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Costs and returns in Rwandan smallholder agricultural production

Gross margins and profitability analyses

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ABSTRACT

This paper explores crop commercialization among smallholder agricultural households in Rwanda from a cost and revenue perspective to determine profitability at the farm level. We use standard revenue and cost equations to assess the commercial viability of the smallholders. In general, we find that a household's total crop production creates positive returns even if implicit costs, such as own family labor and fertilizer subsidies, are included. Specifically, over 80 percent of our sample households generated positive economic returns from farming— referred to as demonstrating a positive gross economic margin (GEM). However, if only crop market sales and market input costs are used in the calculations, only 40 percent of agricultural households generated positive returns—referred to as demonstrating a positive gross marketing margin (GMM).

Most of the explanation for this difference is that the typical farm household sells only about one-third of its crop production by value. This outcome suggests that many agricultural households continue to focus on cultivating food crops for their own consumption and do not specialize in commercial production. This is to be expected in an economic context where input, credit, and commodity markets are still developing, production decisions are still shaped by high levels of weather and market risk, and production risk management options are limited, among many other factors. The results of this research provide a better understanding of how Rwandan smallholders might move towards higher value production, with the ultimate goal being to increase household revenues and welfare and accelerate the country's economic transformation.

1 INTRODUCTION

Typical of most African countries, the majority of Rwanda's population is engaged in smallholder farming. About 69 percent of all households are identified as agricultural households, either engaged in crop production, animal husbandry, or a combination of both (NISR 2023). Smallholder agricultural production contributes about 35 percent of production value to the national economy and 63 percent of exports (NISR 2021). However, most agricultural households produce relatively small outputs because of extremely small farm and plot sizes, limited use of modern inputs, heavy reliance on rain-fed production, and constraints on their access to credit and markets (MINAGRI 2019). In addition, research suggests that both insufficient capacity training and market rigidities limit the commercial activities of rural smallholders (Weatherspoon et al. 2021).

The government of Rwanda has initiated several policies and programs to transform the agricultural sector from subsistence farming to a sustainable, value-creating, market-oriented food sector, with the aim of increasing smallholder farmers' productivity, income, and welfare while simultaneously increasing regional and global trade (MINAGRI 2019). Key programs include the Land Use Consolidation (LUC) program and the Crop Intensification Program (CIP), both of which have increased access to land, inputs, extension services, markets, and supply chains for smallholder agricultural households (Weatherspoon et al. 2021). LUC and CIP have contributed to increased yields for several crops. However, key development issues remain for smallholder households in Rwanda, especially concerning food security, levels of commercialization, and, ultimately, welfare enhancement (Weatherspoon et al. 2021, Singirankabo et al. 2022).

This paper explores crop commercialization from a cost and revenue perspective to determine profitability at the farm level. We use standard revenue and cost equations to assess the commercial viability of smallholder agricultural households in Rwanda. In general, we find that a household's total crop production creates positive returns even if implicit costs, such as own family labor and fertilizer subsidies, are included. Specifically, over 80 percent of our sample households generated positive economic returns from farming— referred to as demonstrating a positive gross economic margin (GEM). However, if only crop market sales and market input costs are used in the calculations, only 40 percent generated positive returns—referred to as demonstrating a positive gross marketing margin (GMM).

Most of the explanation for this difference is because the typical farm household sells only about one-third of its crop production by value. Obviously, if a household consumes two-thirds of its production, then the marketing margins it obtains will be low relative to its GEM. However, it is important to recognize that this difference between GEM and GMM is not necessarily an undesirable finding. Rather, this outcome suggests that many agricultural households continue to focus on cultivating food crops for their own consumption and have not specialized in producing crops for commercial sale. This is to be expected in an economic context where input, credit, and commodity markets are still developing, production decisions are still shaped by high levels of weather and market risk, and production risk management options are limited, among many other factors.

The objective of this research is to provide a better understanding of how Rwandan smallholders might move towards higher-value production, with the ultimate goal being to increase household revenues and welfare and accelerate the country's economic transformation. By exploring costs, revenues, and gross margins, this paper identifies several aspects of agricultural commercialization that are important for understanding how Rwandan agricultural households interact with markets and the implications of these interactions for agricultural and economic development.

The paper is structured as follows: the next section outlines data sources and analytical methods; section three outlines results; section four discusses the results; and section five provides conclusions and policy recommendations.

2 DATA AND METHODOLOGY

2.1 Data

The analysis of the costs, returns, and profitability of the agricultural activities of smallholder agricultural households in Rwanda is based on a nationally representative smallholder agricultural household survey conducted in 2022 (IFPRI 2024). A two-stage stratification cluster sampling method was used to ensure sufficient representation in the sample. The first stage consisted of selecting enumeration areas based on probability proportional to size from the Rwanda 2012 Population and Housing Census, adjusted for subsampling effects.[1] The resulting sample, which is representative at the national level, includes 2,020 households selected from the five main provinces of Rwanda.

2.2 Analysis of agricultural profitability

To determine profitability, a budgetary analysis was used to assess the revenues and costs of the agricultural activities of farming households during the 2022 agriculture season. The cost analysis included the calculation of variable and fixed costs.[2] The total variable cost (TVC) analysis considers expenses and expenditures for farming operation inputs, including seed, fertilizer, transportation, and costs of hired labor costs for land preparation, planting, fertilizer application, weeding, harvesting, and loading, and offloading produce. The total fixed cost (TFC) analysis considers the costs of renting land, irrigation, and smaller costs related to managing the farmland but not associated with producing crops. Conversely, total revenue (TR) is the monetary value of all crop production sold by the households. Taken together, TR minus TVC determines GMM (Aliyi et al. 2021).

To compute GEM for a farming household, first, the total economic revenue (TER), which includes the monetary value of all crop production, including that of crops used for own consumption, sold on the market, used as seeds, or used for other household purposes, is computed. The sum of actual and implicit costs—the monetary value of all direct market input costs, plus the value of implicit subsidies and the value of family labor used for different activities—then is subtracted from the TER to arrive at the GEM value.

The components of smallholder agricultural household profitability are defined more formally in Table 2.1. The profit index is expressed as a binary variable (0/1) where one is assigned to a household that obtained a positive gross margin from their farming activities, specifically GMM>0. This indicates that the household revenues from agriculture production are greater than its production costs—for its agricultural activities, the household is spending

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1 At the time the survey design was prepared, data collection for the 2022 Population and Housing Census had just been completed, so the data required to ensure a more up-to-date sampling frame were not publicly available.

