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Determinants of adoption of improved onion variety in Bangladesh

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Abstract: In Bangladesh, onion production is much lower than its demand resulting in high import bill. Widespread farm level adoption of improved onion varieties may help here through increasing productivity. In Bangladesh, onion production is much lower than its demand resulting in high import bill. Widespread farm level adoption of modern onion varieties may help here through increasing productivity. This paper attempts to identify determinants of adoption and level of adoption with the objective of suggesting policy options for increasing cultivation of different improved onion varieties. A multi-stage sampling technique was used to obtain data from 300 Bangladeshi onion growers. Results show that cultivation of improved variety gives higher returns to the farmers than the traditional varieties, though the former is more capital intensive than the latter. Four different Cragg's double hurdle models were developed to identify factors affecting adoption and adoption intensity. Quality of extension service and access to credit are the two most important factors that contribute to adoption. Farmers practicing crop diversification are more likely to adopt, but when they adopt they devote relatively a lower share of their available land to improved onion varieties since they are characterized to cultivate different crops. With increasing off-farm income farmers tend to adopt less. Level of adoption is likely to be higher among the experienced and educated farmers. Number of fragmented land reduces adoption probabilities.

Keywords: Modern onion variety, adoption, Bangladesh, Cragg's model.

Introduction

Onion is one of the important spice crops in Bangladesh. It ranks top in terms of production among the spice crops. It occupies around a lion share (5942%) of the total area under spices (BBS, 20112013). But the production is not sufficient to meet domestic demand and eventually the country has to rely on imports from international markets. In 2010-11, the country imported 16098 metric tons of onion and shallots, which was worth of US$5.73 million (BBS, 2011). Such a huge volume of import shows urgency and scope to increase domestic production. Recent hike in onion price again emphasizes importance of increasing domestic production. The average onion price in the country almost tripled in October 2013 in a year (DAM, 2013).

There might be two likely options for increasing onion production in the country. One is increasing onion cultivation area and the other is improving its productivity. In a land scare country like Bangladesh, the earlier option is less likely to be extensively explored as demand for land for non-farm activities is tremendously increasing. Annually 1% of the country's agricultural land is diverted to non-agricultural purposes (Planning Commission, 2009). On the other hand, the country's agricultural sector is operating nearly at land frontier, showing almost dried out opportunity to increase production through bringing new land under cultivation (Rahman, 2003). Furthermore, the mean yield of onion in Bangladesh is very low (8.22 ton/ha) (BBS, 2011) compared to world average (19.47 ton/ha) (FAO, 2012). Hence, attention should be given to improving productivity through replacing traditional onion varieties with improved varieties. Though the national agricultural research organizations have developed different high yielding improved onion varieties, unfortunately, traditional varieties still dominate farmers' field.

In the context of Bangladesh we could access few studies about economics of onion production. Using Cobb-Douglas stochastic frontier production function approach, Baree *et al.* (2011) estimated technical efficiency of the different categories of onion producing farms in Bangladesh. Their results showed that medium farms are more efficient compared to the large and small farmers. But all the three categories of farm had scope to increase production through the efficient use of existing production technology. Haque *et al.* (2011) found onion production to be profitable than other competitive crops like mustard, groundnut, and cabbage. They also identified several problems faced by the onion growers including non-availability of high yielding variety (HYV) onion seed at proper time, lack of technical knowledge, high price and non-availability of fertilizer in time, and lack of appropriate storage facility. Awal *et al.* (2004) found that though return from onion production was positive, the onion growers were not efficient in terms of resource allocation. Their results suggested that the onion growers can increase output by efficient utilization of family labour, cowdung, insecticides and irrigation. Using a Cobb-Douglas production function Saha and Elias (1990) found that small farms producing onion were more efficient in terms of input use compared to the medium and large farms. The small farmers also have higher yield and gross margin. Their empirical results suggest that greater use of urea and MP fertilizer by small farms would further increase yield. A recent study of onion marketing and postharvest practices showed that onion production and marketing are profitable at farmers and intermediaries levels. Compared to the market actors the producers get little share of profit. With increasing number of market actors, farmers share to profit reduces. The study emphasized the importance of storage and transportation facility in onion production and marketing (Adnan *et al.*, 2014). Though none of these studies is about the factors influencing improved onion variety adoption, there are studies about adoption of improved varieties in the case of other crops.

