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WOMEN'S EMPOWERMENT IN AGRICULTURE: LEVEL, INEQUALITY, PROGRESS AND IMPACT ON PRODUCTIVITY AND EFFICIENCY

ABSTRACT

This paper examines level, inequality and change in women's empowerment in agriculture and its impact on crop productivity and efficiency using a nationally representative Bangladesh Integrated Household Survey (BIHS) of 5780 and 6195 households from the same villages in Bangladesh in 2012 and 2015 conducted by IFPRI. Results reveal that although women's empowerment score increased significantly from 0.64 to 0.73 between 2012 to 2015, only top 40% of the households have an adequate level of women's empowerment in agriculture i.e., scored above the threshold level of 0.80. The gender-gap in empowerment also reduced significantly from 0.23 to 0.20 during the same period. Female labour input significantly increases productivity. Both women's empowerment in agriculture and a reduction in the gender-gap in empowerment significantly increase production efficiency as expected. Efficiency is significantly lower in Feed the Future Zone. However, female labour use and female education significantly reduce efficiency although the effects are relatively small. The findings argue for policies specifically targeting women to enhance women's empowerment in agriculture and reduce gender-gap in empowerment.

JEL classification: O33; Q18; C21

Key words: Women's empowerment in agriculture; gender-gap in empowerment; productivity and efficiency; stochastic production frontier; Bangladesh.

1. Introduction

Women play an important role in agriculture worldwide and accounted for around 50% of the agricultural labour force in Asia and Africa in 2010 albeit with wide intercountry differences (FAO, 2011). Although labour is an important factor in agricultural production, heterogeneity of labour exists because of gender differences and skills (Rahman and Islam, 2013). Also, there is widespread debate on gender gap in agricultural productivity and efficiency. Although some literature suggests that productivity of men and women in agriculture is same (e.g., Quisumbing, 1996; Croppenstedt et al., 2013), others attribute gender-based differences in productivity due to unequal access to resources and other constraints specific to women including low returns from resources that they generally possess (e.g., Aguilar et al., 2015; Kilic et al., 2015). Therefore, explaining gender differences in productivity only through unequal access to resources may provide misleading information since gender-gap also exists in differences in returns derived from resources possessed by women. Moreover, literature examining the role of gender-gap in empowerment on technical efficiency in agriculture is few and the conclusions are mixed. For example, Udry (1995) reported differences in resource allocation in agriculture between men and women in Burkina Faso while Rahman (2010) noted that female labour input significantly improves production efficiency in Bangladesh. Recently, Seymour (2017) noted that a reduction in gender gap in empowerment significantly improves production efficiency in Bangladesh agriculture..

Since empowerment and autonomy is highly context specific and may carry different meaning to different persons (Basu and Koolwal, 2005) and also sensitive to cut-off points set to qualify an individual as empowered (Gupta, 2019), search for a universally satisfying measurement criterion of women empowerment is quite challenging and contested. Nevertheless, ignoring complexity in defining and measuring women's empowerment may produce unwarranted misleading information. Although literature examining the role of women in agricultural productivity and efficiency is increasing, there are three main limitations. First, is the quality of the indicators used for such investigation. Alkire et al. (2013) criticized that the available indices which measure women's empowerment at the aggregate level (e.g. Social Institutions and Gender Index–SIGI, Gender Gap Index–GGI, Gender Development Index–GDI, Gender Inequality Index–GII and Gender Empowerment Measure–

GEM, etc.) can hardly tell the outcome of empowerment. This is because empowerment is experienced at the individual level whereas these measures are computed at the aggregate level or at a national scale. Moreover, some are indirect measures of empowerment (e.g. GGI, GDI and GII). For example, GDI utilizes imputed wage data, which is an indirect measure. Another limitation is that these indices cannot be decomposed by person-specific and/or social characteristics (Alkire et al., 2013). Consequently, these indices are less appealing for policy because of their vague nature. Most importantly, none of these indices capture women's control over agricultural resources (Alkire et al., 2013). Recently, Alkire et al. (2013) developed a survey-based 'women's empowerment in agriculture index (WEAI)' to measure empowerment and inclusion of women in the agricultural sector in order to identify the constraints faced by women and ways to overcome those. This index is strictly confined to measure empowerment of women in agriculture only, and do not represent measurement of women's empowerment in general or for any other domains of life. We adopt this specific measure of women's empowerment in agriculture, i.e., WEAI, in our study, because it focuses on the ability to make decisions by women as well as the resources needed to carry out those decisions in agriculture while acknowledging empowerment is a multidimensional process (Alkire et al., 2013).

The second major limitation is related to the methods used to identify gender-gap in productivity and efficiency. For example, to measure gender differences in productivity, most use a dummy variable for gender as an explanatory factor on output change, which cannot provide in-depth information on the household structure and intra-household decision making process (Quisumbing, 1996). Rahman (2010) provided an improved measure of gender role on productivity and efficiency in agriculture by specifying quantity of female labour input used in production along with male labour input and the share of female labour input as a driver of production efficiency. Seymour (2017) utilized WEAI and gender-gap in empowerment as drivers of production efficiency in Bangladesh agriculture while including female labour input used in production along with male labour input as done by Rahman (2010).

Another major limitation is that all these studies are cross-sectional in nature, which provides only a snapshot of the existing situation but cannot provide any information on the changes of women's role in agriculture over time. For example, Seymour (2017) emphasized that since his study is based on cross-sectional data, it fails to establish relationship between women's empowerment and production efficiency over time and suggested for further research using panel or experimental data.

Given these limitations, the aims of this study are to: (i) measure level, gender-gap, inequality of distribution and changes in women's empowerment in agriculture (measured by WEAI); (ii) determine influence of women's labour input on agricultural production; (iii) determine whether agricultural productivity is changing over time at the farm-level; and (iv) measure the impact of women's empowerment in agriculture (i.e., WEAI) and gender-gap in empowerment (i.e., GGE) on production efficiency while controlling for women's educational level and share of female labour input as technical efficiency shifters among other factors.

We undertake this task by employing a stochastic production frontier approach (SFA) applied to a nationally representative Bangladesh Integrated Household Survey (BIHS) which is a panel dataset of 6500 rural Bangladeshi households interviewed during 2012 and 2015 by IFPRI. The contribution of our study to the existing literature on women's role in agriculture are as follows. First, we provide a detailed disaggregated analysis of WEAI and GGE scores by quintiles as well as changes over time to examine the level of inequality of these indicators within rural households. Second, with two rounds of survey data collected as a panel of a cohort of households, we provide a robust analysis of the drivers of production and technical efficiency shifters including the use of female labour input, WEAI and GGE. Finally, we also provide changes in resource endowments at the disposal of the rural households and the evidence of whether productivity in agriculture is increasing at the farm-level over time, thereby addressing limitations noted by Seymour (2017).

The paper is organised as follows. Section 2 describes the methodology including data sources, the analytical framework and explanation of women's empowerment in agriculture and all other variables used in the analysis. Section 3 presents results and discussions. The final section concludes and draws policy implications.