2 Total variable costs, or direct costs, are costs associated with the level of output. Total fixed costs, or overhead costs, are costs that do not change with production and are not directly related to the level of production.

less financial resources than they are receiving in market-derived revenue. On the other hand, a value of zero refers to a negative gross margin, which arises when total revenue is less than production costs.

Table 2.1 Economic and market cost and return equations

Elements of costs and returns	Equation
1. Total Revenue (TR)	Sum of all income from crops sold
2. Total Economic Revenue (TER)	Monetary value of all crop production, whether sold or not
3. Total Variable Costs (TVC)	Sum of all input costs, such as hired labor, transport, fertilizer, etc.
4. Total Variable Economic Costs (TVEC)	Sum of implicit family labor costs, subsidies, and TVC
5. Total Fixed Costs (TFC)	Sum of all fixed costs, including renting land and irrigation
6. Total Costs (TC)	Sum of TVC and TFC
7. Total Economic Costs (TEC)	Sum of TVEC and TFC
8. Gross Marketing Margin (GMM)	GMM = TR – TVC
9. Gross Economic Margin (GEM)	GEM = TER – TVEC
10. Net Farm Income (NFI)	NFI = GMM – TFC
11. Economic Net Farm Income (ENFI)	ENFI = GEM – TFC
12. Profit Index	GMM >0
13. Economic Profit Index	GEM >0
14. Net Rate of Return (NRR)	NRR = NFI /TC
15. Economic Net Rate of Return (ENRR)	ENRR = ENFI /TEC

Source: Adapted from Mauki et al. 2023.

We also measure relative profitability using the net rate of return.[3] A net rate of return greater than one indicates that farm agriculture activities are profitable, at least using market values. The economic profit index and economic net rate of return can be used more inclusively to include all crop value produced and all implicit costs.

2.3 Analytical methods

This study employs probit regression models to analyze the determinants of profitability for rural smallholder agricultural households in Rwanda. The mathematical foundation of the probit model is grounded in the cumulative distribution function of the standard normal distribution of a binary variable (Brooks 2014). The probability that a rural smallholder farmer will achieve a positive GMM can be expressed as follows (Kimbi et al. 2021):

$$P(Y = 1|X) = \Phi(X\beta) \tag{1}$$

where $P(Y = 1|X)$ is the probability that the dependent variable Y equals 1, given the vector of independent variables X, Φ represents the cumulative distribution function of the standard normal distribution, and β is the vector of coefficients that measure the impact of each independent variable on the likelihood that $Y = 1$. The objective of the model is to estimate unbiased, efficient parameters $\hat{\beta}$.

Maximum likelihood estimation (MLE) is used to determine the probit model parameters. This method involves finding the parameter values that maximize the likelihood function, which, for the probit model, is the probability of observing the sample data given the

[3] The net rate of return is expressed as a ratio, dividing the net farm income by the total costs incurred. A ratio of one indicates the revenues are just sufficient to cover costs, resulting in a break-even situation (no profit, no loss). A value greater than one means revenues exceed costs, indicating a profit, while a value less than one is a loss. For the purposes here, a net rate of return greater than one indicates that for every RWF of cost incurred, the farm is generating more than one RWF of revenue, which translates into a profitable agricultural activity based on the identified values of inputs and outputs.

estimated parameters. The likelihood function for a sample of n observations can be written as:

$$L(\beta|X,Y) = \prod_{i=1}^{n}[\Phi(X_i\beta)]^{Y_i}\,[1-\Phi(X_i\beta]^{1-Y_i} \quad (2)$$

where Y_i is the observed binary outcome for observation i, and X_i is the vector of independent variables for observation i. MLE seeks to maximize $L(\beta|X,Y)$ with respect to β, providing the estimated coefficients that best explain the relationship between the independent variables and the binary outcome.

Through this probit regression analysis, the study aims to contribute to determining the factors influencing agricultural household GEM and GMM. The overall goal is to better explain the drivers of the gross margins obtained by smallholder farming households in Rwanda, as well as to provide policy recommendations based on this improved understanding of the drivers.

Descriptions of the variables used in our probit models are outlined in Table 2.2, together with the expected signs on the coefficients for each variable. The two probit models predict how our independent variables of interest influence either GEM or GMM. While the coefficients for most variables would be expected to have the same sign for both models, it is possible to have different signs. For example, most food crops should generally contribute positively to GEM based on the likelihood that total economic revenue should be greater than total economic costs. However, since food crops are generally consumed by the producing household, it is plausible that food crops would have a negative impact on GMMs because the reduced marketed output subtracted from total economic variable costs would tend to have a negative impact on GMM.

Table 2.2 Independent variables used in regression models

Variable	Measure	Expected sign	
		Economic	Market
Household demographics			
Female household head, 0/1	binary	+	–
Mature household head, i.e., older than 35 years, 0/1	binary	+/–	+/–
Household size, number	discrete	–	–
Household head completed primary school or more, 0/1	binary	+	+
Land size and land management			
Land size, ha	continuous	+/–	+/–
Plots, number	discrete	+	+
Household practices monocropping, 0/1	binary	+/–	+/–
Access to fertilizer and seed through SNS extension, 0/1	binary	+	+
Household using Twigire-Muhinzi program, 0/1	binary	+	+
Household using anti-erosion measures, 0/1	binary	–	–
Household using irrigation practices, 0/1	binary	+	+
Inputs			
Seed cost, RWF/ha	continuous	–	–
Transport cost, RWF/ha	continuous	–	–
Insurance cost, RWF/ha	continuous	–	–
Household using organic and inorganic fertilizer, 0/1	binary	+/–	+/–
Labor			
Labor cost, RWF/ha	continuous	–	–
Household hiring in-labor, 0/1	binary	+	+
Household hiring in-labor and working for wage labor, 0/1	binary	+	+

Variable	Measure	Expected sign	
		Economic	Market
Crop choice			
Maize, 0/1	binary	+	–
Sorghum, 0/1	binary	+	–
Beans, 0/1	binary	+/–	–
Banana, 0/1	binary	+	+
Root and tuber crops, 0/1	binary	+	–
Cash crop, 0/1	binary	+	+
Vegetables and legumes, 0/1	binary	+	+
Fruit, 0/1	binary	+	+
Location			
Travel time to nearest market, minutes	continuous	+/–	–
Kigali Province, 0/1 (base category)	binary	+/–	+/–
Southern Province, 0/1	binary	+/–	+/–
Western Province, 0/1	binary	+/–	+/–
Northern Province, 0/1	binary	+/–	+/–
Eastern Province, 0/1	binary	+/–	+/–

Source: Authors' compilation.