Rahman (2008) found that along with availability of irrigation facilities, several other factors like farmers' education, farming experience, farm asset ownership, infrastructure and non-agricultural income influence Bangladeshi farmers' choices about a crop. For promoting crop diversification, the literature argued for importance of investing in farmers' education and rural infrastructure development including irrigation. It also emphasized necessities of land reform policies and tenurial reforms. Mottaleb, Mohanty and Nelson (2014) found that in Bangladesh land characteristics, credit facilities and physical infrastructure (such as roads, irrigation facilities) and the availability of government-approved seed dealers, significantly influence the adoption of hybrid and modern rice varieties and land allocation to these varieties. Joshi and Pandy (2006) found that Nepali farmers' perceptions about varietal characteristics such as pest resistance, drought tolerance and suitability for making special products play a key role in explaining their adoption behaviour. They also found that the farm and farmer specific variables such as education, experience, and availability of extension services have significant effects on improved variety adoption. Results from other studies do not differ much from these but they use different farm-specific socio-economic and community level factors to explain differences in adoption under the same macro-economic structure (Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Nkamleu and Adesina, 2000; Shiyani *et al.*, 2002).

Understanding the importance of onion production in the country and keeping in mind scarcity of research, this study aims to determine the factors that influence the improved onion variety adoption and level of adoption. Increased farm level adoption will increase farm production and hence profit. Ultimately farmers enjoy better income and livelihood status. At the macro level, the impact will be less import and more favourable balance of payment.

Methodology

Data and survey

Primary data were collected through a farm level survey. A Multi-stage sampling technique was employed for this purpose. In the first stage, three major onion producing districts, namely Pabna, Faridpur and Rajshahi, of Bangladesh were purposively selected. Then, from each district the top onion producing upazila[1] and from each upazila two top onion producing villages were purposively selected. The study purposively focused on extensively onion growing areas since onion is not grown all over the country. Moreover, programmes for popularizing modern onion varieties are more likely to be successful in these areas. In the final stage, 50 onion growers were selected randomly from each village using a list of onion growers available from the local agricultural extension office. Thus, a total of 300 farmers belonging to six different villages in three different districts of the country were selected and interviewed for the study.

Though rice is the major crop for these sample farmers, they also grow crops like jute, potato, wheat, corn, vegetables and fruits. Some preliminary exploration of the data showed that around 30% of the sample farmers cultivate spices (e.g. garlic, chili, turmeric, etc.) other than onion. Onion is cultivated in around 27% of the sample farmers' total cultivable land. The farmers of the study area cultivate both improved and traditional varieties.

Empirical analysis: Determining factors effecting adoption and level of adoption

Adoption of any new variety or technology not only depends on its profit or production potentials, but also on different farm specific socio-economic and community level factors. The purpose of the empirical analysis employed here is to identify such determinants of improved onion variety adoption and level of adoption.

Among the surveyed onion growers, some cultivate improved varieties (hereinafter called adopters) while others cultivate traditional varieties (hereinafter called non-adopters). Also, there are differences in level of adoption among the adopters. Some of the adopters use all their available land for modern varieties, whereas others use some portion of their land. Hence, we have two questions to answer: (i) why are some of the onion growers adopting modern variety and some not?; and (ii) why does the level of adoption vary among the adopters? We use a Cragg's double hurdle model to answer these two questions. Use of Cragg's model for analyzing adoption and level or intensity of adoption is common in agricultural economics (Cooper and Keim, 1996; Teklewold *et al.*, 2006; Shiferaw *et al.*, 2008; Gebregziabher and Holden, 2011, Mal *et al.*, 2012).