2. Methodology

2.1 Data

The data for this research comes from two rounds of IFPRI's BIHS surveys. The first round of the survey was conducted in 2011/2012, which was followed by another round in 2015. The dataset is representative of the rural Bangladesh as it covers rural areas of all the seven administrative divisions of the country. Furthermore, it is representative of the Feed the Future (FTF) zone characterized by multiple deprivation. Most importantly, it is a panel dataset in nature as the same households were interviewed in both rounds of survey. The surveys covered wider dimensions of livelihood including all aspects of agricultural production. In both rounds, same 6500 households were interviewed of which 5780 and 6195 crop-producing households from 2012 and 2015 surveys, respectively are finally selected for this study.[1]

2.2 Measurement of women's empowerment in agriculture: the WEAI indicators

As mentioned earlier, this study utilizes WEAI developed by Alkire et al. (2013) which measures women's achievement in empowerment, agency and their inclusion in agricultual activities through two indicators: WEAI. The aim of the first indicator is to measure women's achievement in empowerment in agriculture through estimating their role and engagement in agricultural activities, whereas the other indicator focusses on intra-household empowerment

[1] More information about these surveys are available at https://dataverse.harvard.edu/dataset.xhtml?persistentId=hdl:1902.1/21266 and https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/BXSYEL

parity in agriculture related activities. The index is composed of ten indicators on five domains (i.e., production, resources, income, leadership, and time allocation) of agriculture, which are common in literature defining empowerment (see Alkire et al., 2013 for a comprehensive review). Kabeer (1999) explained empowerment as outcome or achievement of three interlinked dimensions where both material resources and various human and social resources are pre-conditions and agencies create an enabling environment so that women can define her own goal and work accordingly. Along with resource ownership, the WEAI duly emphasizes the concept of agency through asking the primary male and female decision-makers within the same household specific questions regarding their ability to make decisions and act accordingly. Beyond the household level, WEAI addresses woman's ability to bargain, negotiate and other related capabilities at the societal level through the leadership domain, the different forms of operationalization of agency as discussed by Kabeer (1999). Alkire et al. (2013) assigned weights and cutoffs for each indicators where a value of one is assigned if the women crosses the threashhold level for the indicator or zero otherwise. Finally, the weighted sum for each of the indicators is estimated to measure individual WEAI score (see Appendix Table A1).

The other indicator, GGE, compares a woman's empowerment in agriculture score with her spouse's score to know woman's relative achievement in empowerment related to agricultural activities. Alkire et al. (2013) suggested a value of zero when a woman scores equal or higher than her spouse; otherwise, the household is assigned with the absolute difference between female and male scores. Here, the indicator value is inversely correlated with inequality, i.e. a lower value represents lower level of inequality within the households and vice-versa. An overall score of 80% is set as the threshold level of women's empowerment in agriculture (Alkire et al., 2013), which Gupta et al. (2019) criticized that changes in threshold significantly influences empowerment status. The WEAI was criticized earlier for having a long questionnaire and practicability issues, such as, understandability of some domains (e.g. autonomy and time use). Through a dynamic process of modification by removing redundant questions, dropping some indicators and modifying existing ones, the index tried to make the measure compatible to other measures of empowerment in the literature (Quisumbing and Meinzen-Dick, 2016; Malapit et al., 2019). Although empowerment is considered to be context and culture specific (Basu and Koolwal, 2005), WEAI is administered with the same questionnaire across countries implying similar activities and decision-making process across countries, which was criticized by Gupta et al. (2019) as quite unlikely to be satisfactory across all cultures and societies. Moreover, WEAI does not allow comparison at the individual level to a standardized level of empowerment because it is measured relative to her own household's standard (Phan, 2016). Despite these criticisms, till June 2019, 86 organizations in 53 countries has adopted WEAI or modified version of it depending on their contexts (Malapit et al., 2019) which confirms its widespread appeal. Therefore, given such widespread adoption of WEAI, we have also adopted this as the main measure of women's empowerment in agriculture to identify its influence on productivity and efficiency in the crop sector of Bangladesh.

2.3 Women's empowerment in agriculture and productivity relationships: The Stochastic Production Frontier model

The major motivation for this research is to understand the association between WEAI and farm productivity, which may not be a direct one, rather empowerment influences productivity through enhancing production efficiency. For instance, when empowered, a woman could efficiently contribute in farming decisions and activities, which is expected to result in higher level of efficiency and ultimately the household will attain higher level of productivity, even with the same input bundle. Empowerment implies increased capabilities and agency for women and their family members as women has better access and possession of material, human and social resources. The manifold effects of knowledge on agricultural productivity, particularly through gains in labour productivity, technology adoption and efficient use of resources are well-documented in the literature (e.g. Huffman, 2001). While through farmers' group, a woman can gain access to new technologies and farming practices, she may also gain social influence or access to other supporting services and assistance (Quisumbing and Kumar, 2011). Access to credit may expand women's capability to invest in efficiency-enhancing innovations and to smooth consumption or production shocks (Fletschner and Kenney, 2014). A woman may achieve a higher empowerment score particularly through reduced gender parity when her male counterpart decides to concentrate more on off-farm activities and/or become incapable to operate effectively in farming activities. It may also be possible that empowerment increase women workload and not necessarily contribute in efficiency improvement. To capture such complex relationship between WEAI and productivity and efficiency, we adopt a Stochastic Frontier Approach in this study. .

In contrast to a conventional production function approach, where producers are assumed to be perfectly efficient, the stochastic frontier approach relaxes this restrictive assumption and allows households to have different level of efficiencies shaped by differences in socio-economic and demographic factors specific to each household. To capture such feature, Aigner et al. (1977) and Meeusen and van den Broeck (1977) independently proposed a two part error term by adding a non-negative unobservable random variable (u_i) representing inefficiency which is uncorrelated with the conventional two-sided error term (v_i). The general form of the equation is as follows:

$$y_i = x_i\beta + \varepsilon_i \quad (1)$$

where,

$$\varepsilon_i = v_i - u_i \quad (2)$$

The specific form of the SFA model to explain production behaviour of the ith farm producing single output using five inputs can be defined as:

$$lny_i = \alpha_0 + \sum_{k=5}^{K} \beta_k lnx_{ij} + \frac{1}{2}\sum_{k=5}^{K}\sum_{l=5}^{L} \beta_{kl} lnx_{ki} lnx_{li} + \tau_t t + \sum_{m=5}^{M} \beta_m lnw_{ij} + v_i - u_i \qquad (3)$$

here, y_i is the value of all the output produced by the ith farm; x_i's are the vector of five variable inputs that includes: farm area, cost of variable inputs, value of assets, and quantity of both male and female labour; t is the year dummy; d is the dummy for the districts; β's are the vector of parameters. The error term v_i is identically and independently distributed (i.i.d.) as $N(0, \sigma_v^2)$. The error component u_i represents any random shifts (i.e. effects of the unobserved factors) on the frontier and is distributed as a truncation at zero of the normal distribution with a mean $-Z_i\delta$, and variance σ_u^2 ($|N(-Z_i\delta, \sigma^2_u|$) where Z_i are the correlates of inefficiencies on farm i. The resulting specific form of the inefficiency effect equation can be stated as:

$$u_i = \delta_0 + \sum_{d=13}^{D} \delta_d z_{id} + \omega_i \qquad (4)$$

where, z_i is the vector of the inefficiency explaining variables; δ is the vector of parameters and ω_i is the unobservable random error term, which is independently distributed and has a positive half normal distribution. The detailed description of the variables used in the model is presented below:

