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Gender Productivity Gap in Farmer-led Irrigation in the Upper East Region of Ghana

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Abstract

In this paper, we explore whether and to what extent there are disparities in vegetable productivity among female and male farmers practicing small-scale irrigation systems in the Upper East Region of Ghana, and what factors seem to drive the disparities. To do so, we use a cross-sectional data set that comprises 58 women and 192 men from 24 communities, gathered between September 2022 and February 2023 and employ Ordinary Least Square regression with community fixed effects, Oaxaca-Blinder and Recentered Influence Function decomposition analyses. Results show a statistically significant gender gap across the entire productivity distribution, except for the 80th and 90th productivity percentile, whereby the gender difference ranges between 56.9% to even 103.3% to the detriment of women producers. On average, this disadvantage amounts to approximately $987.42 per ha. The decomposition analyses further suggest that the gender gap is rather due to differences in the level than in the returns to resources. The gender gap could, hence, be significantly reduced if women would be able to operate the same size of cultivated land as men. Furthermore, overcoming structural disadvantages in terms of labor, knowledge, and liquidity may help women generate the same returns from the factors as men.

Keywords: Farmer-led irrigation, Oaxaca–Blinder decomposition, Recentered Influence Function decomposition, Agricultural productivity, Gender gap, Ghana

JEL Codes:

1 Introduction

The Agricultural sector is a vital component of Ghana's economy and the primary source of livelihood for many households, providing direct income through employment and meeting food security needs. This is particularly true for the Upper East region (UER) where there are limited economic opportunities outside the agricultural sector thus making many households tend to engage in different forms of agricultural activities to sustain their livelihoods (Ampadu et al., 2019; Antwi-Agyei et al., 2013) Although agricultural production in general is rainfed in Ghana, the proximity of the region to the dry Sahel region which is characterized by erratic rainfall patterns because of increasing climatic shocks, negatively affects the productivity of the small-scale farmers who are the backbone of the Ghanaian agricultural sector. Development and adoption of small scale irrigation thus becomes an important adaptation strategy to sustain livelihoods of these vulnerable yet important households whose production remains critical to food security and improved welfare through higher incomes. A well-functioning irrigation setup can provide reliable and controlled water supply to enhance agricultural production, especially in areas crop production is rainfed and rainfall is erratic thus contribute to mitigating drought and related weather shocks (Mango et al., 2018; Mccarthy & Kilic, 2015)

In this regard, over the years, there has been a deliberate policy by the government of Ghana to increase the land under irrigation. For example, since 2017, it has invested in the provision of an additional 7,690 ha of land for year-round production (Ministry of food and Agriculture, 2021). In addition, ground was broken in 2019 for the construction of a multipurpose dam at Pwalugu in the UER for power generation and irrigation purposes.

Aside these formal irrigations schemes that are led and implemented by the central government, there are informal community based self-initiated farmer-led irrigation (FLI) systems often managed by farmers. They are mostly practiced by small-holder farmers, cultivating 0.5 to 2 ha, utilizing various water sources and technologies, and self-financing their activities (Lefore et al., 2019; Woodhouse et al., 2017). These farmer-led irrigation (FLI) schemes, are practiced by small scale vegetable producers in the UER.[1]

[1] In general, irrigation systems can be categorized by scale into large, medium and small-scale systems, and by its form of management and/or establishment into formal or informal systems (Abric et al., 2011). Formal systems are associated with organizational schemes, whereas informal systems are often associated with systems that are self-

The emergence of informal small-holder irrigation varies from place to place and is mostly driven by availability of water and demand for irrigated produce (Karimba et al., 2022) and crises such as extreme weather conditions, failed formal irrigation schemes.

The contributions of FLI to both income generation and food security have been highlighted in various studies in Ghana, including those by (Adams et al., 2020; Akudugu et al., 2021; Domènech, 2015; Lefore et al., 2019). These findings underscore the importance of FLI in improving the livelihoods of farming communities and addressing food security challenges by alleviating the region's vulnerability to erratic rainfall patterns, boosting agricultural productivity, and ensuring consistent food and income supply. FLI plays, therefore, an important role in achieving SDGs 1 and 2 in Ghana, i.e., no poverty and zero hunger.

Women in rural Ghana, as in many other parts of sub-Saharan Africa (SSA), are actively involved in various agricultural activities, including in FLI systems, though their contributions are often underrepresented and undervalued. For example, recent studies by (Aguilar et al., 2015; Huyer, 2021; Quisumbing et al., 2014) who investigated gender-based disparities in agricultural productivity and their underlying causes found inequality in access to and control of productive resources and opportunities such as water and land, plot manager characteristics, household dynamics and structural disadvantages of women to be some of the reasons why women's contribution and productivity in the agricultural sector remains below their men counterparts .

Existing research on FLI in Ghana primarily focuses on gender disparities related to access to productive resources, including land, water, and technology adoption for water lifting (Akudugu et al., 2021; Akuriba et al., 2020; Dittoh, 2020; Van Koppen et al., 2013). However, FLI is dynamic, and its impact and dynamics vary across demographic groups, particularly concerning gender differences. Notably, the existing research does not explicitly address productivity gaps in vegetable crop production under FLI the Upper East Region (UER). Therefore, this study aims to

managed by farmers. Informal small-scale irrigation systems account for the largest part of the estimated 221,000 ha of irrigated land in Ghana with only 11,582 ha falling under public irrigation (Ministry of food and Agriculture, 2021). The terms 'farmer-led', 'emerging' and sometimes 'illegal' irrigation are often associated with informal irrigation. In this paper, we relate farmer-led irrigation (FLI) irrigation to small-scale irrigation systems initiated and managed by farmers individually or in groups with or without some form of external support.

explore gender productivity gaps related to resource availability and access in FLI within the UER.

This paper aims to fill this gap and investigates whether and to what extent gender inequalities exist in the FLI vegetable production and quantifies mechanisms of inequalities that can be attributed to differences in the level of resource use and the returns generated from these resources between female and male FLI practitioners. To do so, we implemented a comprehensive survey of 250 FLI practitioners (58 women and 192 men) in the UER between September 2022 and February 2023.We then estimated the gender productivity gap using harvest value of vegetable per hectare and its underlying factors using Ordinary Least Square (OLS) analysis with community fixed effects. We then proceeded to use the Oaxaca-Blinder and the Recentered Influence Function decomposition analyses to decompose the gender gap into endowment effect such as resource allocation, and structural effect for example differences in returns from resources.

We found that the harvest value per ha of vegetable for women FLI practitioners was on average 76.1% lower than their men counterparts, which corresponds to approximately $987.42 per ha. Looking at the entire FLI productivity distribution, the difference between men and women is statistically significant up to the 70th percentile, ranging from 56.9% to 91.67% for the first five quantiles and even increasing to 103.3% at the 70th percentile. The decomposition analyses showed that 58.39% of the average FLI gender gap can be attributed to differences in endowments, while 41.61% can be attributed to structural differences. Along the entire productivity distribution, the endowment effect is greater than the structural effect, except for the lowest percentile. In other words, Gender-specific productivity differences in FLI arise more from variations in resource levels than from differences in resource returns. This finding is unique to the context of irrigated higher-value vegetable production in the UER, and in contrast to reports of similar studies in by (Oseni et al., 2015) and (Singbo et al., 2021) that investigated rain-fed crop production in Nigeria and Mali respectively.

The rest of the paper is structured as follows. Section 2 describes details on the FLI context in Ghana and derives the conceptual framework. Section 3 presents the data and descriptive statistics of the sample. Section 4 introduces the empirical strategy, while Section 5 presents the econometric results. Finally, Section 6 concludes.

2 Conceptual framework

To conceptually assess gender-specific differences in FLI production, we adapt (Singbo et al., 2021) Singbo et al. (2021)'s approach and define a production function as:

$$Y_i = F(A_i, X_i, V_i), \quad (1)$$

where Y_i is a productivity measure related to farmer *i's* irrigated plots, A_i is a vector of inputs such as land, labor, the type of irrigation system used, and chemical inputs. X_i is a vector of farmer *i's* individual and household characteristics, and finally, V_i is a vector of community characteristics. If women and men FLI practitioners would operate on identical plots, growing identical crops, then gender-specific productivity differences can be due to differences in input use. For example, women may not be able to obtain the same quantities of inputs as men, as they often have less bargaining power with input suppliers and lack access to credit. Similarly, there may be gender differences in input quality, e.g., female FLI practitioners may be unable to hire labor and depend on family labor, specifically children. Another explanation relates to gender differences in the opportunity costs of time as women typically carry the burden of household chores and caregiving. Thus, it is expected that gender differences in FLI productivity may be explained by gender differences in the level and returns of the above-mentioned production factors.

