Driving Agricultural Transformation: Unveiling the Impact of Rural Livelihood Diversification Strategies in Bangladesh

Abstract

The diversification from pure agriculture to a combination of farming and non-farm activities raises questions about its impact on Bangladesh's agricultural sector. Diversified sources of non-farm activities may not even influence agriculture to the same extent. This study intends to assess the impact of rural households' non-farm income-generating activities on farm production and farm input use. A field survey of 153 households that were selected from four villages in Bangladesh was used in this study. Applying the instrumental variables Two Stage Least Square (2SLS), Ordinary Least Squares (OLS), and Seemingly Unrelated Regression (SUR) models, this study finds a positive impact of non-farm income-based livelihood strategies on farm production and farming expenditures on inputs (machinery, chemicals, and hired labor) in general. Participation in wage-based and self-employment activities boosts farm households' investment in modern technology, leading to higher farm production. Conversely, remittance negatively affects agricultural input use and production, possibly due to insufficient amount of remittance or reluctance to engage in farming. From a policy perspective, the findings suggest establishing rural agro-based industries and improving infrastructure to promote wage and self-employment activities in rural areas.

Keywords

Agricultural production, Bangladesh, Instrumental variables, Livelihood diversification, Non-farm income

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1. Introduction

While agriculture has historically been the primary driver of rural development, recent literature has depicted a new dimension in which agriculture serves a more synergistic role (i.e., when combined with other non-farm occupations). The rural households have mostly diversified their livelihood by following complex strategies which involve multiple occupations by one or more household members. These multiple income-generating activities are emerged with the wide practices and involvement of non-farm activities in the rural level. Based on the existing literatures, it has already recognized that rural non-farm income accounts for a major portion of total income in the developing countries (Salam and Bauer 2020; Shilpi and Emran 2016; Davis et al. 2009; Kilic et al. 2009; Haggblade et al. 2007; Davis et al. 2007). In case of Bangladesh, around 70% of household income comes from the non-agricultural sector and 75% of rural households involved at least some form of non-farm activities to earn their livelihood (Bayes 2017). The majority of rural farm households in Bangladesh are still primarily engaged in subsistence farming, and hence they are not entirely inclined to abandon farming as a whole. Therefore, rural households have increasingly been adopting different diversification strategies where major households engage in both agricultural and non-agricultural activity. Households participated in wage-based activities (such as industrial labor, government service, non-agricultural labor, and so forth), self-employment-based activities (such as retail trading, business, cottage industry, transportation services, etc.), and migrating to urban or overseas countries as part of this process of diversification (Salam and Bauer 2020).

Over time, the possibilities for a rural household to expand their economic activities beyond farming have become more significant. The level of household participation in the non-farm sector is caused by different pull and push factors (Bayes 2015). Generally, farm households participate in different non-farm activities for earning more income and effective management of risk, as farming activities involve a lot of risk. According to Reardon et al. (1994) farm households can use non-farm income for mitigating income fluctuations, enhancing investment capacity in farm activities and securing sufficient food for the household when they are facing climatic shock, market failure and consequently less production. Factors influencing household involvement in non-farm work include crop failures, inadequate food intake, household consumption expenditure, gender, family size, literacy, health status, farm animal holdings, access to credit, total hired labor, and agricultural extension services (Neglo et al. 2021; Anang 2017). Normally, households participate in various non-farm activities depending on their different needs or intensions. For example, poorer farm households may be compelled to participate for reducing risk, land and resource inadequacy, stabilizing income and ensuring food security (Osarfo et al. 2016; Sayeeda et al. 2016; Tafesse et al. 2015). On the other hand, richer farm households may be interested in the non-farm sector for maximizing profit by using their productive assets and market accessibility, and for the prestige concern (Schwarze and Zeller 2005; Rosenzweig and Binswanger 1993). At the same time, participation in this non-farm sector and generating income from this sector has an effect on the household farming activities and vice versa. Therefore, it is confirmed that rural farm households engage in different non-farm employment for their better livelihood. However, increasing participation in non-farm sector reduces the number of agricultural labors at the farm level by shifting agricultural labor to the non-farm employment. Besides, many farm households are losing interest in farming and offering farming life to their successive generations (Rigg 2006). Agricultural sector in Bangladesh is suffering with smaller and fragmented land, poor wage rate, and lower labor productivity which act as push factors behind rapid participation in the non-farm sector. The share of employment in agricultural sector has been gradually decreasing from 69.51% to 38.3% during the last three decades (World Bank 2021). All of these issues raise the question of whether rural livelihood diversification is a boon or a bane to agricultural practices. In the case of Bangladesh, the evidence of farm and non-farm linkages is limited. Little research evidence found a mixed impact of migration on agriculture as households lose their family labor but

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this negative impact is mitigated by the remittances they send to the rural households and modern technology adoption (Beaudouin 2006; Miluka et al. 2007; Mendola 2008; Akhter 2015). Conversely, some literature in Albania confirmed that international remittances have little or no influence on mechanization and productivity improving technology adoption in farming; instead, migrant households are diversified to livestock production from crop farming (McCarthy et al. 2006; Miluka et al. 2007). However, for other types of non-farm activities as well as total non-farm sector's impacts, no specific research has been done yet.