The first stage of Cragg's model is a probit model to analyze determinants of adoption, and the second stage is a truncated regression model for determinants of adoption level (Cragg, 1971). If d_i^* is the latent variable describing a farmer's decision to adoption (1 for adopters, 0 otherwise), y_i^* is the latent variable describing its decision on the level of adoption (e.g. ratio of land under modern onion variety and total farm

[1] An administrative unit in Bangladesh that is above the village level, but below the district level.

land), and d_i and y_i are their observed counterparts; based on the specification by Cragg (1971) and Moffatt (2005), the two hurdles for a farmer are:

$$d_i^* = \alpha z_i + v_i \quad (1)$$

$$y_i^* = \beta x_i + \varepsilon_i \quad (2)$$

where,

$$d_i = \begin{cases} 1, & if \quad d_i^* > 0 \\ 0, & if \quad d_i^* \leq 0 \end{cases} \quad \text{and} \quad y_i = \begin{cases} y_i^*, & if \quad y_i > 0 \ and \ d_i^* > 0 \\ 0, & if \quad otherwise \end{cases}$$

here, z_i is a vector of variables explaining a farmer's adoption probabilities; x_i is a vector of variables explaining level of adoption; and v_i and ε_i are the error terms.

Four different models are constructed to explain adoption and level of adoption. The list of exogenous variables used in the basic model (model 1) includes farming experience in years; farmers' education measured through years of formal schooling; Herfindahl index of crop diversification (the value of the index is from 0 to 1 and higher value represents higher level of specialization); a satisfaction index for extension service (where a higher value indicates higher level of satisfaction); farmers access to formal agricultural credit facilities (dummy, 1= farmers with access to credit, 0 otherwise); annual off-farm income of the household (BDT); farm size (decimal); share of own land (ratio of own land to total land); and number of fragmented land. There are reasons to suspect some of these variables to have joint effect on adoption, e.g. the effect of an additional quantity of land on adoption might vary depending on number of land parcels. Similarly, one may suspect effect of off-farm income may vary across households depending on their access to formal agricultural credit facilities. To address these different possibilities, we develop three other models including additional interaction variables along with the variables used in the basic model. The interaction of access to credit and off farm income and the interaction of land and land fragmentation are included in model 2 and model 3, respectively. The model 4 includes both the interaction variables. The detailed description and measurement techniques of these variables are provided in Appendix Table 1.

According to Carroll *et al.* (2005), Equations 1 and 2 are assumed to be independent, and therefore the error terms are randomly and independently distributed, $v_i \sim N(0,1)$ and $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. The log-likelihood function for this version of Cragg's model that assumes the probit and truncated regression to be uncorrelated is given as follows:

$$L = \prod_{y_i=0} \left[1 - \Phi(z_i\alpha)\Phi\left(\frac{x_i\beta}{\sigma}\right)\right] \prod_{y_i>0} \Phi(z_i\alpha)\sigma^{-1}\phi\left(\frac{y_i - x_i\beta}{\sigma}\right) \quad (3)$$

where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The log-likelihood function is estimated using the maximum likelihood estimation (MLE) technique.

One may argue for Tobit model for explaining adoption. In the absence of the probit mechanism ($d_i^* > 0$) in Equation 2, the double hurdle model is reduced to the Tobit model. In such situations farmers made decision about adoption and level of adoption simultaneously. This may also be seen in the log-likelihood function presented in Equation 3, when $\Phi(z_i\alpha = 1)$. The Tobit model arises if $\alpha = \rho/\sigma$ and $x = z$ (Martínez-Espiñeira, 2006). As the Tobit model is nested in the Cragg model, it is possible to compare these two models through a standard likelihood ratio test when the determinants in both hurdles are the same (Buraimo *et al.*, 2010). According to Greene (2000), the test statistics can be computed as:

$$\Gamma = -2\left[\ln L_T - \left(\ln L_P + \ln L_{TR}\right)\right] \sim \chi_k^2 \qquad (3)$$

where L_T, L_P and L_{TR} are log-likelihoods of the Tobit, probit, and truncated regression models, respectively. Rejection of the null hypothesis ($\Gamma < \chi_K^2$) argues for superiority of the Cragg's model over the Tobit model and establishes that farmers do not simultaneously decide about adoption and level of adoption.