3. Study area and Data

3.1 Study area

This study was conducted in the Upper East Region (UER) of Ghana located in the north-eastern corner of the country between longitude 0º and 1º West and latitudes 10º 3ºN and 11ºN. The UER serves as an interesting case study, because it has the largest estimated area (about 47,400 ha) covered by farmer-led irrigation (FLI) in the country (Dittoh, 2020), and is characterized by shallow and accessible groundwater resources (Anayah et al., 2013; Dittoh et al., 2013) . It is also prone to extreme weather events such as high temperatures, droughts, and floods (Issahaku et al., 2016; Kumasi et al., 2019). Figure 1 presents a land use and land cover map of the UER as of the year 2022, highlighting the FLI sites where primary data for this paper was collected. The map illustrates that the predominant land use activity in the region is agriculture, specifically croplands, encompassing both rain-fed and irrigated areas.

In general, FLI development initiatives represent a multifaceted approach and include, among others, awareness-building by e.g., field trials or demonstrations, financial support, knowledge dissemination, collaborative platform creation, promoting sustainable irrigation practices using e.g., solar pumps, drip, and sprinkler irrigation systems, and business model piloting that enhances the adoption of new technologies. International Development Enterprises (IDE), a global development organization that advances market-based approaches in agriculture, access to finance, and water, sanitation, and hygiene (wash), for instance, assisted groups of men and women in the UER with loans for motorized pumps (B. E. Bryan, 2022). Adoption of new technologies helps to expand the area under cultivation as well as increasing productivity and overall farm efficiency. These sometimes come with increased production costs and therefore benefits may only be for resource rich farmers who are likely to be males. There has, thus, been increased emphasis to encourage women participation with the distribution of free or subsidized pumps to women groups (Abric et al., 2011; Dittoh et al., 2013; Giordano et al., 2012; Veldwisch et al., 2019). Yet, an empirical assessment of whether and to what extent gender-specific inequalities exist between male and female FLI producers in the region has not been implemented.

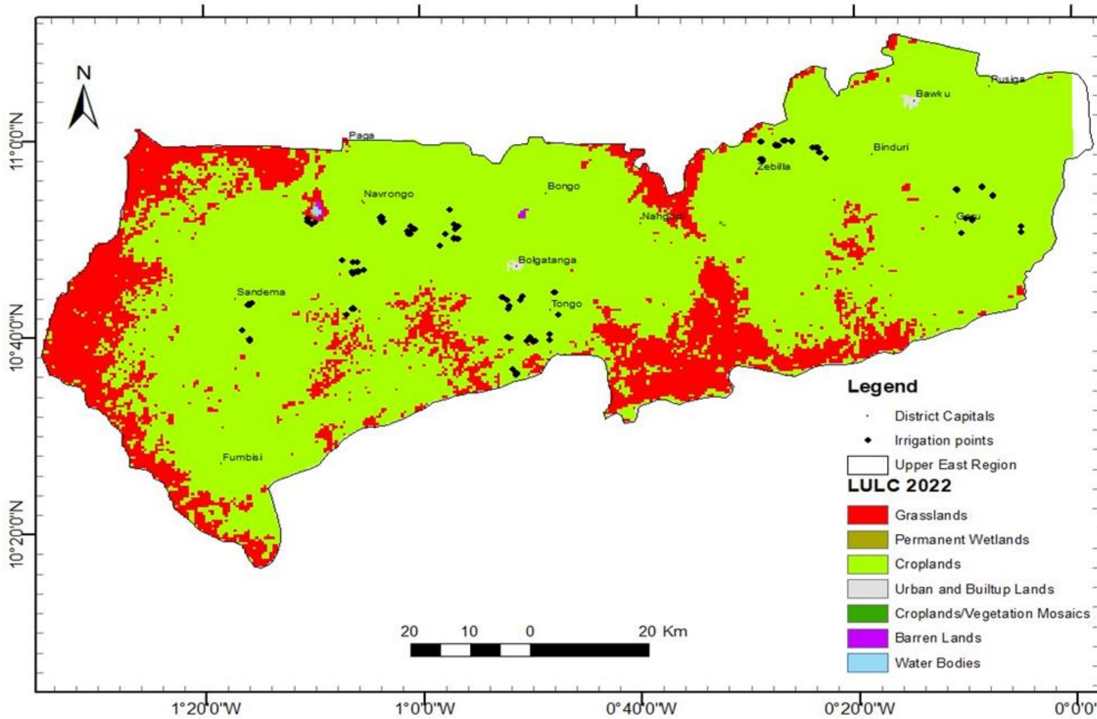

Figure 1: Study sites in Upper East Region
Source: Authors' own compilation.

3.2 Data

The data for this paper was collected using both qualitative and quantitative methods. Focus group discussions (FGDs) and key informant interviews were used to collect qualitative data while the quantitative data was collected using a semi-structured household questionnaire that has been developed based on the qualitative information. For the qualitative interviews and FGDs, key informants included leaders of farmer groups, input dealers, staff of the District Departments of Agriculture (DDAs), and traditional leaders in each community. This helped researchers get an overview of FLI in the region.

For the quantitative household survey, respondents were sampled using a multistage sampling technique. In the first stage, five districts were purposively sampled based on the presence of FLI systems mainly differentiated by water source, and method of lifting of the water. In the second stage, the MoFA office of the DDA in each selected district compiled an exhaustive list of villages with FLI systems. The villages were then grouped based on the dominant FLI system being practiced. A total of 24villages were simple randomly selected from the groups of villages. In the final stage, snow-ball sampling technique was used to identify FLI practitioner households in each of the selected villages. Respondents were interviewed primarily at the irrigation sites using the semi -structured household questionnaire. These were practitioners willing to be interviewed from every other plot/farm, rather than all practitioners of irrigation systems in the villages. In total, 250 FLI practitioner households, 58 women and 192 men Each respondent represents a unique household in the village.

Table A1 in the Appendix shows the distribution of FLI practitioner's sex by district and irrigation systems. One can note that irrigation pumps are the dominant FLI system practiced by both men (76%) and women (50%), followed by manual and gravity systems, where the men to women ratio is 13% to 34.5% and 9.4% to 13.8%, respectively.

To measure the gender productivity gap between women and men FLI practitioners, we follow previous studies such as (Oseni et al., 2015), (Slavchevska, 2015) or (Singbo et al., 2021) and aggregate the monetary value in PPP-USD across all crops cultivated by the FLI practitioner.[2] Table 1 shows the average characteristics of the pooled sample, as well as differences between men and women.

In terms of gender differences in FLI productivity, Table 1 shows that men's harvest value (2,074.37USD/ha) is significantly higher than that of women's harvest value (1,086.95USD/ha). On average, men's harvest value is 62.47% higher.

[2] More specifically, we first calculated the harvest value of each crop by multiplying the quantity of harvest based on various units of measurements (e.g., basins bags and buckets) with the average crop sales prices per community, aggregated the harvest value per crop across all different crops grown on all plots, divided it by the total land size in ha under the respondent's purview and converted the aggregated harvest value into USD equivalent, i.e., 1USD = 6.8 GHC in 2022 PPP.