In many other developing countries, rural agricultural production is positively affected by participation in non-farm sector (DeJanvry et al. 2005). The main reason behind this impact is the serious deficit of credit and insurance markets in rural areas for agriculture. According to Stark (1980), households must solve the discrepancy between cash shortage and agricultural investment by adopting different strategies compatible with their available resources. Therefore, the realization of the impact of non-farm income on agricultural production and agricultural expenditures might help to unveil the development pathways for Bangladesh. Thus, the relationship between agriculture and non-agriculture is mutual and it is difficult to capture. Evaluation of the effects of non-farm income-generating activities of rural households on farm production and input utilization is the ultimate objective of this study.

2. Material and Methods

2.1. Study area, Data, and Sampling

Four villages were chosen for the sample of 153 sample households using a multi-stage selection technique. At the beginning, four Agro-ecological Zones (AEZs) were deliberately selected among a total of thirty AEZs on the basis of comparable geographical topography and elevation, but varying socioeconomic attributes. Following this, three districts—Mymensingh, Cumilla, and Dinajpur—were deliberately chosen among these AEZs based on socioeconomic factors such labour demography, population density, agricultural value addition, and non-farm activities. Four sub-districts—Bhaluka and Haluaghat in Mymensingh, Borura in Cumilla, and Birol in Dinajpur—were chosen in the third round, making sure that they fit the socioeconomic characteristics of the corresponding districts. Based on past data and knowledge, one village was chosen from each subdistrict. Household surveys employing in-person interviews with structured questionnaires were used to collect data. Additionally, focus groups (FGDs) with farmers in each chosen village were held to obtain qualitative perspectives and confirm the accuracy of the data.

2.2. Analytical techniques

When a number of other factors are controlled, it is feasible to calculate the impact of non-farm income-based diversification techniques on agricultural outcomes by contrasting households that engage in various non-farm activities with those that do not. According to this methodology, it is assumed that by including a set of observable factors related to household and locality, the systematic differences between non-farm income earning households and pure agricultural households can be captured. The following regression equation can be used for analyzing these impacts:

$$Y_k = \beta_0 + \beta_1 N_k + \sum \beta_k X_{nk} + u_i \qquad (1)$$

Where k denotes households that generate income from different non-farm sources; β_0 is the intercept; Y indicates the outcome of interest such as farm production, cost for machinery, chemical input and labor uses; N is household income from different non-farm sources; X_n implies a set of explanatory variables regarding household and community characteristics; and u is the error term. As household non-farm income (N) is correlated with error term (u), the estimate of Ordinary Least Squares (OLS) estimation of eq. (1) is considered to be biased and inconsistent (Wooldridge 2002). That means omitted or unobserved characteristics of a household exist that influence both participation of household in non-farm activities and the outcome of interest. Therefore, correlation between N and u is due to the exclusion of these variables. This problem is termed as omitted variable bias or unobserved heterogeneity (Vandercasteelen 2011). The endogeneity problem also arises as it is assumed that both participation in non-farm activities and agricultural decisions might be determined simultaneously by the same set of household and community characteristics (Maharjan 2010).

Previous literature found many possible sources of unobserved household characteristics that not only influence non-farm income, but also agricultural outcomes (Hertz 2009; Kilic et al. 2009; Oseni & Winters 2009; Maertens 2009; Vandercasteelen 2011). Among these unobserved characteristics, some are assumed to have a positive influence on household non-farm earnings, agricultural investment and agricultural production as well. On the other hand, risk aversion shows an ambiguous effect in the present context. Moreover, existing literature mentioned that the determination of the direction and magnitude of the unobserved variable bias in a priori is almost impossible because it is difficult to assume which effect will be dominant among many potential effects. This problem can be solved by using panel data that help to control unobserved fixed effects at household-level or using the instrumental variable (IV) regression. Due to lack of panel data, this study uses IV regression model for removing the above-mentioned

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problems. In a bunch of studies, specifically, in the last decades a number of researchers applied IV regression method in analyzing different non-farm participation effect on agricultural outcomes (Miluka et al. 2007; Mendola 2008; Kilic et al. 2009; Hertz 2009; Maharjan 2010; Vandercasteelen 2011).

2.2.1. Estimation of Two Stage Least Square (2SLS)

In this study, the 2SLS regression method with IV is applied to estimate the impact of participation in various non-farm income-based strategies on agricultural outcome. To estimate this impact, the first step is to apply the following model:

$$N_k = \alpha_k + \sum \alpha_k X_{nk} + \sum \alpha_k I_{ik} + \varepsilon_k \tag{2}$$

Where *k* indicates households that generate income from three specific non-farm sources (wage-employment, self-employment and migration) and all non-farm income; α_k is the intercept term; *N* denotes household income from three specific non-farm sources and all non-farm activities; X_n implies a set of explanatory variables regarding household and community characteristics; I_i indicates the instrumental variables and ε is the error term.

Estimated earnings from various strategies employed in the first stage of the regression are used in the second step:

$$Y_k = \beta_0 + \sum \beta_k X_{nk} + \beta_1 \hat{N}_k + \varepsilon \tag{3}$$

Here, *Y* indicates the outcome of interest such as farm production, cost for machinery and chemical inputs; and $\hat{N}$ implies the predicted values of income from first stage regression.

One of the trickiest issues in these evaluations thus far has proven to be the endogeneity between various income-generating activities and agricultural outcome. A legitimate instrument must meet the next two requirements. When estimating IV, movements in N that are uncorrelated with ε are isolated using a suitable IV that forecasts income without having an effect on outcome Y (Kilic et al. 2009).

