	685	621	440	415
2016	371,892	588,096	632	613	754	683.5	670	357
2017	430,473	574,267	750	669	822	745.5	590	581
2018	393,233	599,139	656	724	891	807.5	570	794
2019	619,151	976,125	634	780	959	869.5	600	272
2020	742,274	743,674	998	836	1028	932	860	673
2021	953,893	819,674	1164	892	1096	994	900	654
2022	953,893	859,236	1110	947	1165	1056	580	526
Source:	ISTEEBU (2021), RDB (2018) and FAO (2023)			Katungi et al. (2020) and PABRA (2022)			FAO (2023)	PABRA (2022)