Table 1: Summary statistics of demographic and socio-economic characteristics of sample

	Pooled		**Men**		**Women**		**Difference in means**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Productivity measures							
Harvest value (USD/ha)	1,845.29	1,810.37	2,074.37	1,883.92	1,086.95	1,289.38	987.42***
Respondent's characteristics							
Age (years)	42.90	9.83	42.62	10.22	43.81	8.43	-1.19
Education (years)	5.09	5.56	5.39	5.72	4.10	4.92	1.28
Married (binary)	0.88	0.33	0.91	0.29	0.79	0.41	0.12*
Migrant (binary)	0.04	0.19	0.03	0.16	0.07	0.26	-0.04
Major occupation (binary)							
Rain-fed farmer	0.54	0.50	0.53	0.50	0.59	0.50	-0.05
Irrigated farmer	0.33	0.47	0.37	0.48	0.21	0.41	0.16**
Salaried worker	0.04	0.21	0.04	0.19	0.07	0.26	-0.03
Other	0.08	0.27	0.06	0.24	0.14	0.35	-0.08*
Experience in irrigation (years)	11.20	9.53	11.82	10.23	9.16	6.34	2.67
Off-farm income (binary)	0.33	0.47	0.34	0.47	0.31	0.47	0.03
Social network (binary)	0.61	0.49	0.62	0.49	0.57	0.50	0.05
Access to credit (binary)	0.30	0.46	0.30	0.46	0.31	0.47	-0.01
Access to extension (binary)	0.78	0.42	0.82	0.39	0.64	0.48	0.18***
Sources of land (binary)							
Rented	0.29	0.45	0.27	0.45	0.34	0.48	-0.07
Inherited/family	0.59	0.49	0.61	0.49	0.52	0.50	0.09
Other source	0.12	0.33	0.11	0.32	0.14	0.35	-0.03
Household characteristics							
Household size	7.04	2.78	7.17	2.94	6.62	2.11	0.55
Dependency ratio	37.84	17.17	37.86	16.69	37.78	18.84	0.07
Farm characteristics							
Land size (ha)	2.16	1.17	2.25	1.16	1.84	1.18	0.41***
Share of irrigated land (%)	34.99	22.94	35.02	22.64	34.91	24.11	0.11
Irrigation technology (binary)							

Manual	0.18	0.38	0.12	0.33	0.34	0.48	-0.22***
Pump	0.70	0.46	0.77	0.42	0.50	0.50	0.27***
Gravity	0.10	0.31	0.09	0.29	0.14	0.35	-0.04
Other	0.02	0.13	0.02	0.12	0.02	0.13	0.00
Number of crops grown	1.56	0.80	1.62	0.84	1.36	0.64	0.26**
Agricultural inputs							
Water (USD/ha)	221.71	284.43	231.76	278.39	188.44	303.72	43.32**
Equipment (USD/ha)	89.25	125.00	91.21	121.72	82.77	136.21	8.44***
Labor (USD/ha)	788.57	964.98	873.83	1,010.12	506.35	737.07	367.48***
Use family labor (binary)	0.70	0.46	0.66	0.47	0.83	0.38	-0.17**
Use hired labor (binary)	0.57	0.50	0.58	0.50	0.53	0.50	0.04
Inputs (USD/ha)	498.27	403.77	488.04	402.19	532.11	410.66	-44.06
Other (USD/ha)	369.86	507.82	395.07	546.67	286.38	340.44	108.69
Observations	250		192		58		

Note: Monetary values are measured in 2022 PPP USD (1USD = 6.8GHC). Inputs is a monetary aggregate that includes expenditures related to fertilizer, seeds, and pesticides. Other includes expenditures such as transportation to the farm, and fencing. Differences in means between Men and Women are based on Wilcoxon rank-sum test and the Fisher's exact test. Alpha = 0.05. ***, **, * denote $p < 0.01$, 0.05, and 0.1, respectively.
Source: Field survey 2023, own calculations.

In addition to the productivity indicators, Table 1 highlights a number of socio-economic differences between men and women FLI practitioners in our sample. Compared to men, a greater proportion of women FLI practitioners (12% points more) are widowed, divorced, or separated, had irrigation farming as a primary occupation (16% points), and also more likely to be diversified in their income sources (8%). Similarly, women FLI practitioners were 18 percentage points less likely to have access to extension services compared to men. With respect to farm characteristics, average area cultivated by FLI practitioners was 2.16ha. Women's cultivated acreage was on average 0.41ha smaller than men's, they grow 17.45% less crop types, and rely more on family labor (17% points). In fact, women's expenditures spent on agricultural inputs such as water, equipment and labor are significantly lower than men's. It should also be noted that though the gender differences are not statistically significant, most men own the land they cultivate (from inheritance) with a few (mostly women) renting or given for free to cultivate for the season. Furthermore, as shown in Table A2 in the Appendix major crops grown under FLI in the study area include onions (55%), pepper (32%), okra (21%), tomatoes (19%), and leafy vegetables (17%). Although there are statistically significant differences between men and women, e.g., women dominating in leafy vegetables and men dominating in pepper and tomato production, we are not able to adequately classify crops into typical male and female crops.

4 Empirical strategies

The empirical strategy follows a three-step procedure. First, we estimate the FLI productivity gap between men and women using Ordinary Least Square (OLS) with community-level fixed effects. Second, we employ Oaxaca-Blinder (OB) decomposition analysis to quantify the contribution of various factors to the average FLI productivity gap. Finally, we complement the latter by Recentered Influence Function (RIF) decomposition analysis to assess how factor contributions change along the FLI productivity distribution.

4.1 OLS analysis

Being equipped with a cross-sectional data set of women and men that practice FLI in 24 communities located in the Upper East Region of Ghana, we can use community fixed effects to investigate whether within the same community, women are as productive as men. The model is specified as follows:

$$ln\ (Y_{iv}) = \alpha + \beta G_i + \gamma X'_{iv} + \delta H'_{iv} + \theta F'_{iv} + \omega_v + \varepsilon_{iv}, \quad (2)$$

where Y_{iv} is the natural logarithm of FLI practitioner's i harvest value per hectare, living in community v. G_i is a binary indicator equal to one if FLI practitioner i is a woman, zero otherwise. The matrix X'_{iv} contains FLI practitioner i's individual characteristics such as age, education, marital status, being a migrant, major occupation, experience in irrigated farming, whether i is engaged in off-farm employment, has access to social networks, formal credit institutions, and extension services. Furthermore, the matrix H'_{iv} includes household characteristics such as household size and dependency ratio, while matrix F'_{iv} represents farm characteristics such as land size, share of irrigated land, irrigation technology in use, number of crop varieties grown, and agricultural input expenditures per ha of land spent on water, equipment, labor, and chemical inputs such as fertilizer, seeds and pesticides . Finally, ω_v reflects the community fixed effects and ε_{iv} is the error term, which is assumed to be independently and identically distributed as $N(0, \sigma^2)$. Including and controlling for community fixed effects eliminates unobserved community-invariant characteristics that may be correlated with FLI practitioners' gender such as prevailing social-cultural norms. Of interest is the coefficient β, which assesses the gender gap in harvest value in FLI vegetable production between men and women. A negative β value means that men tend to have higher harvest values or gross margins in vegetable production than women. We follow a progressive approach, where we include additional sets of right-hand-side (RHS) variables to identify whether and to what extent a specific set of variables affect the conditional gender difference.

4.2 OB decomposition

To better understand the relative importance of factors that contribute to the gender gap in harvest value, we follow recent studies such as (Mccarthy & Kilic, 2015), (Oseni et al., 2015), and (Singbo et al., 2021) and decompose the gap using the Oaxaca-Blinder decomposition method. To do so, we specify the expected harvest value per hectare (Y_g) for FLI practitioners with gender $g = (f, m)$ representing women and men respectively, as:

$$E[Y_g] = \alpha_g + E[X_g]'\beta_g, \quad (3)$$

where *X* encompasses the RHS variables mentioned in equation (2). The gender gap can then be calculated as follows:

$$Gap = E[Y_m] - E[Y_f] = (\alpha_m + E[X_m]'\beta_m) - (\alpha_f + E[X_f]'\beta_f). \quad (4)$$

Following (Oaxaca, 2007), the gender gap arises from two sources, namely differences in explanatory variables, i.e., the explained part, and the unexplained part. To obtain the "two-fold difference", we follow (Jann, 2008) and include non-discriminatory coefficients in the above equation, which can be obtained from estimating a pooled model that also includes the gender indicator g, which is:

$$E[Y_{iv}] = E[y] = \alpha + \beta g + E[X]'\gamma^*, \quad (5)$$

where γ^* is the vector of non-discriminatory coefficients and g allows for the possibility that women's and men's expected harvest value lay on a different curve (Jann, 2008). Following (Fortin et al., 2011), we can then obtain the "two-fold decomposition" by including equation 5 in the gap equation (4), which is:

$$Gap = Q + U, \quad (6)$$

where Q is referred to as the part of the gender gap that is explained by gender differences in the RHS variables and U is referred to as the unexplained part and attributed to discrimination or differences in returns.[3] Q and U can be calculated as follows:

$$Q = \{E[X_m]' - E[X_f]'\}\gamma^* \text{ and} \quad (7)$$

[3] Fortin et al. (2011) refers to *Q* and *U* as the "composition effect" and "structural effect", respectively. *U* is referred to as the unexplained part because of the possibility of omitted variable bias (Oaxaca, 2007).