2.2.2. Estimation of Seemingly Unrelated Regression (SUR)

One of the interests of this research is to assess the impact of non-farm based strategies on farm labor use, which is a combination of family labor and hired labor. In the context of Bangladesh agriculture, family labors and hired labors are highly substitutable for each other. Therefore, cross equation correlation of the error terms in outcome equations are expected in this situation.

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$$L_{fk} = \alpha_0 + \alpha_1 N_k + \sum \alpha_k X_{nk} + e_1 \quad (4)$$

$$L_{hk} = \alpha_0 + \alpha_1 N_k + \sum \alpha_k X_{nk} + e_2 \quad (5)$$

Where, L_f and L_h indicate family supplied agricultural labor and hired labor respectively; N implies household income from three specific non-farm sources (wage-employment, self-employment and migration) and all non-farm activities; X_n denotes a set of explanatory variables regarding household and community characteristics; e_1 and e_2 are respective error terms.

Seemingly Unrelated Regression (SUR) is a single model containing several linear equations, where these equations disturbances are correlated. Therefore, based on this property and the interest of the study, SUR model would be a better-suited estimator for this case.

2.2.3. Instrumental variable (IV) selection

A valid and appropriate instrument must satisfy instrumental relevance and instrumental exogeneity conditions. The first condition indicates variation in the instrument is related to the variation in the instrumented variable. Second condition implies that instrument must be uncorrelated with the outcome variable of choice. So, in a word, instrumental variables should directly influence respective non-farm activities but not the outcomes such as farm production, cost for machinery and chemical inputs. Instruments selected in this study are based on theoretical ground and existing literature.

In IV estimation, for analyzing the impact of income from wage or self-employment on outcome variable, the following two instruments are used: (1) distance from district level urban center and (2) share of non-farm employment at district level. Based on the literature (e.g., Deichmann et al. 2009), we argue that household distance from district urban center play a role in participation of well-paid wage employment and self-employment in the non-farm sector. The closer they live to the urban center, the easier for them to be involved in non-farm activities. We can assume that this distance does not directly influence agricultural production or expenditure. Scharf & Rahut (2014) used proportion of the working population engaged in non-farm sector at the village level as an instrument. Due to unavailability of data at village level, this study followed Kilic et al. (2009) and used share of non-farm employment at the district level. This IV might positively influence the level of non-farm employment opportunity in the respective districts. Therefore, household probability to engage in non-farm activities increases, thereby their earnings from wage

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and self-employment activities also increases (fulfilled instrumental relevance). In addition, it can be also confirmed that the proposed instrument does not influence the outcome variable, which satisfies the exogeneity condition.

In case of estimating the impact of income that generated through migration, two instruments are also used, namely family migration network and district level migration network. The proportion of internal migration at district level is used as district level migration network. The migration network has been used as a valid instrument in many researches (McCarthy et al. 2006; Kilic et al. 2009; Maharjan 2010; Brauw & Harigaya 2007; Akhter 2015; Gyimah-Brempong & Asiedu 2011; Yaméogo 2014). In case of family migration network, it is very easy for current family members to get higher access to information, lower migration cost, accommodation facilities etc., from former migrated family member(s). These types of facilities are also available in the case of district level network, as they have widespread social network among them. Both family and district level migration networks may have a significant impact on household migration decision but have no influence on agricultural production or investment. Theoretically, both of these variables satisfied the conditions for instrumental validity.

2.2.4. Description of the variables used in the OLS, 2SLS and SUR model

Expenditure on agricultural machinery and chemical inputs, use of family labor and hired labor, and total farm production are treated as the outcome variable for examining the impact of different non-farm incomes on agricultural outcomes. Natural logarithm forms of all dependent variable are used in this analysis to reduce the impact of highly skewed outcomes on the estimates.

In the set of explanatory variables, non-farm incomes generated from four strategies (strategy S1, strategy S2, strategy S3 and strategy S4) are used separately for identifying their impact on different agricultural outcomes. In order to get the net income from self-employment, all business costs like shop's rental costs and labor costs, electricity, equipment, expense of raw materials etc., are subtracted from total earned income from the self-employment activities. Both payment in cash and payment in kind are considered as income generated from non-farm wage employment. Finally, household's acceptance of money from its members living outside the locality or country is treated as income from migration or remittance.

In these analyses, strategies exclude agricultural income from all income generated groups and consider only income from wage, self-employment and migration due to ignore the problem of multicollinearity. The set of other explanatory variables under the sub-set of demographic and socio-economic categories and used instruments are briefly described in the Table 1.

