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Determinants of Adoption of Rice Yield Gap Minimisation Technology in Bangladesh

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Increasing rice production through reducing the yield gap between what experiments in research stations achieve and what farmers get in their fields is much emphasised in different policy documents in Bangladesh. By analysing farm level survey data collected from 300 paddy growers belonging to nine different districts in the country, this paper attempts to find out the factors that affect adoption of technology (or technologies) that minimises rice yield gaps and the level of adoption by the adopters. Econometric analysis shows that farm level adoption decision is influenced by a wide range of socio-economic, demographic and natural-physical factors such as education, farm size, off-farm income, access to extension services, adoption of related other practices as well as agro-ecology although their effects on adoption decision may vary. The findings argue for some specific policy interventions and emphasise the importance of designing strategies for technology dissemination considering farm level factors.

Keywords: Yield Gap Minimisation, Adoption, Paddy, Bangladesh

I. INTRODUCTION

During the last four decades and a half, Bangladesh has made major strides in gaining near self-sufficiency in production of rice, the basic staple in the country. Rice is the main crop in the country in terms of production (33-34 million metric tons), area coverage (75 per cent of the total cropped area and over 80 per cent of the total irrigated area) and contribution to national income accounts (one-half of the agricultural GDP) (BRRI 2012). The share of rice value added in total food value added (at current prices) was estimated to be 41 per cent in 2012-2013 (FPMU 2015).

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Over these decades, the population of the country has more than doubled to around 160 million whose food availability has to be ensured. However, the fact remains that the land availability is shrinking for continuous shift of land from agricultural to non-agricultural uses. In such a situation, the best option for a continued supply of rice from domestic production is to increase the yield per unit of land. It is generally known that Bangladesh has one of the lowest yields of rice in the world. Despite major technological changes in raising yield (Baffes and Gautam 2001), the yield gap for different crops (e.g. rice, wheat, potato, oilseeds, pulses, etc.) ranges from 19 per cent to about 64 per cent of the potential yield (Alam 2006, OFRD 2003-04a, 2003-04b & 2008-09, Roy 1997, Matin *et al*. 1996).

Such high yield gaps have significant implications for farm production and profit, food security and, ultimately, agricultural GDP. In this context, the National Agricultural Technology Project (NATP) of the Government incorporated dissemination of technologies for Rice Yield Gap Minimisation (hereafter called RYGM) as one of its core components. This paper attempts to assess how successful this approach has been, and to identify responsible factors underlying any achievements.

In the next section, we will discuss the project features and the methodology adopted for the evaluation exercise followed by the main results of the analysis and finally the implications and conclusions for future policy.

II THE NATP (PHASE I) PROJECT

The NATP (Phase 1, henceforth NATP) project follows a group based extension approach and forms farmers' groups named as Common Interest Group (CIG). The selected group members organise different demonstration plots, where they practice recommended, season-specific production technologies, of which RYGM is one. The RYGM technology includes several selected improved technology packages such as selection of appropriate variety, identification of healthy seed, seedbed preparation and seed sowing, seedling transplantation, land selection and preparation, fertilizer application, pest management, irrigation and drainage, and intercultural operation such as weeding and harvesting.

Reportedly, the yield gap in RYGM technology demonstration plots was reduced by 1.05 t/ha (through 25 per cent yield increase over conventional farmer practices), 1.20 t/ha (22 per cent yield increase) and 0.61 t/ha (17 per cent yield increase) for *T. Aman, Boro* and *Aus* seasons respectively.[1] The high yields resulted in higher gross margins, which were estimated to be 10.4 per cent, 10.2 per cent and 3.9 per cent higher than in the conventional plots for *T. Aman*, *Boro* and *Aus* season respectively (NATP 2012). Based on these findings, the project embarked on the wide-spread diffusion of the technology.

The yield and gross margins are, however, not the only issues considered by farmers for technology adoption. Different demographic and socio-economic characteristics of a farm may have a vital role in adoption. Depending on these constraints, a given technology may appeal differently to different categories of farmers. Adoption is also sensitive to agro-ecological settings. Hence, a proper dissemination strategy should be location and farm category specific. Lack of or limited attention to these issues and adopting a "one size fits all" type of extension strategy therefore may not bring the desired positive result.