Variable	Description
Output variable	
Value of crops (BDT)	Monetary value of all the crops harvested during last year
Input variables	
Farm area (ha)	Total area under crop cultivation
Male labour (person days)	Quantity of male labor (both hired and family) used for crop farming during last year
Female labour (person days)	Quantity of female labor (both hired and family) used for crop farming during last year
Cost of variable inputs (BDT)	Monetary value of different variable inputs (e.g. fertilizer, manure, irrigation, pesticides, seeds, agricultural equipment, animal) used in crop production during last year
Asset (BDT)	Value of productive asset owned by the household during last year
District dummies	63 district dummies where Cox's Bazar is the base.
Efficiency explaining variables	
Paddy growers (dummy)	Dummy for paddy growers (1=paddy grower, 0 otherwise)
Age (years)	Age of the primary decision-making female

Variable	Description
Education (years)	Year of formal schooling for the primary decision-making female
Use of ICT in marketing (dummy)	Dummy for farmers contracting buyer over cell phone (1= user, 0= otherwise)
Non-ag enterprise (BDT)	Annual profit earned by the household from non-ag enterprise
Extension contact (dummy)	Dummy of extension contact (1= farmers receiving extension service, 0= otherwise)
Own land share	Share of own operated land and total area cultivated
Dependency ratio	Ratio of dependent household members (i.e. children below the age of 14 years and elder more than 64 years) to economically active household members (15–64 years old)
Land fragmentation (no)	Number of plots operated
Share of female labour	Share of female labour to total labour
Feed the Future (FTF)	Dummy for Feed the Future zone[2] (1 = if the household belongs to FTF zone, 0= otherwise)
Women's empowerment in agriculture	Women's empowerment score measured as the weighted sum of primary female decision-maker's achievement of empowerment across 10 indicators comprising the WEAI.
Gender-gap in empowerment	Gender gap in empowerment, i.e. difference in the empowerment scores of the primary female decision maker and her spouse; takes a value of zero if a woman's empowerment score is greater than or equal to that of her spouse.

We have estimated two different stochastic frontier models, WEAI and GGE. The same set of production and efficiency explaining variables are used in both models. The maximum likelihood estimates for all parameters associated with the inputs ($x's$) and inefficiency variables ($z's$) were estimated using STATA 14 software, where the associated variance parameters are expressed in terms of $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$ (Battese and Coelli, 1995).

The technical efficiency (TE_i) of the ith farm, which is the ratio of the observed and potential output of the farm defined by the frontier function. The TE value of a farm lies between zero (perfectly inefficient) and one (perfectly efficient). The equation for ith farm's TE is equal to:

[2] The FTF zone is in the south and southwest region of Bangladesh covering rural areas of 20 districts consisting of 120 upazilas (sub-districts) in three divisions. The 28 million people living in the zone faces considerable food security and nutritional challenges. The zone is also characterized with scarce water resources, a rising sea level and changing weather patterns. The zone is under special focus of different development initiatives including U.S. Government's global hunger and food security initiative.

$$TE_i = \frac{y_i}{exp(x_i\beta)} = \frac{exp(x_i\beta - u_i)}{exp(x_i\beta)} = exp(-u_i) \quad (4)$$

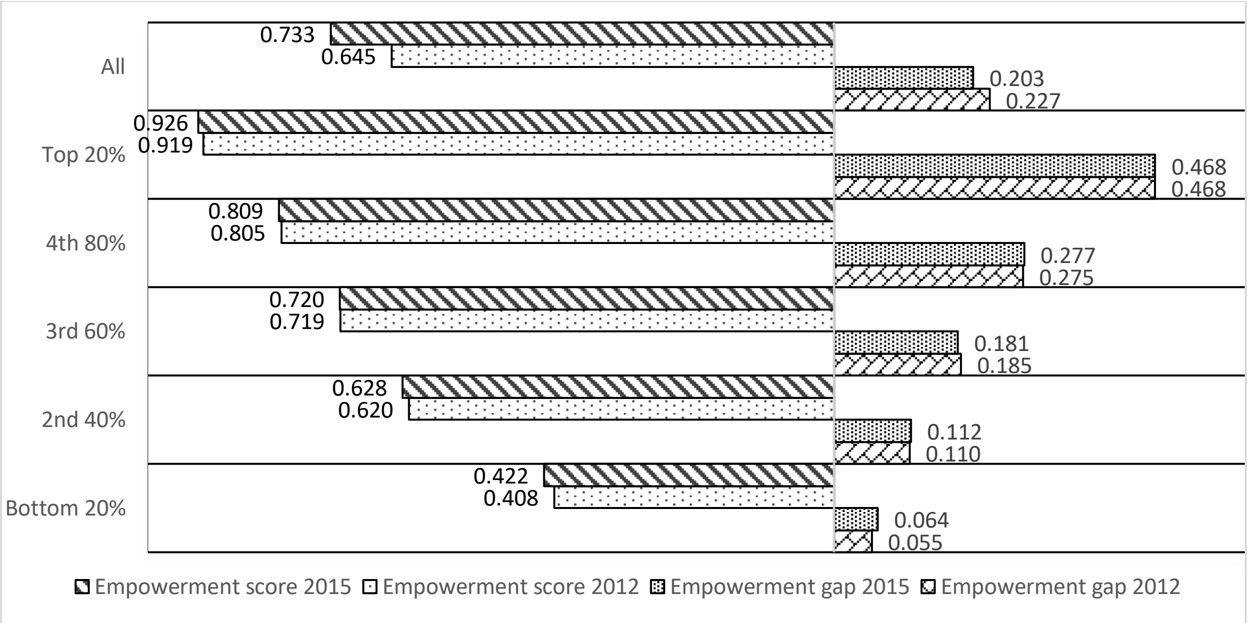
3. Results

3.1 Women's empowerment in agriculture and gender-gap in empowerment: composition, inequality and progress

The distribution of mean and GGE scores by quintiles over time are presented in Figure 1. The estimated WEAI score for 2015 is 0.733, which is a significant improvement of 14% from the 2012 level, but is still well below the cut-off cy level of 0.80 defined by Alkire et al. (2013). About 45% of the households have adequate level of empowerment in 2015 whereas it is only 29% in 2012, which shows a substantial improvement in WEAI over time. Consequently, with an improvement in WEAI score, GGE reduced significantly from 0.227 in 2012 to 0.203 in 2015. However, such optimism about achievements in women's empowerment vanishes when the level of inequality in WEAI and GGE are examined by quintiles. Only women in the top two quintiles have crossed the threshold level of empowerment score, and their scores are more than double as compared with women in the lowest quintile. However, it is encouraging to note that significant improvement in empowerment scores are observed for four of the quintiles except the third quintile, where the score remained stagnant.