$$U = (\alpha_m - \alpha) + \left[E(X_m)'(\gamma_m - \gamma^*)\right] + (\alpha - \alpha_f) + \left[E(X_f)'(\gamma^* - \gamma_f)\right]. \quad (8)$$

Finally, equation (8) is then divided into two parts: the discrimination in favor of men, i.e., the structural advantage (this quantifies the advantage of men), and the structural disadvantage (this quantifies the discrimination against women). In our case, discrimination could refer to the unequal treatment of women emanating from social norms/ burden associated with household chores which influences access to and control of agricultural resources. This effect is assumed to be unidirectional in favor of men because women are less likely to have access to and control over these resources.

It is important to note, that the OB decomposition analysis does not yield estimates of causal mechanisms but helps to understand the relative contributions of gender differences in observable characteristics in terms of the composition effect, and gender differences in unobservable characteristics due to the structural effect (Fortin et al., 2011; Oaxaca, 2007). In addition, the method relies on two key assumptions, which are overlapping support and conditional independence. The former ensures that no single value of an observable or unobservable variable can serve to identify membership into one of the two gender groups. The latter implies that the joint densities of observable and unobservable variables for the two genders should be similar up to a ratio of conditional probabilities (Fortin et al., 2011).

4.3 RIF decomposition

While the OB decomposition described above yields insights into the average productivity gap between female and male FLI practitioners, RIF decomposition allows to investigate gender differences across the entire productivity distribution. As originally proposed by (Firpo et al., 2009), RIF is a regression analysis framework that allows the analysis of unconditional partial effects on quantiles and can be defined as:

$$RIF(y; v) = v(F_y) + IF(y: v), \quad (9)$$

where $v(F_y)$ is the distributional statistic of interest, in our case quantiles of harvest value per hectare and $IF(y: v)$ is the influence function measuring the influence that an observed value of y has on the estimation of the distributional statistic v. The influence function is defined as:

$$IF(y: v) = \frac{\tau - 1\{y \leq v(F_y)\}}{f_y(v(F_y))}, \tag{10}$$

where τ is the τ^{th} quantile of $v(F_y)$, $f_y(v(F_y))$ is the density of y's marginal distribution, and $1\{y \leq v(F_y)\}$ is an indicator function equal to one if the condition inside the bracket holds, zero otherwise (Rios-Avila, 2020). Following (Firpo et al., 2009), we obtain RIF estimates for each observed value of y by assuming a linear relationship between $RIF(y; v)$ and the RHS variables X as specified above. We can then implement the OB-type decomposition using the RIF estimates as dependent variables and can analyze what factors explain the gender differences along the entire harvest value distribution.

5 Results

Following our empirical strategy described above, we first present the OLS results, followed by the results of the OB and then the RIF decomposition analyses.

5.1 OLS – gender differences in FLI harvest value

Table 2 shows the progressive approach used to investigate whether gender differences exist in FLI harvest value and to what extent they are conditional on the addition of RHS variables in Columns 1 to 3. For comparison, Columns 4 and 5 show the results for women's and men's FLI harvest value separately.

The results of the basic regression model are presented in column 1. This includes only gender variable as a predictor of harvest values. The results show that harvest value per ha of women to be 76.1% lower than that of men which is statistically significant at the 1% level. This gap can be viewed as the unadjusted gender gap, which we intend to explain in the following analysis.

Controlling for community fixed effects in Column 2, marginally reduces the harvest value gap to 72.8%. In the final estimation controlling for other respondent and household characteristics such as age, farm size, access to extension services in Column 3, the results show that the gap closes significantly (reduces the harvest value gap to 30.1%) although it still remains significantly visible between men and women. These results thus show that female FLI practitioners largely have lower productivity compared to their male counterparts in the Upper East Region of Ghana (UER), albeit that difference is only statistically significant at the 10%-level. A number of observable characteristics such as size of land cultivated, and experience in irrigation contribute to explaining the productivity difference between men and women. This finding is in line with previous gender gap studies such as (Udry, 1996) in Burkina Faso, (Oseni et al., 2015) in Nigeria, and (Singbo et al., 2021) in Mali.

Looking at the separate regression results in Columns 4 and 5 it is evident that gender-specific similarities and differences in correlations with RHS variables. In terms of similarities, land size and input use are statistically significant at the 5%-level and positively associated with both women's and men's productivity. Both coefficients are larger for women indicating higher returns. Specifically the coefficient on land suggests that a 10% increase in land for a female FLI practitioner would be associated with a 8.05% increase in productivity, while men's productivity would increase by 3.4%. The positive association between land size and productivity observed in FLI production in northern Ghana contrasts with the negative relationship found in other studies in Nigeria and Mali (Oseni et al., 2015; Singbo et al., 2021). Possible explanations could be related to differences in farming practices and the associated dominating market failure. Our case focuses on irrigated vegetable production, where specifically credit market constraints may limit the access to specific irrigation technology, while (Oseni et al., 2015) for example, looks at rain-fed production of staple crops such as cassava, yam or maize, where imperfect labor markets can make access to non-family labor difficult.

In terms of gender-specific differences in correlations with RHS variables, it was observed that having access to extension services, having an alternative main income source than irrigated farming, and household size are positively associated with women's FLI productivity, but not with men's. On the other hand, having more experience in irrigation farming, growing more than one crop, having access to another irrigation system than a gravity system, and irrigation related expenditures are observable characteristics that are statistically significant and positively associated with harvest value for men, but not for women. These findings suggest the importance of access to knowledge, e.g., through extension services, and capital, e.g., through other major occupations such as trading vegetables or small-scale businesses in livestock rearing or handicrafts for women's productivity, while for men it is their own experience and the type of technology.

Table 2 Gender differences in FLI harvest value (ln) using OLS

Dependent variable:	Harvest value (ln(USD/ha))				
	Pooled			Women	Men
	(1)	(2)	(3)	(4)	(5)
Female (binary)	-0.761***	-0.728***	-0.301*		
		(0.109)	(0.174)		
Age (years)			0.040	0.094	0.019
			(0.043)	(0.129)	(0.040)
Age squared (years)			-0.001	-0.001	-0.000
			(0.000)	(0.001)	(0.000)
Education (years)			-0.006	0.035	-0.002
			(0.011)	(0.037)	(0.013)
Married (binary)			-0.234	0.634	-0.117
			(0.180)	(0.873)	(0.244)
Migrant (binary)			0.054	0.084	0.156
			(0.266)	(0.769)	(0.328)
Major occupation (binary) Baseline is irrigated farmer					
Other			0.165	1.405*	-0.044
			(0.195)	(0.680)	(0.285)
Rain-fed farmer			0.224	-0.379	0.330*
			(0.171)	(0.345)	(0.173)
Salaried worker			0.122	-0.567	0.136
			(0.276)	(0.461)	(0.339)
Experience in irrigation (years)			0.021***	-0.043	0.028***
			(0.006)	(0.028)	(0.005)
Household size			0.033	0.149*	0.019
			(0.022)	(0.080)	(0.023)
Dependency ratio			-0.002	0.003	-0.007
			(0.003)	(0.008)	(0.004)
Off-farm income (binary)			-0.099	-0.135	-0.077
			(0.148)	(0.488)	(0.154)
Social network (binary)			-0.014	-0.167	-0.085
			(0.158)	(0.345)	(0.170)
Access to credit (binary)			0.058	-0.066	0.168
			(0.141)	(0.369)	(0.161)
Access to extension (binary)			0.286*	0.713**	0.316
			(0.156)	(0.260)	(0.239)
Land size (ln ha)			0.433***	0.805**	0.340**
			(0.089)	(0.323)	(0.139)
Share of irrigated land			0.002	0.007	0.003
			(0.003)	(0.008)	(0.003)
Number of crops grown			0.169	-0.444	0.206*
			(0.112)	(0.404)	(0.114)