Though the literature about technology adoption is huge (Hossain, Bose and Mustafi 2006, Rahman and Shankar 2009, Mottaleb, Mohanty and Nelson 2015 to name only a few of recent ones), unfortunately, there seems to be a dearth of literature on yield gap minimisation in the Bangladesh context. This paper may, therefore, be one of the first few attempts to understand the socio-economic and policy factors influencing farm decision regarding adoption of RYGM technology. The knowledge of these factors may help in designing more effective policy interventions for agriculture. The adoption of the RYGM technologies is expected to contribute to increasing paddy production in the country without changing the existing resource base. Hence, the findings of this study may not only enrich the empirical literature, but also have its own appeal from a policy perspective.

[1]Bangladesh has basically three rice growing seasons: *Aman* which is largely rain-fed but may necessitate supplementary irrigation during flowering and maturity stage, *Aus* which is fully rain-fed and *Boro* which is grown under fully irrigated conditions. Rice may be cultivated by either as broadcast (B.) of seeds or transplanted (T.) young seedlings germinated from seeds in separate seedbeds. Varieties may be either local (low-yielding) or high-yielding (HYV) or hybrid. The latter two, which have largely replaced local varieties, depend more on controlled water and cash-intensive fertilizer and pesticides application. There is yet a fourth type which is wholly broadcast during *Aman* season and coincides with flooding and high rainfall period and can withstand flooding to an extent but has practically gone out of cultivation.

III. METHODOLOGY

3.1 Factors Influencing Adoption Decision and Extent of Adoption

The present study considers several economic and social variables as well as natural-physical contexts, within which farmers operate, that may influence their adoption decisions and extent of adoption. These include membership of Common Interest Group (CIG), access to extension services, own cultivable land, annual off-farm income, education level of the farmer, adoption of associated water saving technology, known as alternate wetting and drying (AWD) during *Boro* rice cultivation and, finally, the agro-ecological contexts about which we will have some more details. It may be noted here that an artificial variable was generated by multiplying land owned by off-farm income to understand the strength of risk aversion behaviour of farmers. The forms in which these variables are used in the econometric estimations, as well as their average values, are shown in Table 1 in Annex 1.

3.2 Data and Sampling Procedure

Agro-ecology provides the basic idea of suitability or otherwise of a given crop technology under natural conditions (weather, soil and other hydrological characteristics). As RYGM technology has been found to be adopted in all 120 upazilas under NATP, it was only natural that farmers' adoption behaviour be also examined based on agro-ecological conditions as the upazilas have been found to come from several agro-ecological zones and thus vary considerably in their agro-ecological settings. The behaviour of sampled farmers was therefore analysed, among others, based on their respective agro-ecological contexts.

The samples for the study were, therefore, drawn in the following manner: In the first step, nine districts were chosen from the North-West, South-West, North-East, Central and South-East parts of the country. These districts are situated in seven different agro-ecological zones giving a wide variety of natural agro-ecological settings. Once the districts were chosen, ten upazilas from these districts were selected at random. From each upazila, 2 crop CIGs were taken at random and then 20 randomly selected farmers (i.e. 10 from each crop CIG) were interviewed. That gave 200 crop CIG beneficiary respondents in total.

The control group farmers were selected from the same upazilas where selected CIGs were, but from areas not under the project. The number of selected non-beneficiary crop growers was 100 from 10 upazilas (10 from each upazilla). The total sample size for crop farmers was therefore 300 in all (beneficiaries and control).

Before turning to other issues, we would like to discuss a little the agro-ecological zones (AEZ). Once the farmers were sampled, they were found to come from 6 AEZs. The characteristics of these AEZ are described in Table 2 in Annex 1. It is evident that they vary widely in terms of their water availability, soil characteristics and other factors that may affect plant life and thus also suitability for growing rice. The six AEZs were further reclassified into four AEZs, as shown in Table 2 in Annex 1.[2] We have merged the high Ganges river floodplain with the lower Ganges River Floodplain and the Tista Meander Floodplain with the Old Himalayan Piedmont Plain; as they were geographically adjacent and have similarities in natural resource base (soil and water quality and water availability), problems faced (drought and flood) and have similar cropping pattern.

3.3 Analytical Plans and Techniques

A farmer may decide about a technology (here, RYGM technology) adoption in two steps: (a) whether or not to adopt the technology, and (b) extent of adoption, i.e. how much of his/her available land to be allotted for the technology, once decision to adopt is taken. The second step considers only the adopters. These two steps are explicitly treated in econometric analyses with the Heckman selection model (Heckman 1976, 1979, also Greene 2000). Additionally, probit and Tobit models may also be estimated (as done here) to assess the robustness of the Heckman model. For ease of computation, Heckman (1979) proposed to estimate the likelihood in adoption equation by way of a two-step method, which is known as limited-information maximum likelihood (LIML).