The differences in GGE by quintiles are also significant and more pronounced. The progress towards minimizing GGE between male and female is slow, particularly in the three quintiles with highest GGE. The estimates here imply that, though Bangladesh has some success in WEAI, GGE is still a major concern, particularly for those households who are at the tail-end of the distribution.

Figure 1: Women's empowerment in agriuclture and gender-gap in empowerment of the households by different quintiles over time



Note: One-way anova test results show that mean empowerment score differences across different quintiles within a year are significant. Furthermore, t-test conducted shows that mean empowerment score differences between each quintile over time are significant, except the third quintile, whereas the empowerment gap mean differences between the first three quintiles (i.e. quintile 1, 2 and 3) are significant, whereas the test results are insignficant for the top two quintiles (i.e. quintile 4 and 5) .

3.2 Women's empowerment in agriculture and its relationship with income, resource use and socio-economic factors

Here we examine the relationships between WEAI and resource use, income as well as other selected socio-economic indicators. Table 1 clearly shows that households belonging to higher empowerment quintiles have significantly higher income (from both crop and non-agricultural activities), use more production inputs (e.g. labour, equipment, fertilizer, pesticide and irrigation) and have relatively better socio-economic conditions. Households belonging to the upper quintiles employ more female labour in their agricultural activities as well. However, in contrast, the amount of gross cropped area and share of owned land reduces significantly when one moves from the lowest quintile to upper quintiles.

The age of the female decision maker is significantly higher in the upper empowerment quintiles as compared to those at lower empowerment quintiles. In the top two quintiles, dependency ratio is lower than the bottom three quintiles. In households where there are more dependents (i.e. children and elder members), women generally spend more time for care activities, thereby leaving less time for participating in economic and social activities and ultimately have low level of empowerment. Quite surprisingly, we do not see any pattern between WEAI and education.

Almost similar proportion of households across all quintiles use cell phones to contact buyers. As cell phone is the most common household asset in Bangladesh and used by 92.5% of the households nationally (BBS, 2018), no specific pattern between WEAI and cell phone use is expected. Not surprisingly, significantly higher proportion of households in the lower quintiles belong to the FTF zones characterized by relatively poor socio-economic condition and infrastructure (Table 1).

An encouraging feature that can be observed from Table 1 is improvements in different socio-economic indicators such as education, dependency ratio and the value of productive assets in 2015 as compared to 2012. The only exception is land ownership, which reduced to 0.395 ha in 2015 from 0.482 ha in 2012 (detail results not shown due to space limitation).

Table 1: Resource use, income, socio-economic features and production efficiency

Variables	Women's empowerment in agriculture quintiles					
	Bottom 20%	2nd 40%	3rd 60%	4th 80%	Top 20%	Overall
Selected Input use						
Gross cropped area (ha)	0.207	0.195	0.186	0.186	0.174	0.189***
Share of own land to total land (%)	66.856	65.403	61.645	55.718	50.823	60.344***
Total labour (days/ha)	441	500	539	514	588	517***
Share of female labour (%)	3.705	4.641	4.197	5.040	5.515	4.595***
Cost of different inputs						
Equipment (BDT/ha)	20148	24573	29947	27854	30821	26599***
Fertilizer (BDT/ha)	31553	37001	45928	43645	49616	41543***
Pesticides (BDT/ha)	6335	7224	8577	9077	12301	8606***

Variables	Women's empowerment in agriculture quintiles					
	Bottom 20%	2nd 40%	3rd 60%	4th 80%	Top 20%	Overall
Irrigation (BDT/ha)	23161	30523	35687	34432	35758	31744***
Share of gross cropped area under paddy	0.743	0.752	0.753	0.736	0.714	0.735*
Income						
Value of all crops (BDT/ha)	310960	389372	436281	428122	486744	406409***
Annual profit from non-farm activities (BDT)	19745	23366	23729	25059	29745	24393***
Socio-economic factors						
Female decision maker age (years)	37.554	38.823	38.947	39.026	39.070	38.656***
Female education (years)	3.385	3.294	3.259	3.353	3.472	3.352
Dependency ratio	0.757	0.783	0.777	0.717	0.745	0.755**
Proportion of households using cell phone for selling (%)	50.074	49.639	51.271	53.959	52.074	51.412
Proportion of households in FTF zone (%)	30.265	26.063	23.050	24.340	21.567	25.262***
Value of assets (BDT)	60616	75793	67044	68107	84088	70615
Scores						
Women's empowerment in agriculture	0.412	0.624	0.720	0.807	0.924	0.688***
Gender-gap in empowerment	0.346	0.153	0.079	0.035	0.006	0.132***

Note: ***, ** and * indicates mean differences across quintiles are significant at 1%, 5% and 10% level of significance, respectively. The one-way ANOVA test was conducted for the variables continuous in nature, whereas χ^2 test was done for the dummy variables.

3.3 Impact of women's empowerment in agriculture on productivity and efficiency

In any SFA analysis, it is important to conduct several hypothesis tests to check for theoretical consistencies along with selection of the appropriate functional form, so that the estimates are based on theoretically sound and methodologically correct approach, thereby confirming validity and authenticity. Results of such relevant tests are reported in Table 2. The first test is the choice of appropriate functional form, i.e. Cobb-Douglas versus translog functional form. The test result supported appropriateness of the flexible translog functional form over the Cobb-Douglas model, which is simple but has a restrictive assumption of unitary elasticity of substitution. Translog functional form is commonly used to analyse underlying production technology in Bangladesh agriculture (e.g. Wadud and White, 2000; Asadullah and Rahman, 2009; Seymour, 2017). The next is M3T test to check the sign of the third moment and skewness of the OLS residuals of the data. This is necessary to justify use of the stochastic frontier framework (Rahman et al., 2009). The negative test statistic indicates that the OLS residuals are negatively skewed and there are elements of technical inefficiency; as in the stochastic frontier framework, the third moment is also the third sample moment of the u_i (Omer et al., 2007). Rejection of the null hypothesis of 'no inefficiency component' means that the use of the stochastic frontier framework is justified. Almost unitary and significantly different from zero coefficient of γ reported at the lower part of Appendix Table A2, also indicates presence of inefficiency in the production process. Rejection of the null hypothesis of no inefficiency effects (i.e. $H_0 = \delta_0 = \delta_1 = \ldots = \delta_8$) implies that technical inefficiency significantly affects crop production in Bangladesh (Table 2). We find decreasing returns to scale exists in Bangladesh agriculture, which is confirmed through rejection of the null hypothesis of constant returns to scale. This is consistent with many farm-level studies conducted in developing countries (e.g. Appleton and Balihuta, 1996) including Bangladesh (e.g. Asadullah and Rahman, 2009).