Irrigation technology (binary)					
Baseline is gravity					
Manual			-0.561	1.105	-0.444
			(0.346)	(0.982)	(0.557)
Other			0.504	0.427	1.298***
			(0.523)	(1.488)	(0.450)
Pump			-0.092	0.907	-0.110
			(0.293)	(0.804)	(0.363)
Water (ln(USD/ha))			0.064	0.042	0.111**
			(0.042)	(0.085)	(0.048)
Equipment (ln(USD/ha))			0.046	-0.125	0.038
			(0.027)	(0.128)	(0.048)
Labor (ln(USD/ha))			-0.021	0.045	-0.028
			(0.038)	(0.115)	(0.040)
Inputs (ln(USD/ha))			0.229***	0.383**	0.287***
			(0.069)	(0.143)	(0.082)
Constant	7.233***	7.202***	4.330***	-0.979	4.578***
	(0.160)	(0.087)	(0.830)	(4.307)	(1.056)
Controls:	No	No	Yes	Yes	Yes
Community FEs:	No	Yes	Yes	Yes	Yes
Observations	250	250	250	58	192
R^2	0.102	0.201	0.572	0.806	0.576

Note: Robust standard errors in parentheses. ***, **, * denote p < 0.01, 0.05, and 0.1, respectively. Inputs is a monetary aggregate that includes expenditures related to fertilizer, seeds, and pesticides.
Source: Field survey 2023, own calculations.

5.2 OB – Decomposition of the gender gap in FLI harvest value

Table 3 presents the OB decomposition results on the difference in FLI harvest value between female and male FLI practitioners. This decomposition links the average differences in harvest value shown in Table 1 and the pooled regression coefficients in Table 2 (Column 3) and allows a better understanding of the factors that condition the gender gap.

Panel B of Table 3 shows that 58.39% of the average harvest value gap is due to differences in observed characteristics of women and men FLI practitioners, while 41.61% of the gap is due to unobserved characteristics that can be attributed to discrimination against women FLI practitioners. Both shares are statistically significant at the 1% level.

Looking at the disaggregated decomposition in Panel C of Table 3, one can identify the variables that contribute to the endowment effect, which is – as explained earlier – the portion of the gap that is due to differences in observable characteristics between women and men FLI practitioners. Note that a positive coefficient is indicative of increasing the gender gap, while a negative coefficient reduces the gap. In Table 1, we observed that men cultivate larger plots, grow more crop types, are more likely to use irrigation pumps, and are more likely to access extension services than women. Among these variables land size is the only variable that is statistically significant at the 5% level, and it contributes positively to the endowment effect and hence, seems to increase the gender gap in harvest value.

Further exploring the unexplained part of the harvest value gap shows that household size, being married, use of manual irrigation methods, access to extension, being employed in another occupation such as trading, livestock rearing or handicraft, and land size contribute negatively to the female structural disadvantage, and hence toward reducing the gap. Table 1 suggested that female FLI practitioners are less likely to be married and to have access to extension services, while more likely to practice manual irrigation, being employed in other occupations and cultivate smaller plots. The statistically significant and negative coefficients on these variables for the female structural disadvantage indicate that women's returns to these variables for FLI productivity are higher than men's. While we did not find a statistically significant difference in household size between women and men FLI practitioners in Table 1, the negative coefficient for the female structural disadvantage suggests that the return to larger households, and hence a larger pool of family labor, for harvest value is higher among women than among men.

On the other hand, number of crops grown, experience in irrigation, expenditures for equipment, and being mainly engaged in rain-fed farming are statistically significant and positively associated with the female structural disadvantage and therefore, working toward increasing the gender gap. In other words, women have lower returns to growing a larger number of vegetable types, more years of experience in irrigated farming, being mainly occupied in rain-fed farming and spending more on equipment. From field observations and key informant interviews, women's lower returns from growing many crop types may be because they have a main crop for sale and use others for home consumption. The use of motorized pumps requires that there is sufficient water at the source and most women will depend on men's help in one way or the other to use them well.

At this stage, the results suggests that the average gender gap in FLI productivity of 76.1% could be reduced, if constraints in access to land, irrigation technology, and extension services would be removed. Furthermore, the finding that female FLI practitioners can earn higher returns from being married and household size than men is indicative of the persistent social discrimination against divorced or widowed women and the important role of available labor force in the household. Married women in most instances have access to their husbands farmlands for production unlike widows or those divorced.

Table 3 OB decomposition of FLI harvest value per ha (ln)

Panel A: Mean gender gap in FLI	**Harvest value (ln(USD/ha))**					
Mean men	7.233***	(0.066)				
Mean women	6.473***	(0.120)				
Difference	0.761***	(0.135)				
Panel B: Aggregate decomposition	**Endowment effect**		**Male structural advantage**		**Female structural disadvantage**	
	Coeff	Robust SE	Coeff	Robust SE	Coeff	Robust SE
Total	0.444***	(0.141)	0		0.317***	(0.107)
Share of gender gap	58.39%		0%		41.66%	
Panel C: Detailed decomposition	Coeff	Robust SE	Coeff	Robust SE	Coeff	Robust SE
Age (years)	-0.058	0.083	-0.845	0.939	-1.700	2.907
Age squared (years)	0.048	0.099	0.260	0.474	0.149	1.285
Education (years)	-0.009	0.014	0.024	0.038	-0.121*	0.064
Married (binary)	-0.028	0.028	0.123	0.176	-0.752**	0.297
Migrant (binary)	-0.001	0.012	0.009	0.009	0.004	0.028
Major occupation (binary)						
Rain-fed farming	-0.004	0.009	0.102**	0.046	0.408***	0.113
Irrigated farming	-0.029	0.026	0.032	0.038	0.002	0.038
Salaried worker	-0.004	0.007	-0.004	0.009	0.038	0.025
Other	0.001	0.007	-0.010	0.012	-0.174**	0.084
Experience in irrigation (years)	0.060*	0.036	0.090	0.058	0.566***	0.141
Household size	0.018	0.016	-0.090	0.074	-0.755**	0.326
Dependency ratio	0.000	0.007	-0.166*	0.088	-0.209	0.164
Off-farm income (binary)	-0.003	0.011	0.005	0.036	0.021	0.074
Social network (binary)	0.000	0.007	-0.032	0.040	0.077	0.127
Access to credit (binary)	-0.001	0.004	0.029	0.025	0.036	0.063
Access to extension (binary)	0.048	0.035	0.027	0.152	-0.294***	0.105
Land size (ln ha)	0.120**	0.054	-0.114*	0.068	-0.161*	0.089
Share of irrigated land	0.000	0.007	0.046	0.060	-0.128	0.130
Number of crops grown	0.047	0.031	0.048	0.062	0.848***	0.279
Irrigation technology (binary)						
Pump	0.010	0.029	-0.139	0.110	-0.101	0.092
Manual	0.096*	0.058	-0.013	0.024	-0.305**	0.120
Gravity	-0.004	0.011	-0.023	0.017	0.096	0.070
Other	0.000	0.007	0.008	0.010	0.007	0.010
Water (ln(USD/ha))	0.047	0.049	0.156	0.214	-0.032	0.189
Equipment (ln(USD/ha))	0.052	0.035	-0.018	0.127	0.480***	0.174
Labor (ln(USD/ha))	-0.016	0.032	-0.088	0.179	-0.284	0.324
Inputs (ln(USD/ha))	0.001	0.057	0.330	0.326	-0.858	0.549
Observations				250		

Note: Community fixed effects included in model but not reported. ***, **, * denote p < 0.01, 0.05, and 0.1, respectively. Inputs is a monetary aggregate that includes expenditures related to fertilizer, seeds, and pesticides. Source: Field survey 2023, own calculations.

5.3 RIF – Decomposition of the gender gap in FLI harvest value

While the above analysis shed light on the contribution of factors to the mean gender productivity gap, this section investigates whether and to what extent the relationship varies across the entire productivity distribution.