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[2]Ideally, one may argue for not merging the AEZs and including five additional explanatory (dummy) variables in the regression for all the AEZs. But since we are dealing with limited samples, inclusion of five additional variables was not possible unless we drop other variables. Hence, rather than losing a single attribute variable, we decided to have fewer AEZ (through mergers as stated) variables and making our findings to be rather indicative of whether adoption varies across AEZ or not.

3.4 Hypothesised Relationships between Dependent and Independent Variables

Table 3 in Annex 1 shows the hypothesised relationships between these variables and decision to adopt and the extent of adoption once the decision to adopt is taken in columns 3 and 4 respectively. Note that the relationships for the two types of behaviour are expected to be positive in the case of CIG membership, access to extension, size of own land, off-farm income, level of education and number of economically active family members. The basic reason is that in each case, it makes it easier for the farmer to either understand the technology better (as in the case of CIG membership, access to extension or education) or bear the risks of a new practice better (as in case of larger land size or higher off-farm income or their interaction term) or facilitate adoption (through easing labour constraints in the case of higher number of active family members). For the locational dummy based on agro-ecology, there is no *a priori* reason as to which may be more conducive for farmers compared to those in the reference category (AEZ 4: Meghna Floodplain) to adopt, and thus may show either a positive or a negative sign. The explanatory variables that have been used are the same for adoption behaviour and extent of adoption.

IV. RESULTS

4.1 Descriptive Statistics of the Variables Used in Econometric Analyses

Table 1 in Annex 1 presents the summary statistics of the variables used in econometric analyses. In general, it appears that RYGM technology has been adopted more during *T. Aman* than *Boro* season, while the land allocated also seems higher in absolute and relative terms during the *T. Aman* season. The behaviour of farmers, however, seems somewhat different when one considers the agro-ecological settings. While the adoption rate differs, sometimes quite widely, by agro-ecological zones, within a given zone, the *T. Aman-Boro* differentials appear to persist. Again, above differential in adoption behaviour appears to persist when CIG membership and access to extension services are considered. Thus, among the CIG farmers, 78 per cent and 67 per cent adopted the RYGM technology in the *Aman* and *Boro* seasons respectively. Similarly, around three out of every four extension service receivers adopted the *T. Aman* RYGM technology, compared to only 67 per cent in the *Boro* season.

Compared to the non-adopters, the adopters in both *Aman* and *Boro* season owned significantly more cultivable land. In the case of annual off-farm income, the *Aman* season RYGM adopters earned marginally higher than their counterparts who did not adopt; whereas during the *Boro* season, the situation was the opposite in that those with higher off-farm income had lower rates of adoption. Compared to the non-adopters, the adopters in both the seasons have a better educational status. Adopters in both the seasons have more active family members. Around 70 per cent of the AWD technology adopters adopted the RYMG technology in *Boro* season, while the rest did not.

4.2 Drivers of Adoption Behaviour during the Seasons

The determinants of *T. Aman* (RYGM) and *Boro* (RYMG) technology adoption and level of adoption estimated through different econometric models are presented in Tables I and II respectively. Note first that the adoption decision has been analysed using 4 types of equation: probit, Tobit, maximum likelihood and Heckman two-step procedure. As the value of lambda is significant in both *T. Aman* and *Boro* equations in the case of the two-step procedure, this indicates the selection bias and the use of Heckman procedure to correct the bias is justified. Hence, while we have used other equations for checking robustness, the main results and conclusions are based on the two-step procedure.

The econometric results show that farmer's *Aman* RYGM technology adoption decisions are largely influenced by factors such as location (AEZ), CIG membership, own land and number of active family members. Farmers in the AEZ 2, having more land, family member and annual off-farm income, adopt the *Aman* RYGM technology in more land. Farmers living in the AEZ 2 and AEZ 3 are less likely to adopt the *Boro* RYGM technology. The notable difference between the *Aman* and *Boro* RYGM technology adoption models is that, the CIG membership dummy has deciding role in *Aman* RYGM model, whereas the extension service has significant role in *Boro* RYGM technology adoption model. The additional factor playing a decisive role in the *Boro* model is the adoption of AWD technology.