3 FINDINGS

3.1 Market analysis

The relationship between production costs and income helps determine the profitability of the agricultural activities of farming households. A detailed exposition of average costs and revenue for smallholder agricultural households in Rwanda is presented in Table 3.1 and Table 3.2. Rather than absolute values per household, we normalize the values on a per hectare basis to enable direct comparisons between households with different landholding sizes.[4]

The average market revenue from crop production that was sold is estimated to be RWF 322,892 per hectare. The corresponding average total market cost is RWF 463,534 per hectare. The breakdown of production costs shows that around 82 percent of production costs are for variable costs, including the purchase of fertilizer, seed, and hired labor. The remaining 18 percent are fixed costs, largely made up of rental payments for land.

On average, the GMM of a household in the 2022 agricultural season was RWF –57,483 per hectare or a loss of RWF 20,119 per 0.35 hectares, the average agricultural landholding size in our sample. Overall, only 41 percent of households reported positive GMMs. Smallholder households are earning a return on their investment, which is less than double their costs. More specifically, for every RWF 1.00 spent on costs, the agricultural household is earning RWF 0.52 of net profit. This low net rate of return is likely due to a combination of high input costs, low crop yields, low market prices, and, most importantly, the fact that the average household directly consumes two-thirds of its output.

[4] Per hectare comparisons are necessary to make meaningful contrasts between different land size holders. However, because the average land holdings are 0.35 ha in our sample, these values are essentially triple the value or cost that a typical farming household might receive.

Table 3.1 Market cost analysis of smallholder agricultural households, per hectare

Budget items	Average cost, RWF/ha	Percent of total cost
1. Variable Costs		
Fertilizer cost	135,881	29.3
Seed cost	109,356	23.6
Hired labor costs	122,835	26.5
Transport cost	6,649	1.4
Crop insurance	937	0.2
Other costs (post-harvest losses, soil erosion, etc.)	4,718	1.0
Market total variable costs (MTVC)	**380,375**	**82.1**
2. Fixed cost		
Cost of renting land	81,002	17.5
Irrigation cost	2,157	0.5
Market total fixed costs (MTFC)	**83,159**	**17.9**
3. Market total costs (MTC) = MTVC + MTFC	**463,534**	**100.0**

Source: Authors' calculations
Note: Values are based on 2022 agricultural season prices.

Table 3.2 Market profitability analysis among smallholder agricultural households, per hectare

Budget items	Average value, RWF/ha	Median value, RWF/ha
Total revenues (TR)	322,892	153,500
Total variable cost (TVC)	380,375	198,037
Total fixed cost (TFC)	83,159	0
Total costs (TC)	463,534	251,708
Gross marketing margin (GMM) = TR – TVC	–57,483	
Net farm income (NFI) = GM – TFC	–140,642	
Profit index (GM >0)	41%	
Net rate of return (NRR = NFI /TC)[5]	0.52	

Source: Authors' calculations
Note: Values are based on 2022 agricultural season prices.

The average market revenue and cost values are approximately twice their median values (Table 3.2), which indicates that these values are not normally distributed. There likely are some relatively larger commercialized agricultural households that have significantly higher market costs and revenues than the median household. At the same time, 22 percent of the agricultural households sampled in the survey reported not selling any crops at all.

3.2 Economic analysis

To better understand the large component of crops directly consumed by agricultural households, we summed the value of crops consumed and used by the household for other purposes, like saving for seed, with the value of crops sold into an aggregated total value. Estimates of average total economic revenue are approximately RWF 900,000 per hectare. From these total economic revenues, we subtracted both market and implicit costs. The results obtained from this analysis are GEMs. We find that 82 percent of agricultural households obtained positive GEMs (Table 3.3).

[5] This net rate of return (0.52) is obtained by using the household averages of all household ratios, not the direct division between NFI and TC as depicted in Table 3.1.

Table 3.3 Economic profitability analysis among smallholder agricultural households, per hectare

Budget items	Household average, RWF	Household median, RWF
Total economic revenue (TER)	900,428	681,165
Total variable economic cost (TVEC)	446,172	228,370
Total fixed cost (TFC)	83,159	0
Total economic costs (TEC)	529,331	287,052
Gross economic margin (GEM) = TER – TVEC	**454,256**	
Economic net farm income (ENFI) = GEM – TFC	**371,097**	
Economic profit index (GEM >0)	82%	
Net economic rate of return (NERR) = ENFI /TEC	3.2	

Source: Authors' calculations
Note: Values are based on 2022 agricultural season prices.

This is consistent with other findings on the economics of smallholder agriculture in Rwanda (Weatherspoon et al. 2021; Warner et al. 2023). Average total economic costs are estimated to be RWF 530,000 per hectare, which is 14 percent greater than the total market cost expressed in Table 3.2. The slight increase in costs is related to additional family labor costs and subsidies for NPK, urea, and DAP fertilizers, which are applied to crop input expenses. Because total economic revenue increased significantly compared to total market revenues and total economic costs did not change much compared to the market costs reported in Table 3.2, there is a large increase in the number of smallholder agricultural households with an overall positive GEM—82 percent of agricultural households produced positive GEMs with an estimated average 3.2 overall net economic rate of return. Using this methodology, the net economic rates of return are far more positive and well above the value of 1.0, which typically is thought of as a modest rate of return. From this perspective, farming is a much better value proposition than our market analysis would suggest.

3.3 Graphic analysis of market and economic profitability

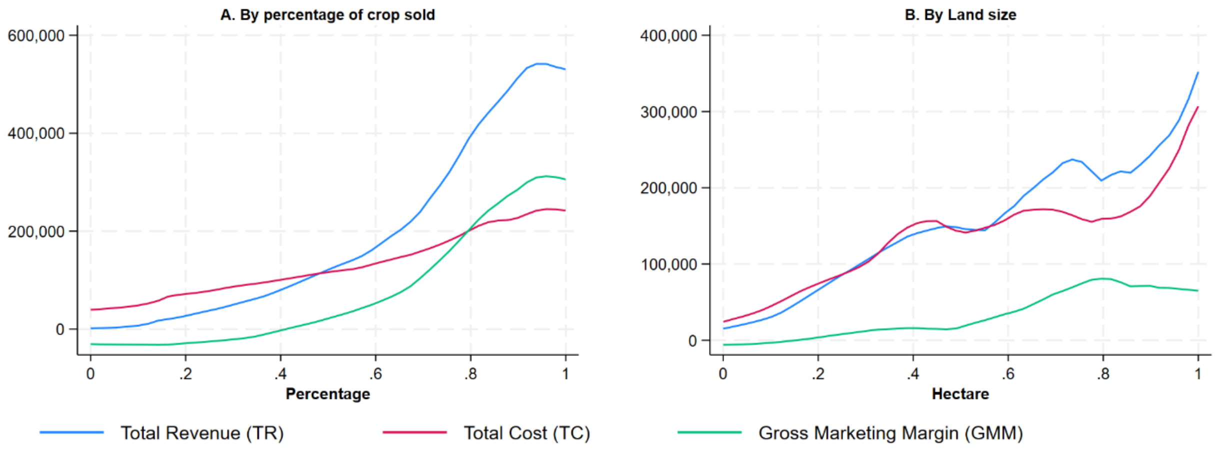
In Figure 3.1, aggregate household costs, revenues, and resulting gross margins are plotted by the percentage of crops sold (left graph) and by land size (right graph). To show aggregate effects on households, we do not adjust for land size, so the values are not presented on a per hectare basis as elsewhere.[6]