Table 2: Test of hypotheses

	Women's empowerment in agriculture model	Gender-gap in empowerment model
Null hypothesis for functional form test: Cobb Douglas versus translog model ($\boldsymbol{H_0}: \boldsymbol{\beta_{jk}} = \mathbf{0}$, all coefficients of the interaction variables are zero)		
Likelihood test statistics ($\boldsymbol{\chi^2}$)	234.18	228.28
p value (Prob> $\boldsymbol{\chi^2}$)	0.00	0.00
Decision	Reject	Reject

	Women's empowerment in agriculture model	Gender-gap in empowerment model
Null hypothesis for frontier test (M3T): No inefficiency component in the model		
z statistic	-29.508	-24.918
p value (Prob<=z)	0.00	0.002
Decision	Reject	Reject
Null hypothesis for no inefficiency effects $(\boldsymbol{H_0} = \boldsymbol{\delta_0} = \boldsymbol{\delta_1} = \cdots = \boldsymbol{\delta_{13}})$		
Likelihood test statistics $(\boldsymbol{\chi^2})$	256.48	245.78
p value (Prob> $\boldsymbol{\chi^2}$)	0.00	0.00
Decision	Reject	Reject
Returns to scale (Scale economy of $\boldsymbol{\varepsilon_Y} < \mathbf{1}$*)* $(\boldsymbol{H_0}: \sum \boldsymbol{\beta_m} = \mathbf{1}$ *for all m)*		
$\boldsymbol{\chi^2}$value	292.56	283.94
Degrees of freedom	1	1
p value (Prob>$\boldsymbol{\chi^2}$)	0.00	0.00
Decision	Rejected	Rejected

3.4 Drivers of agricultural production

The upper part of Table 3 presents estimated elasticities of the input variables driving production (i.e., the value of crops produced). As we have used mean-differenced values of the input variables, the first order coefficients of the SFA models produce elasticities, except for the year and district dummies. Fulfilling our priori expectation generated from production economics theory, all the input variables have positive and significant contribution on the output, except female labour, which is not significant in the WEAI model, but it is significant in the GGE model. The estimated elasticities for all the inputs are almost identical across both models (Table 3) thereby providing confidence in our estimates of two alternative models to examine the impact of WEAI on productivity and efficiency.

Table 3 shows that a 1% increase in gross cropped area will result in an increase of 1.28–1.30% in crop output. Similarly, a 1% increase in male labour input, other variable inputs and assets will increase crop output by 0.30–0.31%, 0.52–0.53% and 0.01–0.011% respectively. Table 3 also shows that the value of crop output has increased significantly over time as indicated by the positive coefficient on the year dummy variable.

Table 3: Estimated elasticity/coefficient of the inputs and inefficiency explaining variables

Variables	Women's empowerment in agriculture model		Gender-gap in empowerment model	
	Elasticity	S.E.	Elasticity	S.E.
Input variables				
Gross cropped area (ha)	1.284***	0.068	1.296***	0.070
Male labour (man-days)	0.310***	0.013	0.300***	0.013
Female labour (man-days)	0.019	0.013	0.022*	0.013
Cost of variable inputs (BDT)	0.520***	0.012	0.525***	0.012
Asset (BDT)	0.010***	0.002	0.011***	0.002
Year[¥]	0.627***	0.013	0.630***	0.014
63 district dummies	Yes		Yes	
Inefficiency variables[€]				
Paddy grower[¥]	1.492***	0.439	1.258***	0.403
Age of the primary women decision makers	-0.873*	0.530	-0.728	0.419
Age square of primary female decision makers	0.350	0.369	0.247	0.219
Share of own land	0.002	0.003	0.010	0.015
Share of female labour	-0.036***	0.124	-0.038***	0.120
Use of ICT in marketing[¥]	5.078***	0.656	4.236***	0.570
Education of the primary women decision makers	-0.050*	0.081	-0.071***	0.107
Profit from non-ag enterprise	-0.001	0.007	0.005	0.015
Extension contact[¥]	-0.738	0.723	-1.036	0.696
Dependency ratio	-0.069***	0.117	-0.090***	0.144
Land fragmentation	0.380***	0.437	0.509***	0.534
Feed the future zone[¥]	-0.878*	0.460	-0.778*	0.428
Women's empowerment in agriculture	0.156*	0.165		
Gender-gap in empowerment			-0.036*	0.055
Total number of observations	5780		6195	

Note: [¥] Coefficient is reported as the variable is dummy in nature. [€] As effects on efficiency are shown here, the signs are opposite than that of the inefficiency model. *, ** and *** represent a significant level of 1%, 5% and 10%, respectively.

3.5 Technical efficiency level

The estimated technical efficiency scores of both models are presented in the lower part of Table 4. The production efficiency scores along with their 95% confidence levels (i.e., upper and lower bounds) for the WEAI and GGE models are presented in Figures 2 and 3, respectively, and Figure 4 presents confidence intervals of technical efficiency scores (i.e. difference between upper and lower bound of technical efficiency scores) for both models. The estimated mean efficiency scores are 0.78 and 0.77 for WEAI and GGE which implies that there is substantial scope to improve production efficiency by reallocation of resources. Though the overall difference in efficiency scores between the two models is only 0.008 point, it is significant at 1% level of significance. The 95% confidence interval of efficiency scores show almost similar pattern for both models and the variation narrowed down for the households with actual efficiency scores above 0.70. The implication is that the low performing households (i.e. households with efficiency scores < 0.70), who constitute about 20% of the total sample, can lose out relatively more and are quite vulnerable to shocks in the production process, thereby need to be vigilant throughout the production cycle (Figures 2 and 3). The variation in confidence intervals narrowed down for the top 20% households in both models (Figures 2 and 3). Among the two models, the GGE model shows relatively higher variation in confidence intervals (Figure 4). The distribution of efficiency scores by WEAI and GGE quintiles show that households in higher empowerment quintiles have higher efficiency scores as compared to those belonging to lower empowerment quintiles and differences are significant (Table 4).

Table 4. Distribution of technical efficiency scores and 95% confidence limits

Efficiency score	Women's empowerment in agriculture model	Gender-gap in empowerment model
Efficiency levels		
Up to 60%	9.78	8.82
61-70%	10.07	9.15
70-80%	26.92	25.64
81-90%	49.25	51.56
91% and above	3.97	4.83
Efficiency distribution by different empowerment quintiles		
Bottom 20%	0.759	0.765
2nd 40%	0.767	0.775
3rd 60%	0.768	0.779
4th 80%	0.778	0.786
Top 20%	0.771	0.779
Overall	0.769***	0.777***
t-ratio of mean efficiency difference (WEAI versus GGE models)	-3.359***	
t-ratio of CI difference CI (WEAI versus GGE models)	3.499***	

Note: ***, ** and * indicates mean differences across quintiles are significant at 1%, 5% and 10% level of significance, respectively. The one-way ANOVA test was conducted for the variables continuous in nature, whereas χ^2 test was done for the dummy variables.