TABLE I

Determinants of *T. Aman* (RYGM) Technology Adoption and Level of Adoption

Regressors	Determinants of adoption (probit model)	Determinants of level of adoption (Tobit model)	Heckman model			
			Maximum likelihood		Two step	
			Determinants of adoption	Determinants of level of adoption	Determinants of adoption	Determinants of level of adoption
	Marginal effect (S.E.)[a]		Coefficient (S.E.)			
AEZ 1	-0.10 (0.11)	-3.24 (19.89)	-0.08 (0.25)	-13.88 (26.28)	-0.27 (0.29)	-5.02 (28.27)
AEZ 2	0.43*** (0.05)	64.47*** (22.01)	1.66*** (0.27)	147.18*** (26.80)	1.93*** (0.43)	131.66*** (39.47)
AEZ 3	-0.04 (0.10)	18.52 (20.06)	0.33 (0.25)	18.85 (25.61)	-0.11 (0.29)	29.78 (27.60)
CIG membership	0.42*** (0.11)	-3.42 (22.35)	0.45** (0.23)	54.39*** (25.30)	1.18*** (0.31)	41.67 (40.16)
Extension service	0.16 (0.12)	0.0002 (0.0002)	0.80*** (0.26)	38.34 (26.70)	0.45 (0.33)	49.27 (31.17)
Own cultivable land[b]	0.02*** (0.01)	19.99 (18.73)	0.04*** (0.01)	0.33*** (0.94)	0.07*** (0.02)	0.55*** (0.11)
Annual off-farm income	0.0000001 (0.0000003)	0.39*** (0.08)	0.0000003 (0.0000007)	0.00002 (0.00008)	0.0000002 (0.000001)	0.0004*** (0.0002)
Interaction of farm area and off-farm income		0.0002* (0.0001)		0.0001 (0.0001)		-0.0004** (0.0002)
Education status of the farmer	-0.05 (0.04)	-9.23 (6.89)	-0.16** (0.09)	-7.49 (9.21)	-0.13 (0.11)	-16.13 (9.96)
Active family members	0.03 (0.03)	11.59*** (4.08)	0.17*** (0.06)	20.02*** (5.47)	0.10 (0.08)	19.13*** (6.22)
Constant			-1.53*** (0.35)	-129.80*** (34.47)	-1.20*** (0.41)	-137.21* (76.86)
Log Likelihood	-133.58	-1115.77	84.05			
Lambda					87.53** (46.79)	
N	300	300	300	300	300	300

Note: [a] Instead of coefficients, the marginal effects are reported here. Marginal effects are estimated at mean and refer to change in the probability due to infinitesimal change in independent variable. The coefficients are available upon request.
[b] log of land is used for determinants of technology, whereas linear relationship is assumed for determinants of level of adoption.

TABLE II

Determinants of *Boro* (RYGM) Technology Adoption and Level of Adoption

Regressors	Determinants of adoption (probit model)	Determinants of level of adoption (Tobit model)	Heckman model			
			Maximum likelihood		Two step	
			Determinants of adoption	Determinants of level of adoption	Determinants of adoption	Determinants of level of adoption
	Marginal effect (S.E.)[a]		Coefficient (S.E.)			
AEZ 1	-0.11 (0.12)	-2.04 (18.31)	-0.06 (0.24)	-17.53 (28.96)	-0.29 (0.31)	-18.15 (35.94)
AEZ 2	-0.37*** (0.11)	30.78 (24.26)	-0.38 (0.26)	-21.27 (32.40)	-0.99*** (0.33)	-34.31 (57.82)
AEZ 3	-0.28*** (0.12)	7.02 (18.83)	-0.26 (0.23)	-33.53 (29.29)	-0.71*** (0.30)	-37.99 (44.27)
CIG membership	0.17 (0.11)	-0.21 (26.12)	0.25 (0.24)	23.96 (30.06)	0.42 (0.27)	39.21 (46.75)
Extension service	0.36*** (0.10)	10.13 (22.54)	1.00*** (0.26)	84.51*** (32.46)	0.96*** (0.29)	104.84* (63.43)
Own cultivable land[b]	0.02*** (0.01)	0.23*** (0.09)	0.03*** (0.01)	0.27*** (0.10)	0.05*** (0.02)	0.45*** (0.14)
Annual off farm income	-0.0000005* (0.0000003)	0.00001 (0.0002)	-0.000002*** (0.000001)	-0.0002*** (0.0001)	-0.000001 (0.000001)	-0.0001 (0.0003)
Interaction of farm area and off-farm income		0.00005 (0.0002)		0.0001* (0.00005)		-0.0001 (0.0003)
Education status of the farmer	-0.04 (0.04)	0.37 (7.48)	-0.07 (0.11)	2.90 (10.75)	-0.09 (0.11)	-1.92 (13.48)
Active family members	0.04 (0.03)	1.40 (4.29)	0.15*** (0.05)	6.78 (6.50)	0.09 (0.06)	9.29 (8.95)
AWD technology	0.21*** (0.07)	0.48 (12.30)	0.33**(0.1)	36.04* (20.28)	0.55*** (0.22)	42.13 (33.45)
Constant			-1.14*** (0.33)	-81.00** (42.06)	-0.64 (0.39)	-147.33 (120.00)
Log Likelihood	-160.51	-942.66	106.83			
Lambda					144.05** (78.10)	
N	300		300	300	300	300