The left graph in Figure 3.1 demonstrates that greater market revenue is generated as the percentage of crop value sold increased. While a positive relationship would seem obvious, it is interesting that the total revenue slope is steepest between 60 and 90 percent of crops sold and then flattens out or declines slightly after 90 percent. GMMs turn positive at around the 40 percent crop sales level and increase thereafter.

The right graph in Figure 3.1 depicts revenues and costs by increasing land size. While total revenue increases with land size, so do costs, although a temporary divergence in revenues and costs is seen in landholding sizes between 0.6 and 0.8 hectares. As a result, rising gross market margins are experienced after 0.6 ha but flatten just after 0.8 hectares. The right graph demonstrates that owning more land is positively correlated with both total revenue and total cost, effectively leaving little impact on GMMs.

[6] For graphing reasons, we focused only on households with less than 1ha, or about 95 percent of our sample.

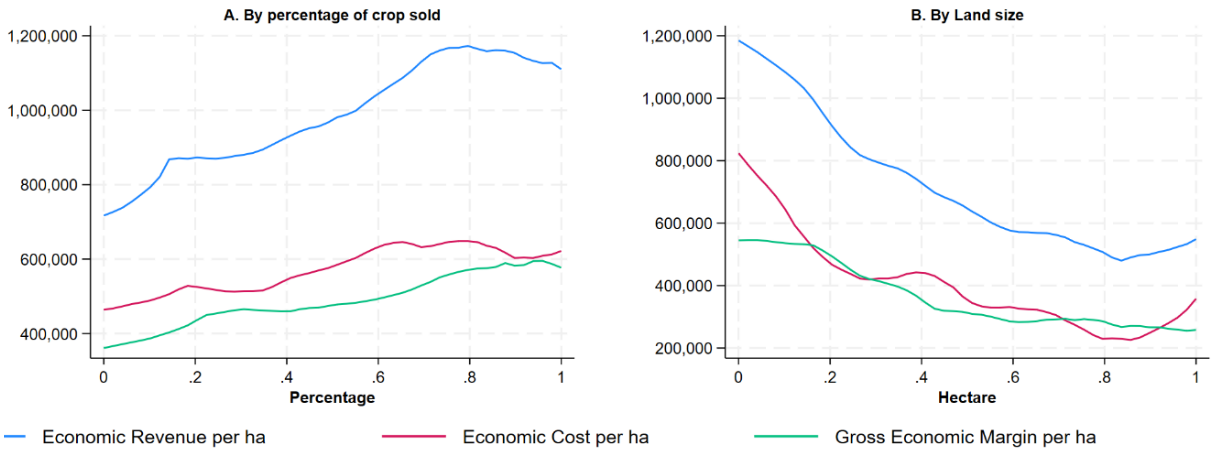
Figure 3.1 Market cost and revenue by percent of crop sold and land size, RWF



Source: Authors' calculations

The graphs in Figure 3.2 explore total economic revenue, total economic costs, and gross economic margins, adjusted for land size for more direct comparisons. As would generally be expected, in the left graph, total economic revenues increase with the percentage of crop sold. Costs are relatively consistent across all levels of percentage of crops sold. This is a somewhat counterintuitive pattern, as one might expect agricultural households to sell more of their crops to purchase additional inputs to increase the amount of produce they sell. Given increasing economic value and constant costs, net gross margins rise as the percentage of crops sold increases. Overall, the left graph in Figure 3.2 indicates that the more commercialized crop farmers obtain higher GEMs.

Figure 3.2 Economic costs and returns by percent of crop sold and land size, RWF/ha



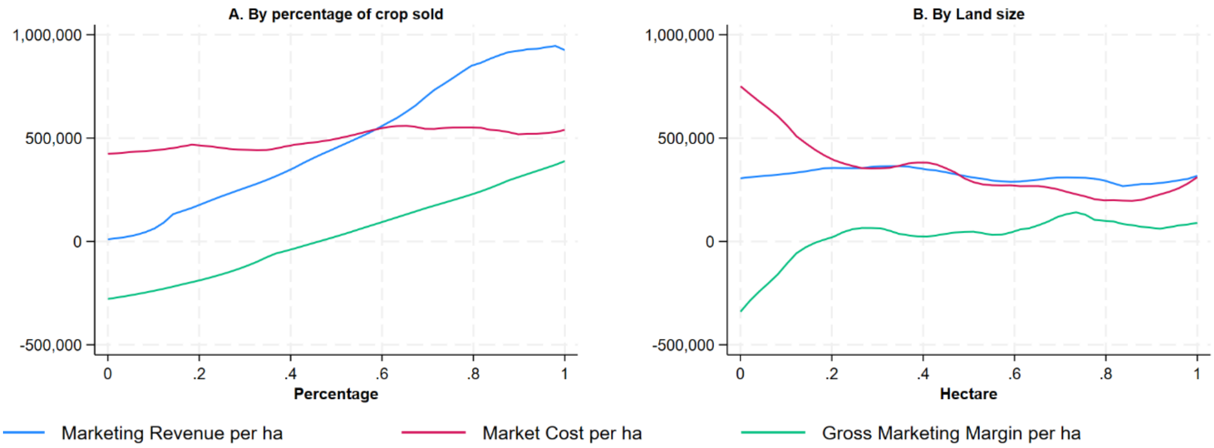
Source: Authors' calculations

The right graph in Figure 3.2 demonstrates that per hectare gross economic revenues fall as land size increases. The finding of higher relative productivity on smaller land areas is consistent with much of the academic literature on this subject (Helfand & Taylor 2021; Desiere & Jolliffe 2018; Gollin 2019; Cheng et al. 2018), although the literature is not in full agreement on this point. While important to acknowledge, the extent to which greater productivity is observed on smaller plots is not the point of principal interest here. Rather, it is that agricultural households with larger landholdings are not likely to be more productive on a per hectare basis than agricultural households with smaller landholdings. Measurement errors might overstate smaller land productivities to a degree in the analysis here. However, we believe that even if returns are constant across landholding size, this result indicates that agricultural households with larger landholdings are unlikely to generate more revenue per hectare, at least at the smallholder level with landholdings of less than 10 hectares.