Figure 2. Efficiency score, lower and upper bound of technical efficiency for the empowerment score model

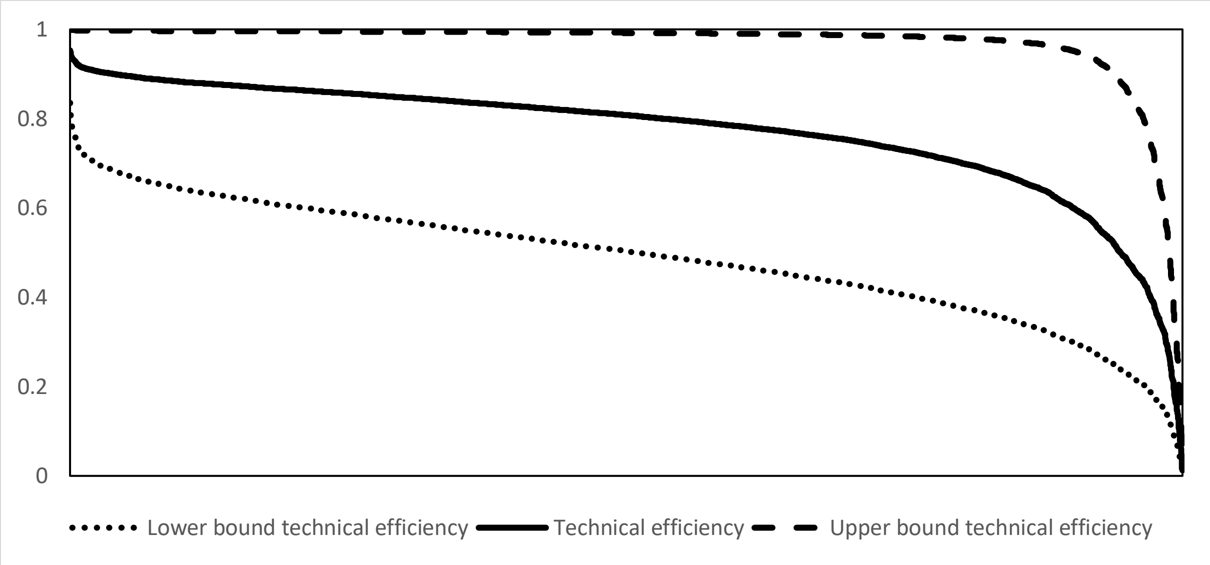


Figure 3. Efficiency score, lower and upper bound of technical efficiency for the empowerment gap model

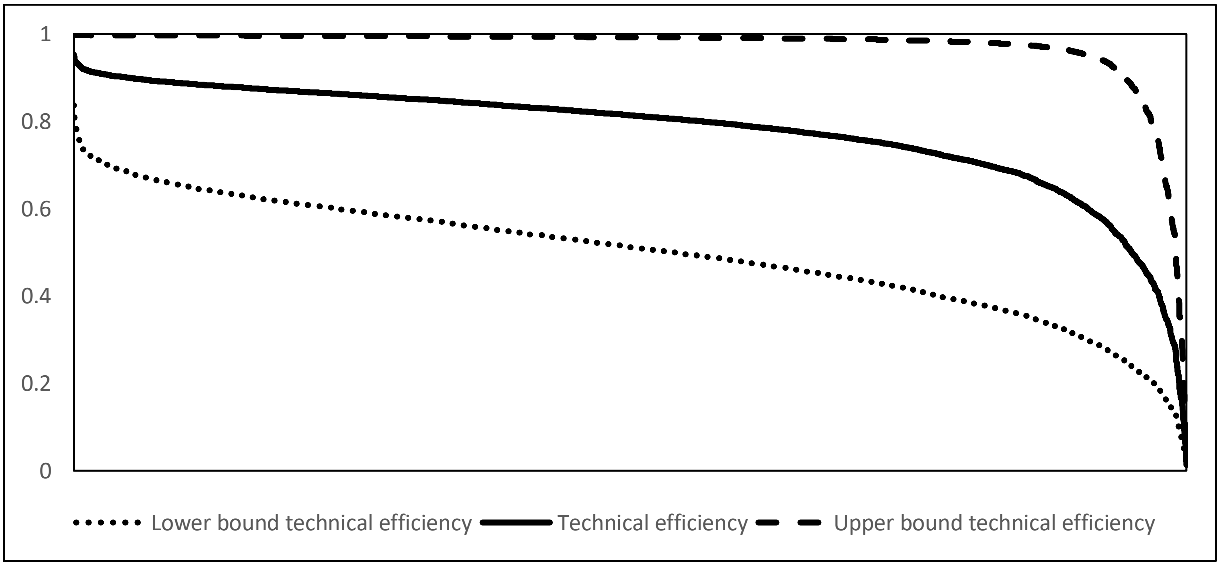
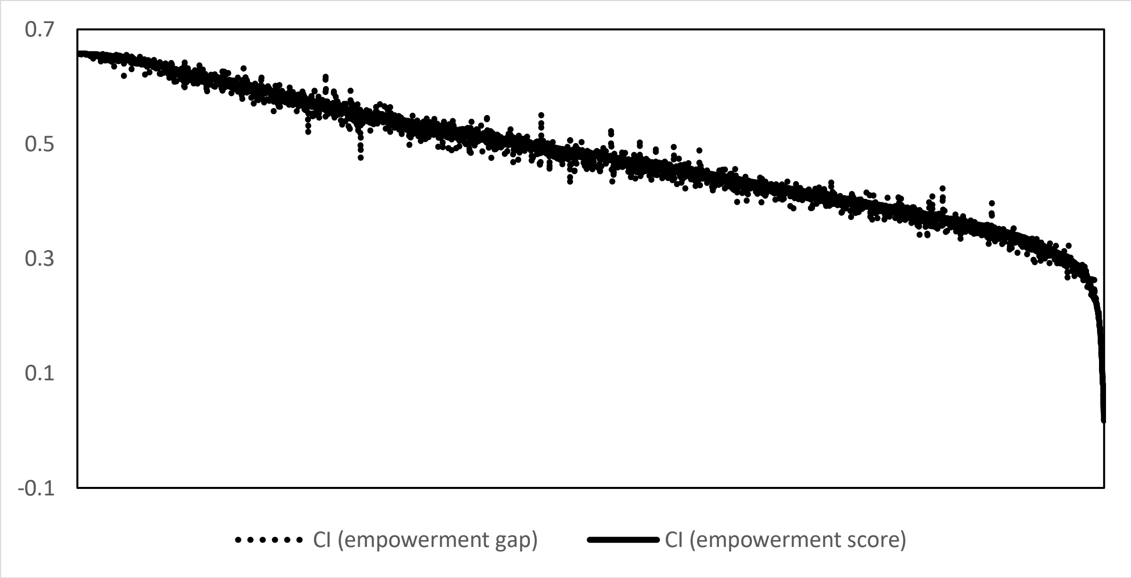


Figure 4. Confidence intervals for technical efficiency of empowerment gap and empowerment score model.



3.6 Impact of socio-economic factors on production efficiency

The lower part of Table 3 presents estimated elasticities/coefficients of the efficiency explaining variables, whereas detailed model estimates are available in Appendix Table 2. Efficiency is significantly higher for households who grow paddy along with other crops compared to those who do not produce paddy at all (Table 3). In line with this, the households practicing monoculture (i.e. only paddy growers) are estimated to lose relatively lower share of their potential output value (Table 5). Efficiency is higher for households who possess more fragmented land. Farmers who use cell phones for marketing their products, operate at a relatively higher efficiency level than their counterparts who do not make such use of cell phones. In line with the literature arguing for negative association between efficiency and dependency ratio (e.g. Asefa, 2011), we observe that households with more economically inactive members (e.g. children and elderly) are less efficient.