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Table 1: Explanation of the model's instrumental and explanatory variables

Variables	Description
Non-farm income source	
Wage employment activity (Strategy S1)	Households generate income from wage-based works in non-farm activities along with farming
Self-employment (Strategy S2)	Households involve in self-employment in non-farm activities along with farming
Migration (Strategy S3)	The sources of income are agriculture as well as remittances from household members who are either in-country or out-of-country migrants.
Non-farm activities (Strategy S4)	Households generating income from agriculture, wage, self-employment and remittances
Respective non-farm income	This income is different for different strategy adaptors. Amount of income from wage for strategy S1, income from self-employment activities for strategy S2, remittance for strategy S3, and income from all non-farm activities for strategy S4.
Demographic and economic	
Very young dependent	Number of household members aged less than 6
Young dependent	Number of household members aged between 6-14
Active male	Number of economically active males (aged between 15 and 59 years) in the household
Old dependent	Number of household members aged more than 59
Household head age	Age of household head in years
Higher educated hh member	Number of higher educated household member
Cultivated land	Total cultivated land holding of household in Ha
Plots	Number of total agricultural plots of the HHs
Machinery (Δ)	Household have own agricultural machines (Yes = 1 & No = 0)
Household assets	Value of household non-agricultural assets (natural log form of value)
Farming experience	Household head's agricultural experiences in year
Credit (Δ)	Household received credit (Yes = 1 & No = 0)
Agri. Extension (Δ)	Availability of agricultural extension service (Yes = 1 & No = 0)
Infrastructure (Δ)	Household's respective village has developed infrastructure (Yes =1 & No = 0)
Instruments	
Distance from urban center	Distance from respective district's urban center
Non-farm employment share	Share of non-farm employment at district level
Family migration network (Δ)	Previous household member involved in migration (Yes =1 & No = 0)
District level migration network	Proportion of internal migrated people at district level

Note: Δ indicates Dummy variable; HH = Household; Ha = Hectare

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3. Results and Discussion

3.1. Test results regarding endogeneity and instrumental validity

The endogeneity of the data is examined using the Durbin-Wu-Hausman (DWH) test, which is probably the most used method for endogeneity testing. The test result is displayed in Appendix 1. In case of farm production and farm machinery expenditure, p-values indicate the rejection of null hypotheses that the incomes from different non-farm based strategies are exogenous. The result is consistent with the previous findings from Kilic et al. (2009), Hertz (2009), Maharjan (2010) and Vandercasteelen (2011). However, the p-values point out the acceptance of null hypothesis or suggest exogeneity in case of chemical expenditure, family and hired labor uses of the household. Generally, the Two Stage Least square (2SLS) estimator applies in the earlier studies whenever an endogeneity problem exists, otherwise different estimation procedures are followed (Kilic et al. 2009; Maharjan 2010; Vandercasteelen 2011; Akhter 2015).

Instrumental variables are used for removing the existing endogeneity problem in farm production and agricultural machinery expenditure. Though the main interest of this study lies in the second stage, the first stage is also important to test the relevance, significance and strength of the selected instruments. The first stage of the 2SLS model is a simple OLS regression stated in equation (2), whereby non-farm incomes from different sources are regressed on the sets of explanatory variables and IVs. Previous research indicates that the set of instruments is weak if the first stage F-statistic value is below the standard threshold of 10 (Kilic et al. 2009). Therefore, the higher and highly significant values of F-statistics in this study conclude that, the considered sets of instruments are strong enough (Appendix .1).

Moreover, the condition of relevance of the instruments can be tested by the underidentification test and weak instrument identification test. Generally, whether the regression is identified, that means correlated with the non-farm income is tested by underidentification test (Vandercasteelen 2011). In this analysis, underidentification test is examined by the Kleibergen-Paap rk LM statistic (see Appendix 1). Highly significant values of this statistic affirm the relevance of the instruments. Besides, a weak identification test is used for testing whether instruments are weakly correlated to non-farm income or not and Cragg-Donald Wald F-statistic is used to test this (Wooldridge 2002; Baum 2006). These statistics are almost greater than the Stock-Yogo weak ID test of 16.85 at 5 percent maximal IV size, exhibiting the strength of the used instruments. Another statistic, named Hansen J statistic is applied for over-identification test of instruments. Both the correctly specified hypothesis and the model's orthogonality criteria are satisfied by the Hansen J statistic (Miluka et al. 2007). The null hypothesis is thus accepted if the orthogonality

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condition is met and the instruments' endogenous factors are appropriately eliminated from the regression analysis. This test result will be discussed along with the results.

3.2. Testing for correlation of cross equation error terms

Substitutable nature of family labor and hired labor in agricultural activities raise the question of correlation between the error terms of these outcome equations. The correlation matrix of error terms and Breusch-Pagan test of independence are performed for recognizing the correlation of cross equation residuals in the labor equations. The result presented in Table 2 clearly points out the existence of the problem of cross equation correlation of error terms. The high correlation coefficients between the family labor and hired labor equation's residuals for all type of part-time farming categories indicate the presence of the problem. Besides, Breusch-Pagan test result also confirmed this problem in all cases, as the null hypothesis of independence of the two equation's residuals is rejected at 1 % level. Thus, OLS estimation in this case would provide bias result and SUR model is used for solving this problem.