Concurrent with falling economic revenue per hectare with increasing landholding size, falling economic costs per hectare determine that the GEM is, on average, about RWF 300,000 per hectare (or about RWF 100,000 per 0.35 hectares) for agricultural household with landholdings of less than 1.0 hectares, which constitute 95 percent of the sample of agricultural households. Households with larger landholdings, although not depicted in the right graph of Figure 3.2, maintain constant GEMs up to a landholding size of two hectares, after which the sample becomes too small to provide statistically robust estimates.

To explore further the market profitability results presented in Figure 3.1, the unadjusted values from those graphs are adjusted by landholding size and presented in Figure 3.3. Doing so allows meaningful direct comparisons between differing landholdings and a better understanding of relative efficiencies. As expected, the left graph in Figure 3.3 shows that market revenue increases as the percentage of crops sold rises. Again, market costs are constant across all percentages of crops sold, which leads to rising gross market margins as the percentage of crops sold increases. Also note that when total revenue is greater than total cost, the GMM turns positive—this occurs when just over 50 percent of crops are sold.

Figure 3.3 Marketing cost and returns by percent of crop sold and land size, RWF/ha



Source: Authors' calculations

The right graph in Figure 3.3 depicts higher costs per hectare on small landholdings of less than 0.2 hectares, possibly due to "lumpy" costs for inputs or, as noted earlier, measurement error. Cost and revenue curves are constant for landholdings larger than 0.2 hectares, indicating that land size is not a particularly important determinant of profitability per hectare. GMMs per hectare are slightly positive above 0.2 hectares, which suggests a greater prevalence of marketed crops on larger plots, while also indicating that a wide range of landholding sizes can be employed for commercial crop production.

The relationship between the percentage of crops sold by an agricultural household and the profitability of the household's agricultural activities can vary depending on a variety of factors. However, this relationship is tied to market conditions. If there is a strong demand for a crop and prices are favorable, selling a higher percentage of the crop can lead to increased

GMM. Other factors such as production costs, access to markets, value addition, government policies, and environmental factors also influence whether smallholder agricultural households can optimize their profits.

3.4 Distribution of profitability across agricultural households

We now examine the extent to which agricultural households incur market profits and losses. Table 3.4 illustrates the relationship between crop commercialization and GMM, disaggregated across five relative loss/profit categories of agricultural households, adjusted on a per hectare basis. The three lower categories exhibit negative gross market margins, while the top two are positive. Seventeen percent of smallholder agricultural households experienced a market loss of more than RWF 300,000, and 38 percent of those experiencing this level of market loss did not sell any crops. In contrast, 19 percent of agricultural households recorded a profit of more than RWF 240,000. Moreover, around three-quarters of agricultural households in this category sold more than half of their total crop production. Conversely, only about 12 percent of these households that sold more than half of the crops they produced experienced economic losses of more than RWF 300,000.

Table 3.4 Profitability distribution among farming households by profitability category

	Categories based on loss or profit per ha				
	Category 1: (< RWF −300,000)	Category 2: (RWF−300,000 to −100,000)	Category 3: (RWF −99,999 to 0)	Category 4: (RWF 1 to 240,000)	Category 5: (> RWF 240,000)
All households	**17.2**	**20.0**	**21.9**	**21.8**	**19.2**
Level of crop sales:					
0% of crops sold	38.0	43.6	30.4	0.0	0.0
1-25% sold	25.7	30.0	28.5	17.4	1.3
26-50% sold	24.0	18.3	27.4	45.2	24.6
51-75% sold	11.1	5.7	11.1	28.9	45.0
76-100% sold	1.1	2.5	2.6	8.5	29.1

Authors' calculations

Further research is warranted, but reasons for the high losses incurred by agricultural households in the first category likely stem from a range of factors, including idiosyncratic shocks and large amounts of own crop consumption. Table 3.5 presents the characteristics of the smallholder agricultural households in each profit/loss category. Households that lost more than RWF 300,000 in the 2022 agriculture season are more likely to be female-headed and have younger heads that are households in the category that realized profits of more than RWF 240,000.

In value terms, agricultural households in the most profitable category sell five times the value of crops of those in the category that made the largest losses—crop sales valued at RWF 935,000 compared to sales of RWF 188,000. Households in the most profitable category also use more fertilizer and seed through the Smart Nkunganire System (SNS), use more irrigation, and appear to have faced fewer shocks than households in the category that made the largest losses. Irrigation use rises with profits, with households in the top category being two and a half times more likely to use irrigation than households in the bottom category.