Results and Discussion

Cost and return from onion production

Among the sample farmers, 40 (13.33%) cultivate different improved onion varieties, whereas the rest (86.67%) cultivate traditional varieties. Table 1 presents costs and returns from onion cultivation. As Table 1 indicates, adopters experience higher costs than non-adopters since they use more inputs. Ultimately, adopters earn 40.51%, 72.40% and 53.63% higher variable cost, fixed cost and total cost than non-adopters, respectively. Higher costs for improved variety growers are compensated by higher production and profit. The average yield of an improved variety producing farm is around 42 kg, whereas it is 31 kg for a traditional variety producing farm. Similarly, adopters enjoy higher gross returns, gross margin and net returns than non-adopters. The benefit-cost ratio for the improved variety growers is around 16% higher than traditional variety growers.

Factors affecting adoption and level of adoption: Preliminary evidences

The summary statistics of the explanatory variables used in the Cragg's model are presented in Table 2. The table shows that a typical farmer had around 15 years of farming experience. The differences between the adopters and non-adopters in regard to farming experience and education are not significant. Adopters are more

Table 1 - Costs and returns from onion production.

VARIABLES	MODERN VARIETY	TRADITIONAL VARIETY	ALL
Total variable cost (tk./farm)	30075.48 (37105.29)	21404.82 (26073.94)**	22630.35 (27981.84)
Total fixed cost (tk./farm)	25787.76 (39759.88)	14958.52 (14828.65)***	16489.15 (20533.14)
Total cost (tk./farm)	55863.24 (74549.73)	36363.33 (34718.85)***	39119.5 (43004.02)
Yield (kg./farm)	41.98 ((1.40)	30.51 (4.61)***	32.13 (6.72)
Production (kg./farm)	3207.59 (4906.11)	2076.85 (1665.22)***	2236.675 (2421.61)
Average price (tk./kg.)[a]	21.36 (4.58)	20.01 (13.71)	20.25 (12.82)
Gross return	72171.90 (111206.40)	39626.99 (43996.29)***	44226.98 (59164.37)
Gross margin	42096.43 (77937.2)	18222.17 (38243.20)***	21596.62 (46524.84)
Net return	16308.66 (39396.39)	3263.66 (28507.43)***	5107.47 (30541.38)
Benefit cost ratio	1.18 (0.37)	1.02 (0.53)**	1.04 (0.52)

Note. Figures in parentheses are standard deviations. [a] Since farmers were selling in different installments, weighted price is calculated and reported here. *, **, and *** indicate that mean differences between the traditional and modern variety are significant at the 10%, 5%, and 1% confidence levels, respectively.

Table 2 - Summary statistics of the explanatory variables used in econometric models.

VARIABLES	MODERN VARIETY	TRADITIONAL VARIETY	ALL
Experience	17.13 (11.41)	14.31 (10.08)	14.71 (10.31)
Education	5.3 (3.96)	5.56 (4.66)	5.52 (4.57)
Herfindahl index of crop diversification	0.26 (0.10)	0.36*** (0.17)	0.34 (0.16)
Extension service	0.45 (0.27)	0.37*** (0.18)	0.38 (0. 20)
Access to credit	55.00 (44.61)	22.76*** (42.02)	27.27 (44.61)
Off-farm income	40.59 (72.20)	19.76*** (48.20)	22.68 (52.57)
Farm area	90.64 (107.38)	64.73*** (46.76)	68.35 (59.49)
Own land share	0.76 (0.39)	0.84 (0.34)	0.83 (0.35)
Land fragmentation	1.45 (2.28)	1.04 (1.64)	1.10 (1.74)
Credit and off-farm income	33.53 (74.03)	11.52*** (42.26)	14.60 (48.41)
Land area and fragmentation	294.40 (843.66)	83.11*** (175.53)	112.66 (359.55

Note: Figures in parentheses are standard deviations. *, **, and *** indicate that mean differences between the adopters and non-adopters are significant at the 10%, 5%, and 1% confidence levels, respectively.

experienced and educated than non-adopters. The Herfindahl crop diversification index for the adopters and non-adopters is 0.26 and 0.36, respectively. The estimated index values for both the categories indicate more than moderate level of crop diversification. Significantly lower Herfindahl index value for the adopters indicates that they practice more diversification than non-adopters. The index constructed for measuring farmer's satisfaction about extension services shows that adopters are more satisfied with agricultural extension services than non-adopters. The proportion of farmers with access to formal credit facilities is almost 1.5 times higher in the group of adopters. Compared to non-adopters, the adopters earn more than two times higher income from off-farm activities. Adopters have more cultivable land than non-adopters.