Table 2: Results of cross equation error terms correlation tests

Strategy	Tests	Value
Agril. & wage-employment (Strategy S1)	Correlation between error terms of family labor & hired labor	0.7218
	Breusch-Pagan test of independence	Chi sq. = 25.87 Prob> chi sq. = 0.0000
Agril. & Self-employment (Strategy S2)	Correlation between error terms of family labor & hired labor	0. 7596
	Breusch-Pagan test of independence	Chi sq. = 10.95 Prob> chi sq. = 0.0000
Agril. & Migration (Strategy S3)	Correlation between error terms of family labor & hired labor	0.8805
	Breusch-Pagan test of independence	Chi sq. = 12.97 Prob> chi sq. = 0.0001
Agril. & all non-farm (Strategy S4)	Correlation between error terms of family labor & hired labor	0.8418
	Breusch-Pagan test of independence	Chi sq. = 13.21 Prob> chi sq. = 0.0001

Source: Author's calculation

3.3. Impact of different non-farm income on farm machinery and chemical inputs expenditure

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The results for the impact of different types of non-farm incomes on the investment in farm improving technology (farm machinery and chemical inputs) are presented in Table 3. Overall, non-farm activities have a positive and significant impact on farm expenditures on modern technology uses. The Nguyen (2019) and Woldenhanna (2000) study lends credence to this conclusion. They found a statistically significant and strong positive relationship between non-farm activities and the use of modern farm inputs in both Vietnam and Tigray. However, Nguyen (2019) stated that farm households did not use the non-farm income for hiring machines. Among four diversification strategies based on non-farm activities, all types of strategies exert positive and significant effects on machinery and chemical input expenses except migration-based activities. In case of investment in machinery, the negative but insignificant effect implies that farm households with migrants might not invest in all modern technologies used in farming. The possible reasons may be due to their lack of interest in spending more money in agriculture or the money they get from migrant member is not sufficient to invest in farming technology. The similar result was also found in the study of Mendola (2008) and Akhter (2015), where less return from migration was treated as the main reasons behind this negative influence in Bangladesh. However, the coefficients of wage income in the farm machinery and chemical inputs regression are higher (40 percent and 11 percent respectively) than the coefficients for the self-employment income. A similar result of non-farm income on investment for technologies was also found in Northern Ethiopia (Vandercasteelen, 2011).

Among demographic variables, as might be expected, the number of active male and household head age show a significantly negative impact on investment in farm machinery. With an increase of one active male member, households with migrant(s) reduce their expense for machinery almost 2 times and 3 times more than the self-employment and wage-employment based households respectively. Similarly, age of the household head is negatively associated with machinery and chemical input expenditures, as older people are less likely to invest in modern technology uses. However, higher educated family members and provision of agricultural extension services positively influence adoptions of both modern technologies. When a household has more educated members and easily gets the technology related information from the agricultural extension organizations, they are more likely to invest in machinery and chemical inputs. However, increasing higher educated member in the migration based household adversely affect machinery expenditure. The possible explanation for this result is that the intension of higher educated member in migrant's households is to migrate in urban area or other countries rather than concentrating in farming activities. Therefore, their higher education might not exert any positive influence on machinery uses.

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Table 3: Impact of different non-farm incomes on farm machinery and chemical input expenditures (results from the 2SLS estimation)

Explanatory variables	Farm machinery expenditure				Chemical input expenditure			
	Strategy S1	Strategy S2	Strategy S3	Strategy S4	Strategy S1	Strategy S2	Strategy S3	Strategy S4
Non-farm income								
Log of respective non-farm income (¤)	0.402*** (0.257)	0.237* (0.018)	-0.084 (0.024)	0.238** (0.030)	0.112*** (0.066)	0.060** (0.003)	0.019* (0.001)	0.071* (0.010)
Demographic and economic								
Very young dependent (No.)	-0.234	-0.070	-0.032	-0.085	0.126	0.016	0.102	0.099
Young dependent (No.)	-0.110*	0.197	0.105	-0.007	0.119	0.096	0.129	0.015
Active male (No.)	-0.062*	-0.111**	0.182***	-0.101***	0.072	0.195**	0.129	0.233*
Old dependent (No.)	0.067	0.075	0.055	-0.055	-0.105	-0.119	-0.133	-0.119
Household head age (year)	-0.032**	-0.016*	-0.142*	-0.184**	-0.014	-0.025***	-0.011	-0.029
No. of higher educated HH member	0.147**	0.074	-0.048*	0.151	0.099***	0.066*	0.016	0.013
Cultivated land (ha)	0.558***	0.519***	0.451***	0.531***	0.331***	0.221***	0.245***	0.422***
Plots (No.)	0.057*	0.052	0.026***	0.070*	0.028**	0.099	0.023	0.026***
Machinery (Δ)	-0.225**	-0.190*	-0.121*	-0.171**	0.077	0.023***	0.092	0.066
Household assets (log value)	0.184*	0.138	-0.005**	0.048**	0.032	0.041	0.071	0.038**
Farming experience (year)	-0.033	-0.036	-0.022	-0.071	0.098***	0.006	0.006	0.084*
Credit (Δ)	-0.103*	0.135	-0.135**	-0.109	0.150	0.158	0.154	0.146
Infrastructure (Δ)	0.434**	0.408**	0.416***	0.333**	0.110*	0.081	0.105**	0.050*
Agri. extension (Δ)	0.258*	0.158**	0.096	0.238**	0.224*	0.201**	0.161*	0.209**
Constant	6.971***	9.945***	10.204***	9.745***	7.978***	8.118***	8.260***	8.192***
Model summary								
F value	13.59**	14.40***	14.15***	12.97***	15.18***	14.69***	14.78***	14.58***

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R^2	-	-	-	-	0.7557	0.7180	0.6369	0.6317
Hansen J statistic (p-value)	0.8851	0.8853	0.3504	0.8948	-	-	-	-

Notes: Δ indicates dummy variable; Asterisks (***, **, *) denote significance at the 1%, 5% & 10% levels respectively; Figure in the parentheses implies standard errors; Strategy S1, Strategy S2, Strategy S3 & Strategy S4 are groups of households involved in wage-employment, self-employment, migration activities, and all form of non-farm activities respectively, as already explained in Table 1; No. indicates number; (¤) Depending on the strategy adopted, this income varies. For example, remittance for adopted households during migration (strategy S3).