Figure 3 plots the productivity gap between women and men FLI practitioners, the endowment effect, and the female structural disadvantage across the productivity quantiles, including the respective 95% confidence intervals. The gender productivity gap follows a horizontally s-shaped curve, where the gender difference exceeds 100% at the 60^{th} and 70^{th} percentiles. At the two highest deciles, the gap decreases, turns statistically insignificant, and falls below 25% at the 90^{th} percentile. The endowment effect exhibits a concave shape, which is relatively small and statistically insignificant at the lowest two deciles and increases to 0.62 and 0.68 between the 40^{th} and 80^{th} percentiles. At the highest decile, the endowment effect decreases to 0.41 and remains statistically different from zero. Finally, the female structural disadvantage is for the most part statistically insignificant and smaller than the endowment effect, except at the lowest productivity decile.

Overall, Figure 3 suggests that the FLI gender productivity gap across the entire productivity distribution can be mostly explained by gender differences in resources (the endowment effect) than by gender differences in returns to resources (the female structural disadvantage). Only at the lowest productivity decile, i.e., among the least productive women FLI practitioners, returns to resources matter more. Our finding that the endowment effect is larger than the female structural disadvantage for the most part of the productivity distribution is in contrast to other studies from Nigeria and Mali by (Oseni et al., 2015) and (Singbo et al., 2021) respectively.

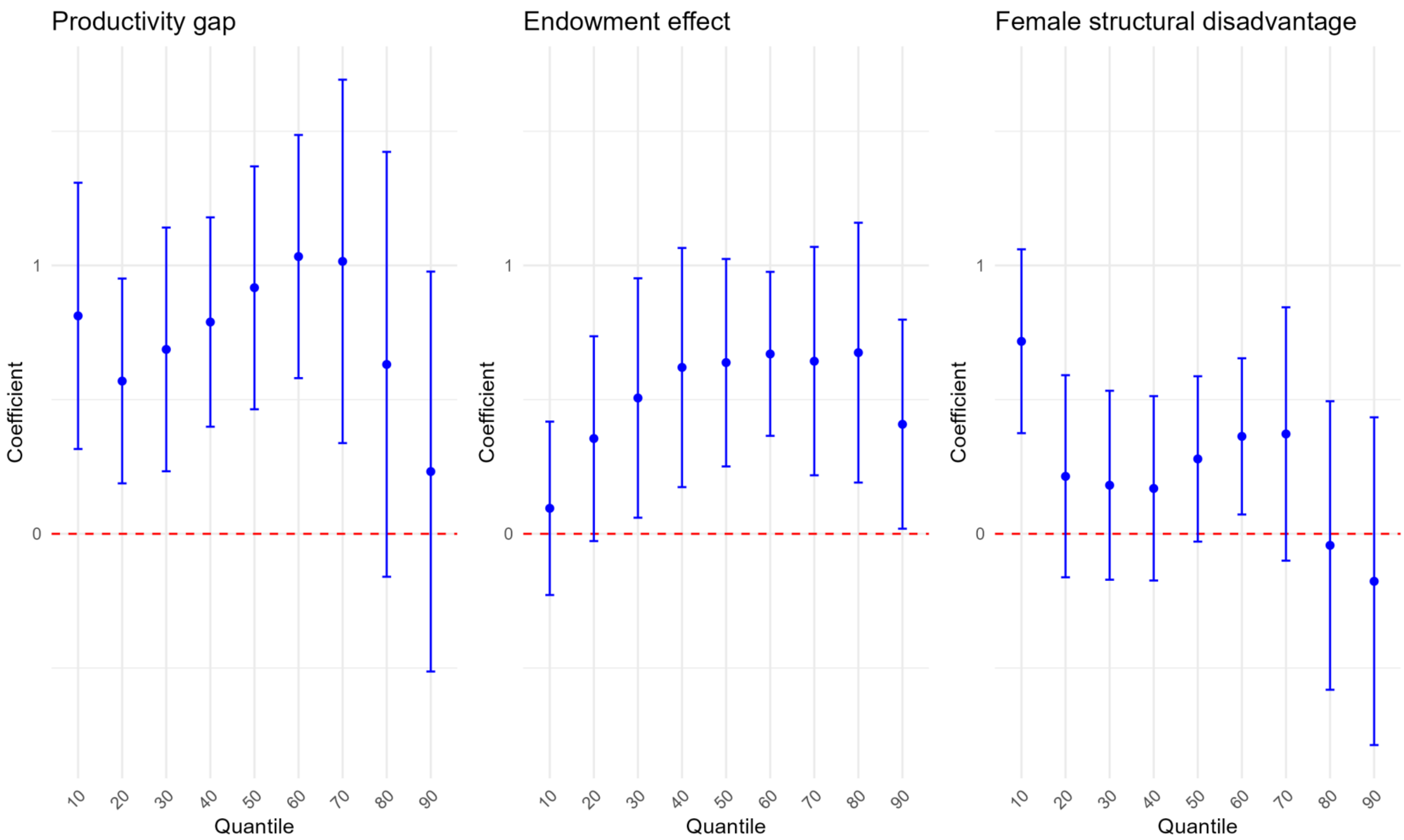

Figure 2: Farmer-led irrigation productivity gap between men and women, endowment effect and female structural disadvantage across productivity quantiles
Source: Field survey 2023, own calculations.

Finally, Table 4 presents the detailed RIF decomposition results for only the 10th, 50th, and 90th percentiles, including the mean results from Table 3 for ease of comparison.

Similar to the findings in the mean composition in Table 3, land size per ha is the only factor that is positively contributing to the endowment effect and is statistically significant for all percentiles at or above the 50th. In other words, land size is the major factor that favors men's FLI productivity and drives the gender gap especially among the more productive FLI practitioners. This finding confirms earlier studies which suggested that irrigated land is a critical constraint for many women in northern Ghana (E. Bryan & Garner, 2020; Van Koppen et al., 2013).

Looking at the female structural disadvantage, one can note that the variables associated with generating higher returns for women in the mean composition, i.e., being married, engaged in other major occupations, household size, access to extension, land size, and using manual irrigation , also persist in the lower percentiles (10th and 20th) and in the higher percentiles (60th to 80th). The exception is household size, which is only statistically significant at the 80th percentile. Other variables associated with higher returns for women, that were not statistically significant in the mean composition, but in the RIF decomposition, are education and dependency ratio. More specifically, women seem to be able to generate higher returns from education in the 40th to 60th percentile, and from the dependency ratio in the lower three deciles.

Furthermore, variables that were associated with a lower return for women FLI practitioners in the mean composition such as number of crops grown, experience in irrigation, expenditures for equipment, and being mainly engaged in rain-fed farming, exhibit the same relationship across the entire productivity distribution. Hereby, both women that are in the lower productivity deciles (10th to 30th) and women that are in the higher productive deciles, specifically in the 80th, generate lower returns from rainfed farming and equipment expenditures. Lower returns from irrigation experience and number of varieties grown are more likely among women in the 40th to 80th percentiles and 20th to 80th percentiles, respectively.

Finally, there are variables that switch sign across the productivity distribution. While returns from off-farm income, social networks, access to credit, pumps, expenditures for water and labor are lower for women in the lower productivity percentiles, more productive women can generate higher returns from these factors. An exception from this pattern is the share of land allocated to irrigated farming, where women's returns are higher in the 80^{th} percentile, and lower in the 90^{th}.

In sum, the RIF decomposition confirms the mean decomposition results in that access to resources such as land, irrigation technology and knowledge dissemination in terms of extension services are important factors in shaping the FLI productivity gap between women and men. For more productive women in particular, access to labor either through the own household or via hired labor, education, access to financial means, either through off-farm income or credit, as well as social networks seem to contribute to reduce the gender gap. For less productive women, however, these factors work in the opposite direction. Factors such as being divorced or widowed, number of crops grown, experience in irrigation, expenditures for equipment, and being mainly engaged in rain-fed farming seem to work toward a larger gender gap irrespective of women's productivity level.