Table 3 - Estimated marginal effect of the factors influencing adoption.

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4
Experience	0.00052	0.00046	0.001219	0.001157
Education	-0.00450	-0.00447	-0.00494	-0.00481
Herfindahl index of crop diversification	-0.80051***	-0.79830***	-0.78913***	-0.78239***
Extension service	0.19429***	0.19261***	0.192517***	0.188551***
Access to credit	0.11202***	0.11342***	0.118285***	0.12231***
Off-farm income	-0.00009	0.00001	-0.00025	-0.00005
Farm area	0.00109***	0.00110***	0.000804	0.00080
Own land share	0.03493	0.03632	0.037842	0.040395
Land fragmentation	-0.02807***	-0.02785***	-0.03762***	-0.03712***

Notes: The marginal effect of the probit model estimates (Tier 1 of Cragg's "two-tier model") are presented here. The coefficients of the estimated probit models are available in Appendix Table 3. Due to the cross term, the coefficients of the variables incorporated in the cross term cannot alone tell about the magnitude of impact of these variables. For instance, in model 2 the marginal effect of the variables access to credit and off farm income is also captured in their cross term. Hence, marginal effects are estimated for these variables considering the cross terms. The marginal effect of the cross terms are not reported here as they are not descriptive. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Factors affecting modern onion variety adoption and level of adoption

Table 3 presents the marginal effect of the explanatory variables used to explain adoption, whereas the determinants of adoption level are presented in Table 4. While Table 3 shows the estimates of probit models, Table 4 truncated regression models' results[2].

The estimates of the probit models are similar in terms of associated signs and levels of significance. The Herfindahl index of crop diversification, farmers' satisfaction about extension service, access to credit and land fragmentation have a significant impact on farmers' adoption decision in all the models. Farm size positively

[2] Four different Tobit models were estimated following the structures of Cragg's models. Then using equation (4) likelihood ratio tests were conducted. In each of the case the null hypothesis was rejected at 1% level of significance. Rejections of the null-hypothesis indicate that farmers' decision about adoption and level of adoption is taken at two different stages and Cragg's model is the appropriate choice in our case. Furthermore, superiority of the Cragg's model over Tobit model was further confirmed through Akakie's Information Criterion (AIC) and Bayesian information criterion (BIC). In comparison to the Tobit model, the AIC and BIC values of the double hurdle model are much lower, indicating that the two-part model has to be favored to explain adoption intensity. For details, see Appendix Table 2.

Table 4 - Determinants of level of adopting (truncated regression).

VARIABLES	MODEL 1	MODEL 2		MODEL 3		MODEL 4	
	Coeff. (S.E.)	Coeff. (S.E.)	Marginal effect	Coeff. (S.E.)	Marginal effect	Coeff. (S.E.)	Marginal effect
Experience	0.0042* (0.0026)	0.0030 (0.0022)		0.0029 (0.0026)		0.0022 (0.0023)	
Education	0.0118* (0.0067)	0.0093 (0.0058)		0.0128** (0.0066)		0.0099* (0.0058)	
Herfindahl index of crop diversification	0.6742*** (0.2863)	0.9890*** (0.2677)		0.7261*** (0.2836)		1.0124*** (0.2657)	
Extension service	0.2857*** (0.1186)	0.2978*** (0.1030)		0.2018 (0.1289)		0.2356*** (0.1149)	
Access to credit	0.1099* (0.0607)	-0.0331 (0.0657)	0.2647	0.0956 (0.0608)		-0.0356 (0.0650)	0.2507
Off-farm income	-0.001*** (0. 0005)	-0.009*** (0. 0024)	-0.0043	-0.001*** (0. 0005)		-0.008*** (0. 0024)	-0.0040
Farm area	0.0009* (0.0004)	0.0005 (0.0004)		0.0016*** (0.0007)	0.0014	0.0010 (0.0006)	0.0009
Own land share	0.0041 (0.0723)	-0.0845 (0.0682)		0.0242 (0.0739)		-0.0670 (0.0695)	
Land fragmentation	0.0068 (0.0181)	0.0101 (0.0157)		0.0260 (0.0226)	0.0125	0.0232 (0.0196)	0.0136
Credit and off-farm income		0.008*** (0.003)				0.007*** (0.003)	
Land area and fragmentation				-0.0002 (0.0001)		-0.0001 (0.0001)	
Constant	-0.255*** (0.107)	-0.0998 (0.0920)		-0.286*** (0.111)		-0.1267 (0.0954)	