Cultivated land is positively related with both farm machinery and chemical input investments for all types of part-time farming households, and these relations are significant at the 1% level. The number of plots is also positively associated with investment in farm technology uses, indicating that fragmentation of land increases both machinery and chemical input expenditure. This is consistent with the practical situation of Bangladesh, where plot sizes are very small and scattered. Sometimes farmers kept land fallow or rented-out some plots due to the difficulties in bringing machinery to the most scattered plots. As only a small percentage of households have their own machines, most of the households rented them in a comparatively higher charge. Using own machines can reduce 22 percent, 19 percent, 12 percent of machinery use expenditure of wage, self-employment and migration-based households respectively. Furthermore, both farm machinery and chemical input expenditure are positively influenced by non-farm based household asset value at a 5% significant level. This positive impact implies that high non-agricultural assets indicate household higher capability for invest in modern technology. However, migration-based households with higher asset value are found less interested in spending in machinery expenditure, but they are more likely to spend in chemical input. As expected, experienced farmers, especially in case of wage-based household heads use more chemical input. This implies that experienced household heads know better about the positive side of chemical inputs and they can use these in better ways. Credit acceptance of the household is another important variable that can affect input uses.

In the end, the null hypothesis of the overidentification test's (Hansen J statistics) suggests that the instruments are together valid and that they are appropriately removed from the estimated equation. The p values (0.8851, 0.8853, 0.3504 and 0.8948) obtained from the statistics indicate the acceptance of null hypothesis. That means instrument set is valid and models are correctly specified. The overall R^2 value shows that about 63 percent of the variation in the chemical input use is explained by the set of explanatory variables in the model.

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3.4. Impact of various non-farm income on farm labor

Farm household participation in the non-farm sector shows significant impact on labor inputs, both family farm labor and hired labor, by holding other factors constant (Table 4). Participation in any type of non-farm activity results in a loss of available family labor in farming, whereas it increases the use of hired labor. With the increase of 100 percent respective non-farm income, farm households with migrant reduces the highest percentage (53 percent) of family farm labor followed by households with wage employment (46 percent) and self-employment (39 percent). Internal or international migration reduces family labor permanently, so these migrated members cannot join in the farm activities in the time of higher labor requirements.

Table 4: Impact of different non-farm incomes on family and hired labor use (results from the 2SLS estimation)

Explanatory variables	Family labor use				Hired labor use			
	Strategy S1	Strategy S2	Strategy S3	Strategy S4	Strategy S1	Strategy S2	Strategy S3	Strategy S4
Non-farm income								
Log of respective non-farm income (¤)	-0.458*** (0.016)	-0.386** (0.016)	-0.529** (0.015)	-0.355** (0.014)	0.480*** (0.012)	0.422* (0.011)	0.631*** (0.011)	0.428*** (0.010)
Demographic and economic								
Very young dependent (No.)	0.091	0.039	0.032	0.073	0.011	-0.009	0.006	0.016
Young dependent (No.)	0.132	0.224**	0.227***	0.094*	0.051	-0.080*	-0.036**	-0.016
Active male (No.)	0.232**	0.166*	0.100*	0.204**	-0.143*	0.109	-0.109	-0.170*
Old dependent (No.)	0.200**	0.103	-0.171	0.141	-0.060	0.032	0.027	0.013
Household head age (year)	-0.007	-0.014	-0.013*	-0.006*	0.002	0.002	0.002	0.003
No. of higher educated HH member	-0.044***	-0.031*	-0.034	-0.043	0.027*	0.013	0.009	0.013
Cultivated land (ha)	0.512***	0.588***	0.582***	0.600***	1.148***	1.156**	1.175***	1.227***
Plots (No.)	0.010	0.007	0.005	0.010	0.045*	0.041	0.046	0.041*
Machinery (∆)	-0.053	-0.170	-0.044***	-0.115*	-0.136	-0.143	-0.162**	-0.158**

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Household assets (log value)	-0.194***	-0.224***	-0.210***	-0.180***	0.102**	0.085**	0.086**	0.072*
Farming experience (year)	0.009*	0.013*	0.014*	0.009	0.002	0.005	0.003	0.005
Credit (Δ)	0.038	0.131	-0.109*	-0.143*	-0.031	0.095*	0.101	0.107
Infrastructure (Δ)	-0.223*	-0.233**	-0.160	-0.228*	0.136	0.147	0.091	0.128
Agri. extension (Δ)	0.123	0.162*	0.175	0.167*	-0.099	-0.111	-0.162	-0.105
Constant	4.847***	5.184***	5.131***	5.144***	2.058***	2.089***	2.317***	2.355***
Model summary								
Chi sq. (p-value)	99.26	83.64	90.73	90.73	196.65	220.55	219.20	219.20
R^2	0.3935	0.3534	0.3723	0.3723	0.7216	0.7362	0.7326	0.7326

Notes: Δ indicates dummy variable; Asterisks (***, **, *) denote significance at the 1%, 5% & 10% levels respectively;
Figure in the parentheses implies standard errors; Strategy S1, Strategy S2, Strategy S3 & Strategy S4 are groups of households involved in wage-employment, self-employment, migration activities, and all form of non-farm activities respectively, as already explained in Table 1; No. indicates number;
(¤) Depending on the strategy adopted, this income varies. For example, remittance for adopted households during migration (strategy S3).