Table 3.5 Characteristics of farming households by profitability category

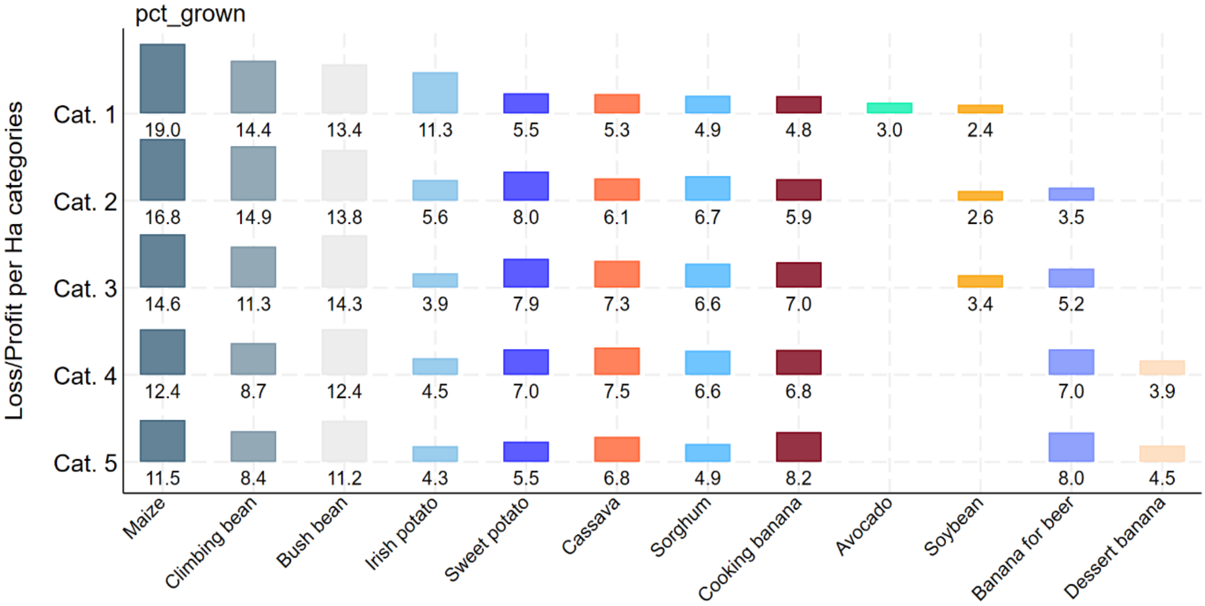
	Categories based on loss or profit per ha					
	Cat 1: (< RWF –300,000)	Cat 2: (RWF –300,000 to –100,000)	Cat 3: (RWF –99,999 to 0)	Cat 4: (RWF 1 to 240,000)	Cat 5: (> RWF 240,000)	Total
Household size, number, avg.	4.4	4.5	4.4	4.4	4.4	4.4
Female headed households, %	34.3	31.6	33.3	25.9	25.2	30.0
Age of head, years, avg.	45.2	47.5	49.4	50.4	49.6	48.6
Education of head, years, avg.	4.0	3.6	3.5	3.8	3.8	3.7
Total landholding, ha, avg.	0.1	0.2	0.4	0.5	0.4	0.3
Plots used in agriculture activities, number, avg.	2.1	2.5	2.4	2.9	3.0	2.6
Livestock ownership, TLU, avg.	0.5	0.6	0.6	0.7	0.7	0.6
Monetary value of crop production, RWF/ha, avg.	953,258	664,382	582,209	746,500	1,636,296	900,428
Monetary value of crop sales, RWF/ha, avg.	188,327	115,804	115,598	286,960	935,739	322,892
Value of production sold, %	21.9	16.5	22.7	45.1	63.0	33.9
Household using inorganic fertilizers, %	61.5	44.3	36.1	44.8	57.7	48.2
Use of fertilizer and seed through SNS extension, %	21.6	24.8	26.9	33.0	33.4	28.2
Household using irrigation, %	6.3	7.7	7.0	9.9	15.2	9.3
Household member in a cooperative, %	11.4	8.9	10.2	13.5	23.9	13.5
Household experienced a negative shock, %	65.2	60.0	53.7	58.8	52.2	57.7
Travel time to nearest market, minutes, avg.	68.7	73.5	74.9	75.4	74.0	73.5

Source: Authors' calculations
Note: TLU = 'Tropical Livestock Unit'. SNS = 'Smart Nkunganire System'. Shocks could be defined as any unusual situation experienced by the household during the 2022 agricultural year that negatively affected their household welfare, e.g., weather shock, health shock, etc.

To better understand the sources of profitability, we identify the crops predominantly grown by households in each profitability category. Significant crop choice differences are seen, which likely influence relative returns. Figure 3.4 depicts the percentage of selected crops grown by households in each of the five profitability categories by the value of total crop production.

Less profitable households in categories 1 and 2 disproportionately produce lower-value food crops. For example, maize comprises 19 percent of the total crop production by value of category 1. In contrast, maize makes up only 11.5 percent of the value of all crops produced by households in the most profitable category 5. A similar pattern is seen with the production of low-value climbing and bush beans. In contrast, the production of higher-value crops, such as cooking, beer, and dessert bananas make up a greater share of the total value of crops produced from the more profitable categories of agricultural households. Crop choice appears to be critical to the relative profitability of agricultural households. Less profitable crops are disproportionately produced by those households that are least likely to be profitable in their agricultural activities.

Figure 3.4 Composition of crops grown by agricultural households, disaggregated by profitability category, by value of total crop production of households



Source: Authors' calculations

3.5 Probit analyses of the drivers of profitable crop production

Table 3.6 depicts two probit econometric models that present coefficient estimates for our identified variables of interest and whether they significantly affect whether an agricultural household obtains a GMM or a GEM profit. The dependent variables are important because, for example, a positive GMM indicates a more commercialized focus, whereas a positive GMM is useful for the viability of own consumption, crop marketing, or a combination of both.

It is important to outline the possible impacts on both models to understand better the actual differences between the two models presented in Table 3.6. Consider a main food crop, like maize. Maize might contribute positively to GMM because input costs are generally less than the value created. However, because food crops are predominantly consumed by the household, the coefficient related to the GMM model would likely exhibit a negative value because smaller sales would be less than the input costs to produce the maize. A cash crop would likely produce a positive contribution for both GMM and GEM, as costs would be less than the value produced for both.

Conversely, certain variables, like higher-than-average labor or seed costs, might negatively affect GMM and market profitability. Another possible outcome is a negative or insignificant coefficient for GEM and a strongly positive coefficient for GMM. One possible explanation for this to occur could be that a relatively small portion of crop production is dedicated to a particularly valuable crop with high input costs. This would result in an insignificant or slightly negative effect on GEM. However, the value of this crop, in terms of profitability, could be highly positive if only market sales are considered.

Table 3.6 Regression results for factors determining agricultural household's profitability

Variables	Gross marketing margin (GMM) profit (0/1)		Gross economic margin (GEM) profit (0/1)	
	Coefficient	Standard error	Coefficient	Standard error
Household demographics				
Female household head, 0/1	–0.051**	0.018	–0.019	0.025
Mature household head, i.e., older than 35 years, 0/1	0.030	0.020	0.006	0.027
Household size, number	–0.093***	0.023	–0.001	0.030
Household head completed primary school or more, 0/1	0.036	0.017	0.008	0.022
Land size and land management				
Land size, ha	0.046	0.033	–0.151***	0.047
Plots, number	0.166***	0.024	0.095***	0.032
Household practices monocropping, 0/1	0.059	0.044	–0.034	0.069
Access to fertilizer and seed through SNS extension, 0/1	0.031	0.019	0.019	0.024
Household using Twigire-Muhinzi program, 0/1	–0.082*	0.040	0.079**	0.045
Household using anti-erosion measures, 0/1	–0.046**	0.016	–0.056***	0.021
Household using irrigation practices, 0/1	0.067	0.032	0.052	0.041
Inputs				
Seed cost, RWF/ha	–0.004	0.002	–0.004**	0.002
Transport cost, RWF/ha	0.005*	0.002	–0.002	0.003
Insurance cost, RWF/ha	0.014*	0.006	0.008	0.008
Household using organic and inorganic fertilizer, 0/1	–0.038	0.017	–0.081***	0.024
Labor				
Labor cost, RWF/ha	–0.068***	0.009	–0.073***	0.012
Household hiring in-labor, 0/1	0.754***	0.115	0.709***	0.140
Household hiring in-labor and working for wage labor, 0/1	0.674***	0.112	0.675***	0.137
Crop choice				
Maize, 0/1	–0.028	0.017	0.040**	0.023
Sorghum, 0/1	0.034	0.021	0.076***	0.026
Beans, 0/1	–0.085***	0.022	0.009	0.031
Banana, 0/1	0.161***	0.017	0.096***	0.021
Root and tuber crops, 0/1	0.009	0.018	0.024	0.024
Cash crops, 0/1	0.239***	0.034	0.097***	0.038
Vegetables and legumes, 0/1	0.106***	0.029	0.023	0.037
Fruits, 0/1	0.051**	0.021	0.055***	0.025
Location				
Travel time to nearest market, minutes	–0.012	0.009	–0.009	0.012
Southern Province, 0/1	0.078	0.049	0.067	0.063
Western Province, 0/1	0.003	0.050	0.024	0.065
Northern Province, 0/1	–0.067	0.051	–0.015	0.063
Eastern Province, 0/1	0.153**	0.050	0.046	0.064