Increased women education reduces efficiency (Table 3), though households where women has some education have higher output value and efficiency and the proportion of the estimated loss of output value is relatively low compared to households where women has no education (Table 5).

Owner operators are significantly more efficient than the tenants (Table 3). They produce significantly higher value of output and have higher level of efficiency (Table 5). Most importantly, they are estimated to lose significantly lower share of the potential value of output (Table 3).

The negative association observed between female labour share and efficiency implies that female labours are less efficient than their male counterparts (Table 3), which may be outcome of female's lower education and empowerment.

3.7 Impact of women's empowerment in agriculture and gender-gap in empowerment on production efficiency

Turning to our variables of major interest, WEAI as well as a reduction in GGE significantly increase production efficiency (Table 3), which corroborates with the findings of Seymour (2017). The implication is that households with higher level of WEAI have a relatively higher level of efficiency and production and loose significantly less share of their potential output compared to households where women are less empowered (Table 5).

A 1% decrease in GGE will lead to 0.156% increase in production efficiency (Table 3). Households above the mean level of GGE loose significantly higher portion of their potential output compared to their counterparts whose scores are below the mean. The earlier category also produces less and operates at a relatively lower level of efficiency (Table 5).

Table 5: Output-loss in farming and women's empowerment in agriculture

Empowerment and other characteristics	Actual output value (BDT/ha)	Estimated output value loss/ha (%)	Technical efficiency	Actual output value (BDT/ha)	Estimated output value loss/ha (%)	Technical efficiency
	Women's empowerment in agriculture model			Gender-gap in empowerment model		
Output-loss by WEAI score						
Empowered	447294	22.55	0.774			
Not-empowered	382862	23.49	0.765			

Empowerment and other characteristics	Actual output value (BDT/ha)	Estimated output value loss/ha (%)	Technical efficiency	Actual output value (BDT/ha)	Estimated output value loss/ha (%)	Technical efficiency
	Women's empowerment in agriculture model			Gender-gap in empowerment model		
t-ratio (empowered vs. not empowered)	2.45***	-2.63***	2.63***			
Output-loss by GGE score						
Gender-gap below mean				440036	22.07	0.779
Gender-gap above mean				387596	22.74	0.773
t-ratio (gap below vs above mean)				1.91*	-1.93*	1.93*
Output-loss by primary women decision maker's education level						
Some education	437194	22.68	0.773	449786	22.07	0.779
No education	366794	23.75	0.763	380101	22.67	0.774
t-ratio (some vs. no education)	2.75***	-3.12***	3.12***	2.58***	-1.77*	1.77*
Output-loss by tenancy status						
Owner operator (has own land)	452061	22.66	0.773	466606	21.73	0.783
Pure tenant (has no cultivable land)	256884	24.75	0.753	265075	24.30	0.757
t-ratio (owner operator vs. pure tenant)	6.53***	-5.19***	5.19***	6.38***	-6.44***	6.44***
Output-loss by crop diversification practice						
Monoculture (only paddy grower)	385843	21.94	0.781	394556	21.26	0.787
Diversified crop growers	444286	25.37	0.746	465140	24.34	0.757
t-ratio (monoculture vs. diversified crop growers)	-2.20**	-9.68***	9.68***	-2.50***	-8.69***	8.69***

Note: The maximum output value is computed by dividing the actual output value of an individual farm by its efficiency score. The difference between the estimated value and actual value is the estimated output value loss. ***, ** and * indicates mean differences across quintiles are significant at 1%, 5% and 10% level of significance, respectively.

4. Discussion

Traditionally women were argued to have limited role in Bangladesh agriculture, particularly outside homestead, leading to underappreciated and undervalued contribution of women (Kabeer, 1994; Rahman, 2000). But now-a-days, women perform beyond their orthodox role and their participation in agriculture is increasing, which is demonstrated by significant improvements in WEAI and GGE scores in 2015 as compared to 2012 (Figure 1).

The households where women are relatively more empowered, make more intensive use of agricultural inputs and belong to higher income classes (Table 1). The relationship between age and empowerment level indicate the importance of experience and time that women require to establish their position in the household. This is in line with the findings of Afshar and Alikhan (2002) who challenged the common negative view that the Western researchers generally hold about age. The insignificant difference in female education by quintiles is largely due to similar, low average years of schooling and high dropout rates, which raises serious concerns. Although the net enrolment rate in primary education was 97.85% in 2018, about 18.6% of enrolled students leaves school early (DPE, 2018).

Although women's participation in agriculture is around 60% of the total labour force (BBS, 2018), less than 5% of total number of hours were contributed by women in paddy fields, consistent with our estimates of female labour use. For other crops (i.e. potato, sweet gourd, leafy vegetables, tomatoes, etc.) the number of person-days contributed by female labour range between 19-42% of total labour (Akhter et al., 2013). The dominant role of land area in driving productivity in our study was also confirmed by others for Bangladesh (e.g., Wadud and White, 2000; Asadullah and Rahman, 2009). Similarly, our estimated efficiency scores are close to earlier estimates of Bangladesh agriculture (e.g. Rahman 2003; Wadud and White, 2000; Asadullah and Rahman 2009). Higher efficiency level for the paddy growers is not surprising as paddy is the main crop in the country spearheaded by a rice-based green revolution technology since the early 1960s.

However, the positive association between efficiency and land fragmentation is in contrast with some of the available literature (e.g. Niroula and Thapa, 2005; Manjunatha et al. 2012). But some argued for alternative relationship as well. For instance, Tan et al. (2008) observed that land fragmentation promotes crop diversification, thereby increase farm income, reduce environmental risks (e.g. drought, flood, etc.) and minimize seasonal labour bottlenecks. Todorova and Lulcheva (2005) noted positive impact of land fragmentation on efficiency for Bulgarian farmers, consistent with our findings.

Significant impact of cell-phone use by farmers on production efficiency was also noted by Forero (2013) and Mwalupaso et al. (2019). A cell phone can help its user to establish regular communications with buyers and other agents and obtain information about market, price, transportation, weather, etc. (Aker and Mbiti, 2010; Mwalupaso, et al., 2019), which ultimately contribute towards higher efficiency.

Relatively lower level of efficiency of households living in the FTF zone as compared to rural Bangladesh is not surprising, as the adoption rates of modern varieties of some of the crops (e.g. Boro paddy, pulses, oilseeds and potatoes, etc.) and the associated yield rates are relatively low in the FTF zone. Furthermore, prevalence of poverty is relatively high and households have relatively low income and expenditure in the FTF zone (Ahmed, et al., 2013).