On the other hand, self-employed household members are more flexible about their working hours and they can spend their time in farming when it is highly required. However, wage-employed household members are not as flexible as self-employed members but they can also manage some fieldworks on the weekend or off-time. Therefore, participation in different non-farm activities as well as earning from these activities may not have the same level of impacts on the family labor use in farming. This loss of family labor is replaced by hired-in labor from the market, as females did not work in fields. Therefore, migrant households require the highest number of hired labor for replacing the higher gap of family labor. Nguyen et al. (2019) explored that rural households receiving remittances from migrants improve their land productivity and increasingly concentrate on non-farm labor allocation. It is also clear from the Table 4 that the magnitude of family labor loss is smaller than the hired labor used in farming. This result indicates the more efficient nature of family labor than hired labor. These results are in line with the empirical evidence in the literature on labor use (Kilic et al. 2009; Miluka et al. 2007; Maharjan 2010; Salam and Bauer 2015; and Akhter 2015). However, the findings revealed that farm households did not allocate non-farm income for hiring labor. However, these findings contradict those of Nguyen (2019), who found that farm households did not allocate non-farm income for hiring labor.

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In the demographic variable list, the number of household member within the age group of 6-14 has a significant positive effect on farm family labor and consequently a negative effect on hired labor use in self-employed and migrant households. These results can be explained in that, when family labor is reduced due to active member's migration or participation in self-employment activities, child labors (age between 6-14) have to come forward to help in the farm activities. Therefore, household can partially replace the loss of active family labor with this child labor. However, the impact of this group of household members is not found significant for wage earning households. The possible explanation of this result is that, households, participating in wage employments are more educated than other households and generally they are more interested in sending their children to the educational institute. Similarly, number of active labor also has significant positive effect on family labor use in farming.

In case of family labor use in farming, the number of higher educated household members shows a negative impact. In case of wage-earning households, one additional number of higher educated members decreases family labor supply in farming by 4 percent and this effect is significant at the 1% level. It is not surprising that higher education reduces the incentive for doing farming activities and encourages participating in non-farm sector (Corral & Reardon 2001; DeJanvry & Sadoulet 2001). This implies reduction of family labor use in farming and consequently increases hired labor. Cultivated land is positively and highly significantly related to family labor and hired labor use in farming. The magnitudes of this variable are much higher than the other variable for all types of households, which represents the labor-intensive farming system of Bangladesh. As expected, having own machinery reduced family and hired labor requirements in farming. Another significant impact is found in the case of household assets. Generally, rich households are less likely to participate in farming activities even though they have sufficient amount of time to work. Besides, they like to hire-in more labor for their farming activities and are interested in enjoying leisure time. Another push factor for participating in non-farm activities as well as losing family farm labor could be the available infrastructural facilities. It mostly affects farm households in participating in wage and self-employment activities rather than migration.

3.5 Impact of various non-farm income on farm production

The result of responses in farm production of different strategies (non-farm-based) adopters due to generated income from that strategy is reported in Table 5. Farm production is seen to be influenced differently by the participation in various forms of non-farm activities along with farming. Overall, non-farm income has a statistically significant,

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positive and strong impact on farm production. This result is consistent with the findings of Pender & Gebremedhin (2004). Anang (2017), Adelekan and Omotayo (2017), and Nguyen (2019) also found a positive significant effect of non-farm employment participation on farm productivity and production efficiency. However, a negative impact of non-farm activities on agricultural production is found in the study of Holden et al. (2004), where they considered both crop and livestock as agricultural production unit. In the present analysis, the impact of income from wage employment is found highest among the three categories of non-farm income. A household 100 percent increase of income from wage activities led to 36.5 percent increase in farm production, whereas half of this enhanced production could be earned by increasing 100 percent self-employment income. However, income from migration exerts a negative impact on household farm production. This result is in line with other literature in Bangladesh and some other countries (McCarthy et al. 2006; Beaudouin 2006; Miluka et al. 2007, Maharjan 2010; Akhter 2015). This outcome is however contradictory with the findings of positive impact of migration obtained by Taylor and Lopez-Feldman (2010) and Gray et al. (2014). As the impact of overall non-farm income is found positive, this negative impact of migration is a somewhat surprising result. The reasoning behind it might be explained by the impact of this non-farm income on different input use, as crop output is a function of used inputs.