Table 4 RIF decomposition of FLI harvest value per ha (ln)

Panel A: Gender differential	**Mean**		**10th**	**20th**	**30th**	**40th**	**50th**	**60th**	**70th**	**80th**	**90th**	
Men	7.233***		6.042***	6.310***	6.664***	6.945***	7.280***	7.592***	7.874***	8.123***	8.389***	
	(0.066)		(0.118)	(0.134)	(0.134)	(0.148)	(0.154)	(0.156)	(0.169)	(0.115)	(0.096)	
Women	6.473***		5.230***	5.741***	5.977***	6.155***	6.363***	6.559***	6.859***	7.491***	8.158***	
	(0.120)		(0.217)	(0.201)	(0.241)	(0.209)	(0.227)	(0.215)	(0.319)	(0.404)	(0.392)	
Difference	0.761***		0.812***	0.569***	0.687***	0.789***	0.917***	1.033***	1.015***	0.631	0.232	
	(0.135)		(0.253)	(0.195)	(0.232)	(0.199)	(0.231)	(0.231)	(0.345)	(0.404)	(0.380)	
Panel B: Aggregate decomposition	**Endowment effect**				**Male structural advantage**				**Female structural disadvantage**			
	Mean	**10th**	**50th**	**90th**	**Mean**	**10th**	**50th**	**90th**	**Mean**	**10th**	**50th**	**90th**
Total	0.444***	0.095	0.638***	0.408**	0	-0.000	0.000	0.000	0.317***	0.717***	0.279*	-0.177
	(0.141)	(0.165)	(0.197)	(0.199)	(0.033)	(0.057)	(0.046)	(0.102)	(0.107)	(0.175)	(0.157)	(0.311)
Share of gender gap	58.34%	11.70%	69.57%	175.86%	0%	0%	0%	0%	41.66%	88.30%	30.43%	-76.29%
Panel C: Detailed decomposition	**Mean**	**10th**	**50th**	**90th**	**Mean**	**10th**	**50th**	**90th**	**Mean**	**10th**	**50th**	**90th**
Age (years)	-0.058	-0.092	-0.040	-0.101	-0.845	-0.028	-0.691	-3.309	-1.700	-3.450	-5.098	8.515
	(0.083)	(0.129)	(0.067)	(0.132)	(0.939)	(1.759)	(1.587)	(2.317)	(2.907)	(9.180)	(3.875)	(9.493)
Age squared (years)	0.048	0.065	0.035	0.072	0.260	-0.313	0.245	1.400	0.149	-0.253	0.821	-3.768
	(0.099)	(0.136)	(0.076)	(0.148)	(0.474)	(0.872)	(0.775)	(1.070)	(1.285)	(4.121)	(1.807)	(3.584)
Education (years)	-0.009	-0.012	0.011	-0.018	0.024	0.010	0.035	0.014	-0.121*	0.023	-0.582***	0.302
	(0.014)	(0.023)	(0.021)	(0.028)	(0.038)	(0.050)	(0.052)	(0.076)	(0.064)	(0.109)	(0.145)	(0.234)
Married (binary)	-0.028	-0.012	0.015	-0.082	0.123	0.020	-0.114	0.703	-0.752**	-2.922***	-0.766	0.915
	(0.028)	(0.033)	(0.031)	(0.083)	(0.176)	(0.217)	(0.281)	(0.439)	(0.297)	(1.013)	(0.643)	(1.416)
Migrant (binary)	-0.001	-0.018	-0.002	0.008	0.009	0.015	0.008	0.002	0.004	0.076	0.045	-0.108
	(0.012)	(0.030)	(0.020)	(0.019)	(0.009)	(0.016)	(0.011)	(0.012)	(0.028)	(0.084)	(0.049)	(0.097)
Major occupation (binary)												
Rain-fed farming	-0.004	-0.009	-0.006	0.011	0.102**	0.064	0.054	0.189	0.408***	1.196***	-0.170	0.356
	(0.009)	(0.021)	(0.014)	(0.024)	(0.046)	(0.095)	(0.078)	(0.127)	(0.113)	(0.336)	(0.158)	(0.318)
Irrigated farming	-0.029	-0.058	-0.068	-0.014	0.032	0.080	-0.018	0.130	0.002	0.206**	-0.055	-0.172
	(0.026)	(0.041)	(0.048)	(0.056)	(0.038)	(0.090)	(0.044)	(0.111)	(0.038)	(0.092)	(0.078)	(0.158)

Salaried worker	-0.004	0.012	-0.011	-0.007	-0.004	0.007	-0.006	-0.002	0.038	-0.005	0.042	0.149
	(0.007)	(0.018)	(0.016)	(0.020)	(0.009)	(0.009)	(0.011)	(0.024)	(0.025)	(0.041)	(0.042)	(0.097)
Other	0.001	-0.042	0.002	-0.004	-0.010	-0.034	0.007	-0.040	-0.174**	-0.409*	-0.008	-0.268
	(0.007)	(0.042)	(0.017)	(0.023)	(0.012)	(0.029)	(0.014)	(0.028)	(0.084)	(0.215)	(0.061)	(0.174)
Experience in irrigation	0.060*	0.024	0.099	-0.002	0.090	0.183*	0.036	0.075	0.566***	0.761	1.364***	1.185
	(0.036)	(0.029)	(0.061)	(0.023)	(0.058)	(0.098)	(0.086)	(0.080)	(0.141)	(0.510)	(0.320)	(0.969)
Household size	0.018	0.009	0.002	0.057	-0.090	0.039	-0.052	-0.148	-0.755**	-0.574	-0.365	-1.754
	(0.016)	(0.013)	(0.011)	(0.048)	(0.074)	(0.124)	(0.122)	(0.238)	(0.326)	(1.019)	(0.379)	(1.102)
Dependency ratio	-0.000	-0.000	-0.001	0.000	-0.166*	-0.074	-0.438**	-0.095	-0.209	-1.073**	0.063	0.799
	(0.007)	(0.009)	(0.023)	(0.016)	(0.088)	(0.205)	(0.171)	(0.157)	(0.164)	(0.421)	(0.223)	(0.591)
Off-farm income (binary)	-0.003	-0.003	-0.010	0.001	0.005	0.142	-0.035	-0.058	0.021	0.767***	-0.484**	-0.395
	(0.011)	(0.012)	(0.031)	(0.008)	(0.036)	(0.101)	(0.059)	(0.081)	(0.074)	(0.261)	(0.223)	(0.395)
Social network (binary)	-0.000	0.002	-0.010	0.001	-0.032	0.065	0.025	0.008	0.077	0.573*	0.194	-0.106
	(0.007)	(0.010)	(0.022)	(0.012)	(0.040)	(0.087)	(0.049)	(0.101)	(0.127)	(0.298)	(0.179)	(0.309)
Access to credit (binary)	-0.001	0.000	-0.003	-0.004	0.029	0.030	0.032	0.052	0.036	-0.141	0.365***	0.208
	(0.004)	(0.004)	(0.017)	(0.026)	(0.025)	(0.049)	(0.032)	(0.057)	(0.063)	(0.205)	(0.131)	(0.158)
Access to extension (binary)	0.048	0.044	0.040	0.057	0.027	-0.285*	0.235	-0.103	-0.294***	-0.544*	-0.412*	-0.883
	(0.035)	(0.034)	(0.048)	(0.084)	(0.152)	(0.155)	(0.193)	(0.383)	(0.105)	(0.296)	(0.245)	(0.673)
Land size (ln ha)	0.120**	0.099	0.140**	0.168*	-0.114*	-0.156	-0.127	-0.366**	-0.161*	-0.384*	-0.086	0.286
	(0.054)	(0.065)	(0.070)	(0.092)	(0.068)	(0.131)	(0.084)	(0.150)	(0.089)	(0.223)	(0.122)	(0.262)
Share of irrigated land	0.000	0.001	0.001	-0.000	0.046	0.044	0.076	0.064	-0.128	-0.283	-0.042	0.823**
	(0.007)	(0.018)	(0.018)	(0.008)	(0.060)	(0.120)	(0.080)	(0.126)	(0.130)	(0.377)	(0.237)	(0.419)
Number of crops grown	0.047	0.080	0.075*	0.060	0.048	-0.155	0.196*	-0.066	0.848***	1.114	1.469***	-1.032
	(0.031)	(0.051)	(0.044)	(0.042)	(0.062)	(0.138)	(0.109)	(0.101)	(0.279)	(0.834)	(0.512)	(1.491)
Irrigation technology (binary)												
Pump	0.010	-0.044	0.071	-0.059	-0.139	-0.293	0.081	-0.291***	-0.101	-0.114	-0.161	-0.353
	(0.029)	(0.048)	(0.050)	(0.053)	(0.110)	(0.200)	(0.155)	(0.100)	(0.092)	(0.308)	(0.104)	(0.273)
Manual	0.096*	0.098	0.147	0.034	-0.013	0.023	-0.015	-0.045	-0.305**	-0.516**	0.001	0.001
	(0.058)	(0.066)	(0.092)	(0.064)	(0.024)	(0.028)	(0.041)	(0.041)	(0.120)	(0.249)	(0.136)	(0.136)
Gravity	-0.004	-0.002	0.002	-0.016	-0.023	-0.004	-0.021	-0.036	0.096	0.238	0.123	-0.181
	(0.011)	(0.018)	(0.017)	(0.025)	(0.017)	(0.029)	(0.022)	(0.025)	(0.070)	(0.179)	(0.104)	(0.263)