Note: [a] Instead of coefficients, the marginal effects are reported here. Marginal effects are estimated at mean and refer to change in the probability due to infinitesimal change in independent variable. The coefficients are available upon request.

[b] log of land is used for determinants of technology, whereas linear relationship is assumed for determinants of level of adoption.

First, consider the agro-ecological dummies. Among the agro-ecological dummies, the dummy for the farmers living in the AEZ 2 (i.e. the Tista Meander Floodplain & the Old Himalayan Piedmont Plain agro-ecology) has significantly positive effects on the adoption of *T. Aman* RYGM technology and its level across different models, including the two-step one. On the other hand, when we look up the coefficients for the *Boro* equations, the picture is the opposite in that other AEZ dummies compared to the reference AEZ, in general, have negative coefficients but significant ones only for the two-step and probit equations.

Among the AEZs under consideration, the Middle Meghna River Floodplain AEZ, which is taken as the reference category perhaps, is the most advanced in terms of the early adoption of modern agricultural practices such as ground water irrigation.[3]Compared to this zone, all others are on the western side of the country and are more susceptible to natural disasters. However, among these zones, AEZ2 is perhaps the least susceptible being part of the Old Himalayan Piedmont Floodplain. The other two are within the more active flood plains of River Jamuna and the River Ganges and, therefore, more susceptible to floods which generally affect *Aman* production but not *Boro*.

Compared to the other AEZs, farmers in the reference zone had been more likely to be aware of and may be practising the various elements of RYGM technologies from an earlier time. They were, therefore, already on a higher plane of awareness and activities relevant to adoption of the RYGM technological package (both because of early practice and lower susceptibility to natural disasters) and thus had only a limited incentive for additional marginal efforts for the newly packaged and introduced technology. Hence, the adoption probability and level of adoption by farmers in other zones are likely to be higher than by those in the reference zone, particularly during the *Aman* season. But note that the coefficients for the other zones are generally insignificant, perhaps because of the possible effects of risk in these zones.

Contrary to that of *Aman* season, farmers in AEZs compared to the reference zone have in general lower adoption probability of RYGM package during *Boro* season, but, in most cases, these are not significant. Similar is the case with the extent of adoption. One reason for the insignificance may be the pervasive role of

[3]Indeed, the ground water based irrigation during the *Boro* season started here in the 1960s as part of the initiatives of the Comilla Academy.

irrigation during *Boro* farming which may be practised in all AEZs, particularly with ground water.

As argued earlier, CIG membership and access to extension services were expected to contribute positively to adoption and its extent. The signs of the relevant regression coefficients were in general positive but not always significant. Interestingly, CIG coefficients were significant for *T. Aman* but not for *Boro*, while the opposite was true for extension service in the two seasons. Again, one may speculate though not necessarily prove definitively the reasons behind the differential impacts of CIG membership and extension service. As the *Boro* farmers have already on an individual basis, in many cases, adopted various elements of RYMG over time, any group-based approach under CIG may not impart additional useful technological knowledge to farmers inducing them further to adopt RYGM. Thus, CIG membership has little or no significant influence on the adoption of *Boro* RYGM technology. On the other hand, access to extension services on an individual basis may have more useful information, for which reason one finds mostly significant coefficients for adoption and its extent in *Boro*. In the case of *Aman*, the modern practices are less frequently observed and a group-based approach may be more effective, particularly for lowering the risks which are more community-wide than individual.

Among all the variables, land has the most robust and positive effect and the indicated elasticity is the highest in the case of adoption under the two-step procedure for both the rice seasons. Farm land also significantly increases land allotted to RYGM in both the seasons. Such results have traditionally been explained in terms of the better capacity of large farmers to withstand risk as well as higher costs of modern inputs and practices (Feder, Just and Zilberman 1985, Abara and Singh 1993), though a few also observed a negative relationship (Mal, Anik, Bauer and Schmitz 2012). Adoption of the RYGM technologies has some additional cost implications over conventional technology. Furthermore, in the case the of *T. Aman*, there are risks of natural hazards which raise the over-all risk.