Notes: Truncated regression is the Tier 2 of the Cragg's double-hurdle model. As was done in the probit model, the marginal effect is estimated for the variables assumed to have joint effect. Figures in parentheses are standard errors. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

contributes to adoption decision, though the impact is significant only in models 1 and 2 (Table 3).

The associated signs with the variables used to explain level of adoption are the same for the variables having a significant impact across the models. Herfindahl index of crop diversification and off-farm income have significant impacts in all the models. Education is found to have a positive impact on level of adoption, though the effect is not significant in model 2. Farmers' satisfaction about extension services is positive in all the models. But only in model 3 the variable failed to show a significant impact. Farm size is significantly and positively associated with adoption level in model 1 and model 2. In model 1, access to credit facilities and farming experience have positive and significant impacts (Table 4).

Experience positively contributes to both adoption and level of adoption, though the effect is significant only in the second stage of model 1 (Tables 3 and 4). The descriptive statistics presented in Table 2 show that adopters are more experienced than the non-adopters. Findings of literature about experience and adoption are mixed. A study found that because the experienced Indian farmers do not want to change their traditional or conventional seed varieties, they have a lower probability of adopting pearl millet hybrids (Matuschke and Qaim 2009). On the contrary, another study observed in South Africa the experienced Bt cotton growers have higher adoption level (Thirtle *et al.,* 2003). As converting a traditional onion growing farm to a modern one does not require any major structural changes, we think the hypothesis of Matuschke and Qaim (2009) does not work in our case. Rather, due to experience these farmers have more foresight to understand the importance of cultivating improved varieties. Furthermore, the less experienced can be assumed to be less interested in farming and hence want to devote lower level of capital and effort in farming. The education variable shows a significant positive impact in the second stage of models 2, 3 and 4 (Table 4). The positive sign here indicates that educated farmers are more likelyto devote a higher share of their land to improved varieties than the less educated farmers. The positive correlation between education and adoption is well documented in literature (Feder *et al.*, 1985; Adeogun *et al.*, 2008).

The inverse relationship between crop diversification index and adoption probability implies that adoption probability is higher with the farmers practicing more crop diversification (Table 3). Relatively high profit potential of modern onion varieties may encourage these farmers to adopt. But the same variable has a positive sign in the second stage (Table 4), which indicates that those farmers who practice diversification have lower adoption level. As these farmers are characterized to diversify farming, they cultivate different varieties in their fields, whereas their counterparts are likely to specialize. Hence, when farmers with low level of diversification adopt, they cultivate on relatively higher portions of land and vice-versa.

Famers' satisfaction about extension services is another crucial factor behind adoption and level of adoption (Tables 3 and 4). Those farmers who are more satisfied with the services of extension agents (e.g. the farmers who are getting their required extension services) adopt more and have higher adoption level. Improved variety cultivation requires extensive extension services than the traditional variety cultivation do, as farmers are less familiar with these varieties and these varieties are more sensitive to different input implications and intercultural practices. Adegbola and Gardebroek (2007) noted that as farmers adopt modern agricultural technologies if they are aware of the availability and benefits of these technologies and their inherent characteristics. Hence, farmers who are able to get their required extension services adopt more. Contribution of extension services in adoption is well documented in agricultural economics literature (Baidu –Forson, 1999; Mwanga *et al.*, 1999; Gregory and Sewando, 2013; Khonje *et al.,* 2015)