Source: Authors' calculations.
Note: SNS = 'Smart Nkunganire System'. *** p<0.01, ** p<0.05, * p<0.10. Observations: 2,006 households.

Forty-one percent of agricultural households produced a positive GMM (Table 3.2) and 82 percent a positive GEM (Table 3.3). Our two models seek to better explain how identified variables individually contribute to each model, controlling for all other variables of interest.

Four variables were included in the models that addressed some demographic or educational aspects of the agricultural household. Household size and having a female head have no significant impact on GEM, but both negatively impact GMM. This suggests that, while positive economic value is created, it is likely that a large amount of crop value produced by female-headed or larger households is consumed directly by the household. Results from a companion study confirm that agricultural households with these characteristics have consistently lower levels of crop sales (Benimana et al. 2024). While households headed by older, mature individuals or those with heads with higher educational attainment are more likely to contribute to positive GEM and GMM, the coefficients are not statistically significant. The age variable is of interest given that youth-headed households tend to have fewer land assets than households headed by older individuals but are just as likely as those households to market cash crops. None of the demographic variables contribute to any statistically significant impact on GEM.

Turning to land-related variables, contrary to economies of scale arguments and consistent with findings in this and other research, increasing land size does not have a measurably positive impact on either GEM or GMM. This suggests that land is not a primary indicator of efficient commercialization. Rather, farm management variables, such as the number of plots planted, appear to be more relevant to predicting profitability—specifically, the number of plots planted variable is significantly positive in both models. From a program participation perspective, *Twigire-Muhinzi* increases GEM but reduces GMM, which suggests that participants are likely to be more effective at producing food crops for their own consumption. Using anti-erosion measures has a negative impact on both models and may be a result of the expenses undertaken in a challenging production environment. The irrigation coefficients were positive but not statistically significant. However, effects of irrigation on profitability are likely captured by some of the crop variables, as irrigation is employed on only a few crops, like vegetables and rice (rice is included in the cash crops variable).

Coefficients on input use—seed, transport, insurance costs, and fertilizer use—are mostly statistically insignificant. The only exception is the coefficient on household fertilizer use which negatively contributes to GEM. While additional research seems warranted, implicit costs, such as the added cost of fertilizer subsidies, were included in the computation of GEM, which could negatively influence GEM profitability.

Labor is a critical component of agricultural production. All three labor variables were significant for both equations, although not in the same direction. Both hiring in and hiring in and out positively contributed to GEM and GMM. Conversely, increasing labor rates per hectare were negative and suggests that paying above-average costs for labor reduces relative gross margins for both models. All of these coefficients suggest that using labor creates value but has potentially negative impacts if relative labor costs are increased.

As would be expected, crop choice has a significant impact on gross margins as farm households choose between food crops and more market-oriented cash crops (Warner et al. 2024). These variables have important implications for both our models. Based on relative sample sizes we used both individual crops (beans, maize, and sorghum) and aggregated crop types (roots and tubers, banana, cash crops, vegetables and legumes, and fruits) to better identify the contributions crop choice makes to profitability. For food crops, the GEM coefficients are positive, but are either insignificant or negative for GMM. This is not surprising because increased own consumption reduces the likelihood of generating a positive GMM. Maize is an interesting crop as it is most widely grown among agricultural households, including by those who do not sell crops and those who are predominantly commercialized. However, the results suggest that most households produce maize primarily for their own consumption rather than for sale. Beans (both climbing and bush) are the most commonly grown crop and are infrequently sold. This results in bean having a highly negative coefficient for GMM. Crops grown for sale—bananas, cash crops, and fruits—are typically positive for both categories. While vegetables and legumes contributed positively to GMM, the coefficient for the variable is not statistically significant in the GEM model. This suggests their production involves relatively higher input costs but high sale value. Finally, the coefficients on roots and tubers are not statistically significant. This could reflect that these crops are neither primarily food nor cash crops but are on a continuum for agricultural households, so the coefficients reflect this possibility.

Finally, the models included distance to market and individual provinces. Using Kigali City as the omitted administrative area, the Eastern Province had significantly higher levels of GMM. However, none of the province coefficients significantly contributed to GEM, suggesting relative homogeneity in terms of economic costs and revenue. The coefficients for the distance to market variable, while negative, as expected, are not statistically significant.

4 DISCUSSION

This research finds that smallholder agricultural production in Rwanda is a reasonable value proposition from a GEM perspective. Over 80 percent of agricultural households produce economic crop value in aggregate that is greater than the sum of all actual and implicit costs. However, the percentages are much different if only crop sales and market costs are considered—only about 40 percent of agricultural households produce positive GMMs. Recognizing that two-thirds of the crop production of agricultural households in Rwanda is directly consumed, most agricultural households operate at a GMM deficit. The 22 percent of households that sell no crops, for example, will operate at a gross market loss if they purchase even a small amount for inputs. However, given the positive GEM findings, this is not necessarily a negative result. Rather, it suggests that the market-focused analysis has to also be considered within the broader economic context of own crop consumption. While gross margin analyses enable the analysis of profitability, it is also important to understand the producer objectives that determine gross margins, revenue, and costs.

In terms of costs, our survey indicates that farm households spend approximately 80 percent of their total crop input expenditures on three variable cost items—fertilizer, seed, and hired-in labor. The remaining production costs are fixed and primarily are land rents.

From a total economic revenue perspective that goes beyond the market (Table 3.3), crop production is a relatively good proposition. A majority of agricultural households report positive GEMs of about RWF 450,000 on average and a net economic rate of return of 3.2. Farming provides important direct access to food for most smallholder agricultural households.