Results regarding the relationship between adoption and its extent and off-farm income are generally positive in the case of *T. Aman* but generally negative in the case of *Boro*. But, in both cases, the coefficients are generally insignificant and may thus indicate either the low opportunity of off-farm income or that off-farm incomes allow farmers to engage less in riskier farming (Ali and Flinn 1989, Wang, Cramer and Wailes 1996, Asadullah and Rahman 2009). The interaction term between the off-farm income and own land does not seem to have any clear-cut effect.

Contrary to expectation, the categorical variable representing education is inversely correlated with adoption and level of adoption in most equations in both seasons. But these are in general insignificant. For both the RYGM technologies, farm households with more active family members (family members within the range of 15 to 65 years) have higher adoption probability and their extent of adoption.

The positive sign of the coefficients for the dummy of *Boro* AWD technology implies that the AWD technology adopters are more likely to adopt *Boro* RYGM technology and they adopt the technology on more land. The AWD adopters have 21 per cent to 55 per cent higher adoption probability for RYGM over the AWD-non adopters depending on the model. As *Boro* is basically an irrigated crop and irrigation costs cash, AWD, which lowers use of water without reducing productivity, is attractive to them. On the other hand, farmers practicing AWD are already on a higher plane of understanding and practice of the intricacies of rice production potentials under irrigated agriculture and thus when a more complex package of technology such as RYMG is introduced, they adopt it.

V. CONCLUDING REMARKS

Applying different econometric models on a sample of farms numbering 300 rice crop growers, the study has explored the determinants of adoption of rice yield gap minimisation technology and the corresponding extent of adoption in Bangladesh. Econometric analyses show that farmer's adoption decision is influenced by a wide range of socio-economic, demographic, and agro-ecological factors, such as location, education, farm land, off-farm income, extension service, and adoption of related technologies. Yet there are interesting differences between season and the effects of variables.

Perhaps the most robust result seems to be that even after so many years of modern rice production practices since the late 1960s and large-scale spread of irrigated agriculture and development of various kinds of varieties suited to different agro-ecological situations, large land holders still are at the forefront of the adoption of similar technologies and one is immediately reminded of the great debates of the implications of small farmer adoption behaviour during the latter quarter of the past century. Second, agro-ecological differences do matter, but the pathways are not yet clearly understood. And the third, perhaps based on the first and second, one clearly needs fine-tuning of approaches depending on seasons, particularly when in one, crop cultivation is practically hazard free but costlier due to cash-based inputs than in the other where cash costs are comparatively lower but are more likely to be affected due to natural hazards. The same or similar approach for *Boro* and *T. Aman* may not work equally well, as has been attempted under the NATP- Phase I.

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Annex 1

Table 1: Summary Statistics of the Variables Used in Econometric Analysis

Variables	*Aman* RYGM		*Boro* RYGM	
	Adopters (%)	Non-adopters (%)	Adopters (%)	Non-adopters (%)
Dependent variables				
Adopter farms (%)	62.7	-	52.3	-
Area under RYGM technology (decimal)	133.8	-	115.9	-
Independent variables				
Farmers in ref AEZ (i.e. AEZ4)	60.0	40.0	70.0	30.0
Farmers in AEZ1	51.0	49.0	59.0	41.0
Farmers in AEZ2	95.0	5.0	45.0	55.0
Farmers in AEZ3	56.0	44.0	47.0	53.0
CIG farmers	78.0	22.0	67.0	33.0
Farmers receiving extension service	76.0	24.0	67.0	33.0
Own cultivable land (decimal) in adopter category	115.25	75.37	117.57	81.47
Annual off-farm income in adopter household (Tk.)	123,144	121,930	116,367	129,656
Education status of the farmer (%) by adopter category				
Illiterate	22.0	26.0	20.0	26.0
Up to primary	19.0	20.0	17.0	21.0
More than primary	60.0	54.0	63.0	52.0
Active family members in adopter households (no.)	3.2	2.9	3.2	2.9
Boro (AWD) adoption (dummy) by adopter category			70.0	30.0

Note: For AEZ categories, see Table 2 in Annex 1.
Merged AEZs are as follows:
Reference AEZ category: Middle Meghna river floodplain
AEZ1: Young Brahmaputra, Jamuna and old Brahmaputra floodplain;
AEZ2: Tista Meander floodplain and old Himalayan Piedmont plain;
AEZ3: Low and high Ganges river floodplain.