Improved variety cultivation requires more capital than traditional varieties (Table 2). Thus, budget constraint becomes more binding for the adopters. As farmers with access to formal agricultural credit facilities are less likely to be affected by such constraint, they demonstrate higher adoption probability. Compared to farmers' without access to formal credit facilities, these farmers have 11.20%, 11.34%, 11.83% and 12.23% higher adoption probability according to model 1, model 2, model 3 and model 4, respectively (Table 3). In the second stage of model 2 and model 4, the coefficients of access to credit have negative signs, but the marginal effect is positive that is estimated considering the interaction of access to credit and off-farm income. Thus, in all models farmers with access to credit adopt more, though the effect is significant only in model 1 (Table 4). The positive association between credit and adoption is well documented in literature (Aikens *et al.*, 1975; Smale *et al.*, 1994; Langyintuo and Mekuria, 2005; Mottaleb, Mohanty and Nelson, 2014).

The off-farm income variable is found to be negatively affecting level of adoption in all four models, i.e. farmers earning more off-farm income use lower portion of their available land for cultivating improved onion variety (Table 4). As alternative income sources may be more attractive for these farmers, they invest less capital, effort and time in farming. Consequently, they prefer traditional varieties to improved varieties. Mal *et al.* (2012) reported a negative association between off-farm income and level of adoption for the Indian Bt cotton growers. Ali and Flinn (1989), Wang *et al.* (1996), Rahman (2003) and Asadullah and Rahman (2009) found situations where farmers with higher opportunity to engage in non-agricultural activities pay less attention to their rice production activities and hence tend to be less efficient.

The variable farm area has a significant positive impact on adoption in the first two models and a decimal increase in farm size increases adoption probability by approximately 11% (Table 3). Farm size also positively contributes to level of adoption. The associated sign between farm area and share of land under modern variety is positive in all the models, though the effect is significant in model 1 and model 3 (Table 4). Most agricultural economics literature reports a positive relationship between adoption and farm size (Abara and Singh, 1993; Feder *et al.*, 1985; Fernandez-Cornejo, 1996; Kasenge, 1998; McNamara *et al.*, 1991). As modern varieties require more investment, the farmers with more farm size, who are generally rich, are more likely to adopt. Furthermore, since onion is less likely to be in top of the farmers' priority list the small farmers are less likely to manage land for onion after cultivating food crops. The estimated average farm size (68.35 decimal) for our sample farmers is noteworthy here (Table 2).

The associated negative sign with the land fragmentation variable in the probit model implies that farmers with fragmented land are less likely to adopt (Table 3). Jha *et al.* (2005) and Parikh and Nagarajan (2004) show how land fragmentation promotes inefficiency in agriculture by discouraging commercialization. Input use for the farmers' with fragmented land is generally at sub-optimal level. Farmers loose productive land for bounding or hedging. Fragmented land is also associated with excess travelling costs and difficulties in monitoring. There are also difficulties in using modern machineriestechnologies in fragmented land. All these may discourage farmers with fragmented land to go for improved onion variety.

Conclusion

The study was aimed to identify the factors that affected adoption of improved onion varieties and its level of adoption with a view to suggesting policies for boosting onion production in Bangladesh through enhancing farm level adoption of improved onion varieties. In e doing so, it compared production and profitability between improved and traditional varieties grown by the farmers in the study areas. Cultivation of improved variety results in higher production though it requires more capital. Ultimately, compared to non-adopters, adopters earn significantly higher level of return.

Extension services play a crucial role in adoption of improved variety. Effective extension services significantly influence both adoption and level of adoption. The extension programmes for improved onion variety adoption are more likely to be successful among the experienced and educated farmers. Those farmers who rely more on farming for their livelihood (e.g. the farmers earning less from off-farm activities) are more likely to be adopters. Since farming plays greater role in these farmers' livelihood than that of farmers with higher off-farm income, these farmers are more likely to be motivated by the higher profit potentials associated with modern varieties.

Access to credit helps farmers to adopt. It also positively contributes to level of adoption. Since farmers with access to credit are more capable in accumulating capital than their counterparts who do not have access, these farmers adopt more. The central bank of Bangladesh may suggest some guidelines for the commercial banks to prioritize improved onion variety growers while disbursing credit.