Median per hectare returns are less than half the average per hectare value produced, indicating that there are large variations in produced value, even among smallholder producers. Fundamentally, this research indicates that, while land size is important for increasing absolute production and crop sales, it is not a strong predictive variable for market returns. Normalizing the GMM analysis on a per hectare basis reveals several important efficiency insights and that absolute versus relative returns are important distinctions for such economic analysis.

While absolute returns are generally greater per hectare and are important for household welfare, relative returns show decreasing efficiencies with increasing landholding size, suggesting decreasing returns to scale for land. However, although a large economic return on a very small plot of land may be impressive from a percentage perspective, it is not necessarily significant for the welfare of the agricultural household. The general finding here is that economies of scale are not found with increasing landholding size. Rather, our results point towards constant or even slightly negative returns to landholding size.

Our finding of constant or decreasing returns to scale of landholdings is consistent with other research on this subject and has important policy considerations. If all smallholder land is equally productive per unit area and higher value is created on more commercialized land, then any size of landholding can be commercialized for greater value production and higher relative GMMs. For example, 5.5 percent of agricultural households farm less than 0.1 hectares but sell more than half of the crops they produce (Warner and Mugabo 2024). Given that percentage sales is an indicator of profitability, these agricultural households with smaller plots likely have very positive GMMs. An important policy conclusion from this research is that regardless of the size of its landholdings, any agricultural household in Rwanda, given proper capacities, resources, access to markets, and sufficient mechanisms to remove many of the risks to production, can produce highly valuable crops, increase their income, and improve their welfare.

Our regression models are consistent with the profitability analyses but also provide additional insights. From our demographic variables, larger families and female headed households create positive GEMs but, because of large amounts of own consumption, negatively impact gross market margins. Importantly, land size does not statistically contribute positively to either GEM or GMMs. Other variables, such as labor decisions, number of plots, and crop choice, are more influential. Food crops, like beans, maize, and sorghum, are important for implicit value creation but, because they are mainly consumed rather than sold, they do not contribute to market profitability. Most cash crops, in contrast, contribute positively to both GMM and GEM. In terms of government programs, access to inputs via SNS contributes positively to both models but the coefficients are not statistically significant. The results of the Twigire-Muhinzi program are similar to the food crop results, suggesting improved GEM but a negative impact on GMM. In sum, the regression models provide added understanding of the drivers of both market and economic profitability. Given the large amount of direct consumption of their crops by agricultural households, both models are important for understanding total economic value creation and how crops are marketed.

5 CONCLUSIONS AND POLICY RECOMMENDATIONS

This research indicates that most households generate more value than both their actual and implicit input costs, suggesting that Rwandan agriculture is a positive economic value activity. However, because two-thirds of production is not sold but consumed or used for other household purposes, positive market profits are limited to only about 40 percent of all agricultural households. The importance of these more profitable and more market-oriented households needs close consideration—they certainly are important for achieving improved income generation, better food security, increased resilience, and higher levels of welfare in farming communities across Rwanda. Understanding both the market and broader economic revenues and the costs of smallholder agricultural households helps shape our understanding of the rural sector's economic activity and potential.

A large portion of this analysis explores crop-related revenues and costs and assesses them against several variables of interest. As expected, absolute market revenues increase with increases in the share of crops sold or landholding size. Importantly, however, while costs increase at approximately the same rate as revenue with land size, they increase more slowly with increases in the share of crops sold. The implication is that GMM rises with commercialization but is relatively constant across landholding size. Further analysis on a per hectare basis supports these general findings.

More commercialized agricultural households generate higher value per hectare and have higher positive GEM, but, critically, GEMs are not positively correlated to farm size. High market value per hectare can occur at any landholding size. This suggests that, while agricultural households with smaller landholdings tend to produce less valuable crops, this is not universally true. Many smallholder agricultural households produce for the market. In absolute terms, more than twice as many agricultural households in Rwanda with landholdings of less than 0.3 hectares sell more than half of their crop production than do agricultural households farming more than one hectare.

However, these findings should be placed into a broader context of absolute income requirements—the total needs of smallholder agricultural households deserve additional consideration. There seems to be clear evidence that land could be used more efficiently for commercial purposes. However, the absolute gains in revenue in doing so may not be as large as might be needed for a complete agricultural transformation. Nonetheless, increases in revenue could be a good start for smaller agricultural households. The crop choices agricultural households make matters for profitability. Consequently, close examination of agricultural households with smaller landholdings that produce for the market may be important for designing improved interventions to increase crop sales and, ultimately, to improve incomes and welfare. Improving our understanding of the motivations behind farmer crop choices could improve intervention strategies for economic development.

From a Rwandan smallholder agricultural household perspective, production is a positive value proposition when evaluated in broad economic terms from a GEM perspective. This positive economic value serves as a main source of food for these households. However, improved household income is possible if higher-value crops are prioritized over directly consumed food crops. Doing so appears achievable on any farm size, which suggests that any agricultural household could be more commercially oriented. From a variety of perspectives, the results of this research support encouraging crop marketing for increased net income to reduce food insecurity, increase household economic resilience, and improve household welfare. Specifically, the conclusion reached here is that producing more valuable crops with relatively constant input costs generates improved GMMs.

Based on the results of this research, we suggest several policy recommendations:

- **Promote crop diversification:** Encourage agricultural households to diversify their crops to include higher-value, market-demanded, and climate-resilient varieties. In order to support this transition, enhance agricultural extension services to educate farmers on cost-effective farming practices, including optimal input usage and crop selection based on market demand.

- **Improve market access:** Develop infrastructure and market linkages to reduce transaction costs and improve farmers' access to markets. This includes physical infrastructure, such as improved roads and storage facilities, and digital platforms for market information.
- **Facilitate access to finance:** Expand access to affordable credit for smallholder agricultural households to invest in inputs, labor, and land improvements. This includes microfinance options and insurance products to mitigate the risks associated with farming.
- **Increase access to irrigation:** Support and expand the development and maintenance of small-scale, community-managed irrigation systems that are more accessible to smallholder agricultural households. Provide training on efficient water use and management practices to maximize the benefits of irrigation systems and to ensure their sustainability. Encourage public-private partnerships to invest in larger-scale irrigation projects, with a focus on inclusivity and accessibility for smallholder agricultural households.
- **Conduct further research on the motivations of smallholder agricultural households to continue to produce food crops for their own use rather than cash crops for the market:** Quantitative analysis shows that larger households and those headed by women are more likely to produce food crops over cash crops. More focused, qualitative studies could improve our understanding of the motivations behind household crop choices and improve the design of programs that target increased production of cash crops by smallholder agricultural households.

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