Table 2: A Comparison among the Selected AEZs

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
Middle Meghna River Floodplain AEZ4 (reference)	Southern part of Sylhet basin and the confluence of the Meghna river with the Dhaleswari and Ganges rivers. Parts of Kishoreganj, Brahmanbaria,Comilla, Chandpur, Narsingdi and Narayanganj; covering 1,609 km.^{2}	Medium high: 7 per cent; Medium low: 45 per cent; Low land and very low land: 38 per cent; Settlement + water: 10 per cent	OMC: Low, FL: Medium	• Mean annual rainfall is about- <2,000 mm p.a. in the centre and 2,200-2,300 mm in the north and south • Mean annual temperature is about 26.0^{0}C. • Early rise of flood water, deep flooding and slow drainage • River bank erosion along parts of the main Meghna channel.	• Ample surface water for irrigation. • Deeply flooded in the rainy season. • Readily available groundwater. • The Meghna river is tidal, with reverse fresh water flow in the dry season.	• Veg(R)/Wheat/Potato/mustard /pulse- *B.Aus*/Jute-T.Aman • Chillies-*B.Aus*/Jute-Fallow • Mustard-*Boro*-Fallow • *Boro*-Fallow-Fallow

(Contd. Table 2)

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
Young Brahmaputra,Jamuna and Old Brahmaputra Floodplain AEZ1	Western parts of Sherpur, Jamalpur and Tangail districts, parts of Manikganj,Dhaka, Munshiganj and Gazipur districts and a belt of adjoing and old Brahmaputra channel through Mymensingh, Kishoreganj and Narsingdi districts covering 5,924 km^2.	High: 18 per cent; Medium high : 42 per cent; Medium low: 19 per cent; Others: 9 per cent	OMC: Low to medium, FL: Low	• Mean annual rainfall is about 1,500 mm in the southwest and 2,500 mm in the northeast. • Mean annual temperature ranging from 24.8^0 C to 26.5^0 C. • Cool winter temperature (<15^{0}C) ranging from 50 to 90 days. • Max temp (>40^0 C) rarely occurs • Uncertain time of onset and recession of the rainy season and seasonal flooding. • Occasional high flood and late floods damaging crops.	• Easily usable and exploitable surface water supplies and ground water. • Seasonally flooded. • Permanent water bodies (bils) and many basin centres stay wet long in the dry season. • Shortage of water for retting of jute in highland soil areas.	• *Boro*-Fallow-*T. Aman* • Wheat/mustard/potato • *B. Aus*/Jute *T. Aman* • Fallow-*T. Aus*-*T. Aman* • *Boro*-Fallow-Fallow.

(Contd. Table 2)

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
Tista Meander Floodplain AEZ2	Most of greater Rangpur, eastern part of Panchagarh and Dinajpur; northern Bogra and part of Jaipurhat, Noagaon and Rajshahi districts; covering an area of 9,468 km^2.	High: 35 per cent Medium high: 51 per cent Medium low land: 4 per cent Low land 1 per cent Homestead and water bodies: 9 per cent	OMC: Medium, FL: Medium Infertile, sandy, ridge soils.	• Mean annual rainfall increases from about 1,500 mm in the south-east to about 2,300mm in the extreme north. • Mean annual temperature is 24.6^{0}C in north and 26.1^{0}C in the south. • Extremely high summer temperature (>40^{0}C) remaining for <5 days in the north and east and>10 days in the south west. • Occasional serious flood, especially near rivers and in basin centres.	▪Ample groundwater apparently exists at a shallow depth throughout the region. ▪Limited amount of surface water is found in small rivers crossing the region. ▪Irregular relief and complex soil pattern cause difficulties for distribution of irrigation water.	• Wheat-*Aus*/Jute-Fallow • Mustard-*Aus*/Jute-Fallow

(Contd. Table 2)

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
Old Himalayan Piedmont plain AEZ2	The total land area is 4,008 km^2 which covers most of Panchagarh and Thakurgaon districts and north-western parts of Dinajpur district	High 58 per cent, Medium high 34 per cent, others 8 per cent	OMC: Low, FL: Low to medium	• The rain starts later and ends and the kharif growing season is correspondingly shorter. • Mean annual rainfall is about 1,600 mm in south and more than 2,500mm in the north. • The mean number of days with maximum summer temperature exceeding 40^0C is 5-10 in south and less than 5 in the north. • Occasional prolonged rainy season and cloudiness in the rainy season cause local flooding.	▪Ample ground water is available at a shallow or moderate depth. ▪Limited surface water for dry season irrigation. ▪Shortage of surface water for retting jute. ▪Low water temperature which damages HYV *Boro* rice in seedbed and delay transplanting.	• Wheat/Potato/Pulse-*B. Aus*-Fallow • Wheat/Potato-*B.Aus*-*T.Aman* • *Boro*-Fallow-*T.Aman* • Wheat-Fallow-*T.Aman*