Table 5: Impact of different non-farm incomes on different strategy adopter's farm production (2SLS estimation)

Explanatory variables	Strategy S1	Strategy S2	Strategy S3	Strategy S4
Non-farm income				
Log of respective non-farm income (¤)	0.365**	0.179**	-0.130*	0.236 **
	(0.126)	(0.061)	(0.116)	(0.396)
Demographic and economic				
Very young dependent (No.)	0.044	0.005	0.031	-0.177
Young dependent (No.)	0.038	0.063*	0.040*	0.051
Active male (No.)	0.025**	0.029	0.001	0.005
Old dependent (No.)	0.019*	0.024	0.046*	0.267**
Household head age (year)	-0.044	0.001	0.001	-0.029
No. of higher educated household member	0.034*	0.011**	0.002	0.056**
Cultivated land (ha)	1.121***	1.046***	0.962***	1.399***
Plots (No.)	-0.027*	-0.026***	-0.023***	-0.001*
Machinery (Δ)	0.232**	0.256**	0.226**	0.393*
Household assets (log value)	-0.030	-0.047	-0.047*	-0.061
Farming experience (year)	0.002	0.025*	0.008*	0.042*
Credit (Δ)	-0.076	0.104	-0.020*	-0.305
Infrastructure (Δ)	0.022*	0.015*	0.024	0.155
Agri. extension (Δ)	0.101**	0.064**	0.053	0.118***
Constant	10.962***	11.086***	11.286***	12.916***
Model summary				
F value	18.18***	24.76***	30.34***	14.35***
Hansen J statistic (p-value)	0.3518	0.1877	0.6996	0.2729

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Notes: Δ indicates dummy variable; Asterisks (***, **, *) denote significance at the 1%, 5% & 10% levels respectively;
Figure in the parentheses implies standard errors; Strategy S1, Strategy S2, Strategy S3 & Strategy S4 are groups of households involved in wage-employment, self-employment, migration activities, and all form of non-farm activities respectively, as already explained in Table 1;
(¤) Depending on the strategy adopted, this income varies. For example, remittance for adopted households during migration (strategy S3).

Farm households with migrants have weak influence on farming improving technology; even this exerts a negative impact on farm machinery use. Though these households increase the use of chemical inputs with the increase of their remittance, this magnitude is not found so big. Another reason might be due to the loss of a higher portion of efficient labor as they cannot fully compensate for the loss of family labor with less efficient hired labor (Akhter 2015). Therefore, crop output is negatively influenced by the remittance income, as input use. This is also consistent with the current practical situation of Bangladesh, where farm households are losing their interest in farming when they get money from the migrant household member(s).

Among demographic and economic variables, number of children (aged between 6-14), number of active male member (aged between 15-59) and number of old dependent member (aged above 59) show positive impacts on part-time farm production for all types of non-farm earning households. Moreover, in case of overall part-time farm households as well as wage and self-employment based households, higher educated member, infrastructural facilities and availability of agricultural extension service positively and significantly influence farm production. The magnitudes of response of these variables to farm production are higher in wage generating household than self-employment. Though these variables have positive effects on migration-based household farm production, these are not significant.

Cultivated land, the most important factor of farm production shows a positive and statistically highly significant impact on farm production. Farm production of wage, self-employed and migration participated households will increase by 121 percent, 105 percent and 96 percent with the increase of land by 1 hectare. The reason behind these high magnitudes of coefficient is explained by Cornia (1985). The author identified land scarcity is the main reason behind this high land elasticity. Not only cultivated land, but also number of plots significantly influences farm production. This result implies that households have less farm production if their land is more fragmented. Moreover, farm production is also boosted by having its own machines, which implies easy access to machinery at comparatively low cost when it is required in the field.

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The p values of Hansen J statistics (Table 5) indicate the acceptance of null hypotheses, and confirmed both instrumental validity and correctly specification of the models.

4. Conclusions

Using survey data, this paper has attempted to explore the impact of different rural livelihood diversification strategies on farm input uses and farm production. The result indicates a complex impact of these strategies on the agricultural outcomes. In general, combination of farm and various non-farm income-based strategies has a significant and positive impact on household investment in modern technology (such as machinery and chemical input), hired labor uses, and farm production. Farm household's wage income is found to have the highest positive impact whereas migration-based farm household is found to be less interested in farm investments and production. Therefore, introducing policies that would increase rural non-farm, especially wage-based and self-employment opportunities in rural areas complements agriculture as well as agricultural production. Establishing agro-based industries in the rural area would be a better option for the rural inhabitants to increase earning through both directly working in these industries and selling raw materials to them. Since the results also imply that benefitting from higher education, availability of agricultural machinery and agricultural extension service translates into increased farm investments and production, thus, enhancing education and training program, decreasing price of agricultural machinery, and improving agricultural extension services should be the priority plan of action for rural development.

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Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Appendix 1: Result of endogeneity test and instrument identification test

Variables	Strategy	DWH test p- value	F test	Kleibergen-Paap rk LM statistic	Cragg-Donald Wald F statistic
Farm produ-ction	Strategy S1	0.049	14.38***	21.16***	20.24
	Strategy S2	0.058	18.45***	16.07**	16.23
	Strategy S3	0.002	20.63***	17.86***	25.94
	Strategy S4	0.034	16.92***	21.49***	20.85

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Farm machinery expen-diture	Strategy S1	0.008	17.92***	13.95***	17.26
	Strategy S2	0.012	16.88***	5.93**	12.89
	Strategy S3	0.000	23.96***	19.10***	23.65
	Strategy S4	0.008	21.20***	18.34***	22.81
Chemical input expen-diture	Strategy S1	0.287			
	Strategy S2	0.222			
	Strategy S3	0.317			
	Strategy S4	0.382			
Family labor use	Strategy S1	0.372			
	Strategy S2	0.853			
	Strategy S3	0.807			
	Strategy S4	0.735			
Hired labor use	Strategy S1	0.920			
	Strategy S2	0.141			
	Strategy S3	0.388			
	Strategy S4	0.658			

Source: Author’s calculation

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