Farmers' adoption probability and level of adoption increase with farm size. Farmers with more land are more likely to adopt and allot a relatively higher share of their land for improved varieties. In the context of Bangladesh, where farm size is generally small and agriculture is still not fully commercialized, a cash crop like onion generally comes in farmers' priority list after food crops. Thus, adoption becomes more difficult in the farms with relatively small land size. Furthermore, the positive association between farm size and cash capital may impede adoption by the small farmers. Farmers' adoption probability reduces with increasing number of fragmented land. This happens as cultivation becomes expensive in fragmented land and effective land size reduces due to boundary or hedging.

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Appendix

Table 1 - Measurement techniques of the explanatory variables used in Cragg's double hurdle model.

VARIABLES	MEASUREMENT TECHNIQUE
Experience	Year(s) of farming experience
Education	Year(s) of formal schooling
Herfindahl index of crop diversification	The Herfindahl index represents crop diversification/specialization and is estimated as the summation of all squared area shares occupied by crop/s in total cropped area. The value of this index varies from zero to one. It takes the value of one when there is full specialization and approaches to zero when there is full diversification.
Satisfaction index for extension service	Extension service variable represents farmers' satisfaction about extension service. During the survey farmers were asked to report their satisfaction about different extension service (demonstration plot, mela, advice service and training) through a 5 point likert scale. A higher value in the scale represents higher satisfaction level. The variable is constructed as the ratio of an individual farmer's score and maximum possible score.
Credit	Dummy: 1 = farmers with access to formal credit facilities, 0 = otherwise
Off farm income	Annual off farm income of the household (BDT)
Farm area	Total farm land (decimal)
Own land share	Share of own land to farm land
Land fragmentation	Number of fragmented land
Credit and off farm income	Cross term of access to credit and off farm income
Land area and fragmentation	Cross term of farm area and number of fragmented land

Table 2 - Test statistics of the regression models.

	MODEL 1		MODEL 2		MODEL 3		MODEL 4	
	Cragg Model	Tobit Model	Cragg Model	Tobit Model	Cragg Model	Tobit Model	Cragg Model	Tobit Model
Wald χ^2	33.78	52.31	33.82	52.39	31.65	54.91	31.77	55.27
Prob > χ^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AIC	166.85	191.63	161.46	193.56	164.69	191.03	159.75	192.67
BIC	231.81	243.33	237.39	245.23	234.86	248.45	240.16	250.79

Table 3 - Probit models to identify factors influencing probability of adoption.

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		Coef. (S.E.)		
Experience	0.0030 (0.0110)	0.0027 (0.0111)	0.0071 (0.0113)	0.0068 (0.0114)
Education	-0.0263 (0.0250)	-0.0262 (0.0250)	-0.0290 (0.0256)	-0.0284 (0.0257)
Herfindahl index of crop diversification	-4.6830*** (1.1614)	-4.6793*** (1.1628)	-4.6276*** (1.1668)	-4.6151*** (1.1697)
Extension service	1.1366*** (0.5215)	1.1290*** (0.5231)	1.1911*** (0.5440)	1.1122*** (0.5419)
Access to credit	0.5587*** (0.2317)	0.5843*** (0.2584)	0.5867*** (0.2361)	0.6495*** (0.2694)
Off farm income	-0. 0005 (0.0022)	0.0004 (0.0044)	-0.0015 (0.0025)	0.0004 (0.0044)
Farm area	0.0064*** (0.0021)	0.0064*** (0.0021)	0.0031 (0.0027)	0.0031 (0.0027)
Own land share	0.2043 (0.3232)	0.2129 (0.3257)	0.2219 (0.3260)	0.2383 (0.3279)
Land fragmentation	-0.1642*** (0.0807)	-0.1633** (0.0807)	-0.3197*** (0.1380)	-0.3196*** (0.1365)
Credit and off farm income		-0.001 (0.005)		-0.003 (0.005)
Land area and fragmentation			0.0014 (0.0010)	0.0015 (0.0010)
Constant	-0.6343 (0.4279)	-0.6527 (0.4360)	-0.4657 (0.4406)	-0.5035 (0.4478)
Log likelihood	-94.01	-93.99	-91.87	-91.74
Prob > chi^2	0.000	0.000	0.000	0.000

Note: Tier 1 of the Cragg's double hurdle model.