The observed negative relationship between female education and efficiency contradicts with the commonly held view of a positive association although findings in the literature are mixed. Many failed to find any significant impact (e.g. Wadud and White, 2000; Coelli et al., 2002), while Rahman (2002) observed both positive and negative association between production efficiency and farmer’s education for Bangladesh. Bangladeshi households showed preference for non-farm enterprises with increasing education (Anik et al. 2018). Therefore, educated female might be reluctant about farming leading towards low efficiency.

Our findings argue in favour of enhancing WEAI and reducing intra-household GGE, i.e. creating scope for female to participate in farming decisions and activities, which can exert positive impact on agriculture. Several pathways through which WEAI may contribute towards agricultural productivity was reported by Beetstra et al. (2017). For instance, when women gain access to and control over resources and inputs, they yield relatively higher marginal productivity than men. Moreover, women tend to practice more intercropping than men (Mishra et al., 2009), which increases land productivity through improving soil quality (Verma et al., 2014).

Closing GGE means women to have similar access to and control over agricultural inputs and production decisions and achieving gender parity will mean higher productivity and efficiency. Positive association between farm productivity and a reduction in was noted by Udry et al. (1995). Our results argue that enhancing WEAI and closing GGE is important as these could lead to higher level of productivity and efficiency in agriculture.

5. Conclusions and policy implications

The study examines level, inequality in distribution, gender-gap and progress in women's empowerment in agriculture within rural households of Bangladesh and its impact on crop productivity and efficiency using a nationally representative panel dataset (i.e., BIHS 2012 and 2015). Results reveal that although WEAI increased and GGE decreased significantly over time, only top 40% of the households have adequate level of women's empowerment and significant inequality exists in the level of WEAI and GGE.

Though crop productivity increased significantly over time, a substantial amount of potential output is lost due to inefficiency. Female labour input contributes significantly to productivity. Both an increase in WEAI and a reduction in GGE scores significantly increases production efficiency as expected. Efficiency is significantly lower in the FTF zone. Other significant divers of production efficiency are the use of ICT in farming, land fragmentation and rice monoculture. Owner operators are significantly more efficient than the tenants.

Several policy implications can be drawn from this study. First, the necessity of devising policies specifically targeted to improve women's empowerment in agriculture and reduce gender-gap in empowerment is clear and such measures will significantly increase productivity and efficiency in agriculture, which were echoed by Malapit and Quisumbing (2015), Sraboni et al. (2014) and Quisumbing (2003). Second, development of rental market for female hired labour will enable women to contribute towards increased productivity, also noted by Rahman (2010). Third, relatively low efficiency of female labour can be addressed by providing training on modern agricultural technologies targeted at women, which were traditionally focused on men. Fourth, the depressing effect of female education on production efficiency can be addressed through provision of further and higher level of education for women. For instance, Asadullah and Rahman (2009) noted that efficiency gains are higher for farmers with secondary or higher level of education. Fifth, special attention needed for rural households in the FTF zone, which suffers from multiple level of deprivation (Ahmed et al., 2013). And finally, encourage use of ICT in farming.

Realization of these policies are challenging but involving women actively in decision-making and production process in agriculture is essential, and the most effective route is to improve women's empowerment in agriculture and reduce gender-gap in empowerment.

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Appendix Table 1: WEAI domains, indicators and assigned weights

Domain	Indicator & description	Weight
Production	Decision making role in farming activities	1/10
	Autonomy in production, i.e. decisions are based on ones own benefit and values and not externally influenced	1/10
Resources	Asset ownership, both agriculture and non-agriculture	1/15
	Decision making in purchase, sale or transfer of assets	1/15
	Access to and participation in decisions-making over credit	1/15
Income	Control over use of income and expenditure	1/5
Leadership	Active group member at least in one economic or social group	1/10
	Comfortably speaking in public to express own views about development works, protest unlawful activities and intervein in public disputes, etc.	1/10
Time	Excessive workloads with respect to productive and domestic tasks	1/10
	Enough leisure	1/10

Source: Alkire et al. (2013)

Appendix Table 2: MLE estimates of the cross-terms and district dummies

	Empowerment score model		Empowerment gap model	
	Coefficient	S.E.	Coefficient	S.E.
Production function				
Gross cropped area (ha)	1.284***	0.068	1.296***	0.070
Male labour (mandays)	0.310***	0.013	0.300***	0.013
Female labour (mandays)	0.019	0.013	0.022*	0.013
Cost of variable inputs (BDT)	0.520***	0.012	0.525***	0.012
Asset (BDT)	0.010***	0.002	0.011***	0.002
½ (Farm area)^2	-0.380	0.266	-0.409	0.267
½ (Male labour)^2	0.166***	0.027	0.167***	0.028
½ (Female labour)^2	0.048***	0.014	0.050***	0.015
½ (Asset)^2	-0.002*	0.001	-0.002	0.001
½ (Cost of variable inputs)^2	0.146***	0.021	0.144***	0.021
Farm area * Male labour	0.002	0.077	0.016	0.078
Farm area * Female labour	-0.075*	0.043	-0.079*	0.045
Farm area * Asset	0.021	0.017	0.016	0.018
Farm area * Cost of variable inputs	-0.584***	0.077	-0.593***	0.077
Male labour * Female labour	-0.058***	0.014	-0.065***	0.015
Male labour * Asset	0.004	0.004	0.004	0.004
Male labour * Cost of variable inputs	-0.131***	0.022	-0.129***	0.022
Female labour * Asset	0.002	0.003	0.004	0.003
Female labour * Cost of variable inputs	0.018	0.012	0.020*	0.012
Cost of variable inputs * Asset	0.002	0.004	0.001	0.004
Year	0.627***	0.013	0.630***	0.014
63 district dummies	Yes		Yes	
Constant	10.159***	0.047	10.191***	0.048
Inefficiency model				
Paddy grower	-1.492***	0.439	-1.258***	0.403
Age of the primary women decision makers	0.195*	0.106	0.138	0.096
Age square of primary female decision makers	-0.151	0.121	-0.094	0.110
Share of own land	-0.021	0.235	-0.110	0.281
Share of female labour	5.509***	1.078	5.802***	1.240
Use of ICT in marketing	-5.078***	0.656	-4.236***	0.570
Education of the primary women decision makers	0.115*	0.062	0.141***	0.058
Profit from non-ag enterprise (BDT)	0.0000004	0.000004	-0.000001	0.000004
Extension contact	0.738	0.723	1.036	0.696
Dependency ratio	0.688***	0.250	0.811***	0.258

	Empowerment score model		Empowerment gap model	
	Coefficient	S.E.	Coefficient	S.E.
Land fragmentation	-0.525***	0.106	-0.571***	0.109
Feed the future zone	0.878*	0.460	0.778*	0.428
Empowerment score	-1.682*	1.003		
Empowerment gap			1.784*	1.038
Constant	-11.391***	2.828	-10.982***	2.623
Model diagnostics				
Variance parameters				
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	2.883*** (0.188)		3.426*** (0.233)	
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.954*** (0.003)		0.961*** (0.003)	
log likelihood function	-3698.665		-4052.812	
Total number of observations	5780		6195	

Note: *, ** and *** represent a significant level of 1%, 5% and 10%, respectively.