Other	-0.000	-0.001	-0.001	-0.000	0.008	0.004	0.004	0.018	0.007	0.000	-0.010	0.035
	(0.007)	(0.013)	(0.011)	(0.000)	(0.010)	(0.008)	(0.006)	(0.018)	(0.010)	(0.021)	(0.015)	(0.046)
Water (ln(USD/ha))	0.047	0.089	0.093	-0.034	0.156	0.693**	-0.117	0.257	-0.032	0.377	0.048	-1.342***
	(0.049)	(0.092)	(0.091)	(0.053)	(0.214)	(0.322)	(0.338)	(0.386)	(0.189)	(0.544)	(0.320)	(0.494)
Equipment (ln(USD/ha))	0.052	-0.092	0.060	0.096	-0.018	0.080	-0.009	-0.248	0.480***	1.106***	-0.012	0.821*
	(0.035)	(0.078)	(0.056)	(0.085)	(0.127)	(0.242)	(0.189)	(0.238)	(0.174)	(0.429)	(0.210)	(0.482)
Labor (ln(USD/ha))	-0.016	0.014	-0.094	0.039	-0.088	-0.684*	0.045	-0.409	-0.284	-1.020	0.401	0.491
	(0.032)	(0.055)	(0.057)	(0.042)	(0.179)	(0.400)	(0.239)	(0.348)	(0.324)	(0.942)	(0.539)	(0.902)
Inputs (ln(USD/ha))	0.001	0.001	0.001	0.000	0.330	0.047	0.068	0.502	-0.858	-0.678	-1.891*	-3.106
	(0.057)	(0.073)	(0.044)	(0.007)	(0.326)	(0.812)	(0.505)	(0.519)	(0.549)	(1.597)	(1.063)	(2.587)
Observations							250					

Note: Community fixed effects included in model but not reported. ***, **, * denote $p < 0.01$, 0.05, and 0.1, respectively. Inputs is a monetary aggregate that includes expenditures related to fertilizer, seeds, and pesticides. Other includes expenditures such as transportation to the farm, and fencing.
Source: Field survey 2023, own calculations.

6 Summary and conclusions

In this paper, we investigated the gender-based productivity gap among 250 vegetable farmers, 58 women and 192 men from different households, in the Upper East Region of Ghana practicing farmer-led irrigation (FLI) systems. To that end, we employed Oaxaca-Blinder and Recentered-Influence Function decomposition to quantify the magnitude of the gender gap in FLI production and to assess what factors in the production process seem to be affecting the disparities at the average and at different quantiles of the productivity distribution, respectively.

The study shows a number of interesting findings. First, the unadjusted gender gap in FLI production amounts to 76.1% to the detriment of women, which corresponds to approximately $987.42 per ha. Second, 58.39% of the average FLI gender gap can be attributed to differences in the level of resources (i.e., the endowment effect), while 41.61% can be attributed to structural differences in returns to resources (i.e., the structural effect). Third, considering the entire FLI productivity distribution, the productivity difference between men and women is statistically significant up to the 70^{th} percentile ranging from 56.9% to 91.67% for the first five quantiles and even increasing to 103.3% at the 70th percentile. Except for the lowest productivity percentile, the endowment effect is greater than the structural effect, which suggests that gender-specific productivity differences in FLI are rather due to differences in the level than in the returns to resources.

The gender gap could be reduced if differences in the access to resources, specifically cultivated land, were improved, especially among more productive women. However, to completely close the FLI gender gap, structural disadvantages in terms of labor allocation, knowledge, disposable income in terms of credit and off-farm income, as well as social networks need to be addressed, especially among less productive female FLI practitioners. Women that exhibit relatively higher productivity levels are able to generate higher returns from these factors while less productive FLI women exhibit lower returns from these factors. Irrespective of women's productivity, however, structural disadvantages in terms of being divorced or widowed, number of crops grown, experience in irrigation, and being mainly engaged in rain-fed farming work towards an increased gender gap.

In terms of policy implications our findings suggest the following. First, policies targeting at improving women's access to productivity enhancing tools (modern crop production methods) and financial services through tailored programs such as women-focused extension services and micro-financial credit and agricultural insurance institutions. This can potentially enable women to hire in labor, adopt and use improved farm technologies and cultivate larger areas of land. These policies must also consider women's unique needs in their dual role as farmers and major caretakers in the family and help them thrive in agriculture, e.g., by assisting them to access groundwater in fenced areas near their homes. Second, as our results showed interesting differences between more and less productive female FLI practitioners, we suggest programs that facilitate and strengthen peer-to-peer learning amongst female farmers as a means to facilitate knowledge transfer or diffusion. Learning from successful women farmers and adopting their techniques can boost productivity among less productive women. Collaborative platforms, workshops, and field visits can foster this exchange. Third, in order to overcome cultural barriers that hinder collaboration between men and women FLI practitioners, elf-help groups, community dialogues, and awareness campaigns that promote cooperation among farmers regardless of gender should be pursued at the local community level engaging local stakeholders and village leaders as leads in that regards. Finally, community interventions should be deliberately directed at empowering resource-poor and vulnerable groups, including single mothers, widowed, or divorced women.

Author Contributions:

Mercy A. Abarike: Conceptualization, data curation, formal analysis, investigation, methodology, visualization, original draft preparation, writing- review & editing

Sabine Liebenehm: Formal analysis, methodology, original draft preparation, visualization, writing – review & editing and funding acquisition for publication.

Alirah E. Weyori: Methodology, review & editing

Margaret A. Akuriba: Methodology, review & editing

Saa Dittoh: Methodology, supervision, review & editing

Raymond A. Kasei : Supervision, review & editing

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Data availability

Data for this research will be made available upon request

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Conflict of interest

No potential conflict of interest was reported by the authors.

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Appendix

Table A1: FLI practitioner's sex by district and FLI system

	Manual		Gravity		Pump		Other		Total
District	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**	
Bawku West	1	4	1	3	52	4	0	1	66
Bolga Municipal					11	4			15
Builsa North			1	2	12	4			19
Kasena Nankani Municipal	2	2			30	2			36
Talensi	2	1	13	3	30	8	3	0	60
Tempane	20	13	3	0	11	7			54
Total	25	20	18	8	146	29	3	1	250

Source: Field survey 2023, own calculations.

Table A2: Crops cultivated by FLI practitioner's sex

	Pooled		Men		Women		Difference in means
Crop variety cultivated	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Tomato	0.19	0.39	0.22	0.42	0.09	0.28	0.14*
Pepper	0.32	0.47	0.36	0.48	0.17	0.38	0.19**
Okra	0.21	0.41	0.19	0.39	0.29	0.46	-0.11
Onions	0.55	0.50	0.57	0.50	0.47	0.50	0.11
Leafy vegetables	0.17	0.37	0.12	0.3	0.31	0.47	-0.19***
Cabbage	0.06	0.25	0.08	0.28	0.00	0.00	0.08*
Beans	0.05	0.22	0.06	0.23	0.03	0.18	0.02
Number of observations	250		192		58		

Note: Crop varieties cultivated are not mutually exclusive. Differences in means between Men and Women are based on Wilcoxon rank-sum test and the Fisher's exact test. Alpha = 0.05. ***, **, * denote $p < 0.001$, 0.01, and 0.05, respectively.
Source: Field survey 2023, own calculations.