(Contd. Table 2)

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
High Ganges River Floodplain AEZ3	Nowabganj, Rajshahi, southern Pabna,Kushtia, Meherpur,Chuadanga, Jhenaida, Magura, Jessore, Satkhira and Khulna district together with minor areas in Noagaon and Narail districts, covering13,205 km^2.	High: 43 per cent, Medium high 32 per cent, Medium low: 12 per cent, others 13 per cent	OMC: Low, FL: Low	• Mean annual rainfall is about 1,000mm in the west, 1,600mm in the east and >1,800mm in the south. • Mean annual temperature is about 26.1^{0}C. • Rainfall variability, sometimes dry, sometimes wet, sometimes a false early start to the rains followed by drought. • Uncertain flood level.	▪Water is pumped from the Ganges river channel to irrigate *kharif* crops to the southern part of the region. ▪Elsewhere, only limited amount of surface water is available from small river and ox-bow lake to irrigate dry land in the rabi season. ▪Limited surface water supplies.	• Wheat-*B.Aus*/jute-Fallow • Wheat – *B.Aus*/Jute- *T.Aman* • Mustard-Jute-*T.Aman* • Lentil-Sesame-*T.Aman* • Sugarcane • *Boro*-DW *T.Aman*

(Contd. Table 2)

Name of the AEZs	Location	Land type	Organic matter content (OMC) and Fertility level (FL)	Climate and climatic events	Water resources and drainage	Major cropping patterns
Lower Ganges River Floodplain AEZ3	Natore, Pabna, Goalando, Faridpur, Madaripur, Gopalgonj and Sariatpur; eastern part of Khulna, Magura and Narail; north eastern part of Khulna and Bagerhat; northern Barisal and south western part of Manikgonj, Dhaka and Munshigonj district, covering 7,968 km^2 area.	High: 13 per cent, Medium high 29 per cent, Medium low: 31 per cent, others 27 per cent	OMC: Medium to high Wide spread Zn and S deficiency , FL: Medium	• Mean annual rainfall is about 1,600mm in the northwest and 2,000mm in the southeast. • Mean annual temperature is about 26.4^{0}C. ▪Droughtness of ridge soils. ▪Wide spread deep flooding, sometime cause serious crop loss.	• Limited amount of surface water is available in bils for dry season irrigation. • Limited surface water supply and uncertain ground water supply. • Shortage of water for retting jute.	• Wheat/Mustard-*B.Aus*/Jute-Fallow • Sugarcane • Wheat-*B.Aus*/Jute-*T.Aman* • *Boro*-DW T.Aman • Chickpea – Mixed broadcast *Aus* and *Aman.*

Source: FAO/UNDP (1988), BARC (2005), ILRI (n.d.), Brammer (2012).

Table 3: Measurement Units and Expected Signs of the Explanatory Variables Used in Models for Explaining Adoption and its Extent

Variables	Unit of measurement	Expected sign	
		Adoption (probit model)	Extent of adoption (Tobit or 2nd stage of Heckman model)
Dummy for AEZ (Reference category)			
Dummy for AEZ 1	=1 if farmer is in AEZ 1, 0 otherwise	±	±
Dummy for AEZ 2	=1 if farmer is in AEZ 2, 0 otherwise	±	±
Dummy for AEZ 3	=1 if farmer is in AEZ 3, 0 otherwise	±	±
Dummy for CIG membership	1 = CIG farmers, 0 = control farmers	+	+
Dummy for extension service	1 = DAE provided service receiver, 0 = non-receiver	+	+
Own cultivable land	Decimal	+	
Annual off farm income of the household	BD Tk	+	+
Education status of the farmer	Categorical variable; 0 = illiterate, 1 = class 1 to 5, 2 = grade 6 and above	+	+
Active family members	Number	+	+
AWD technology adopters[a]	Dummy, 1= adopter ; 0 = non-adopter	+	+

Note: The AEZs are

Reference AEZ category: Middle Meghna River Floodplain
AEZ1: Young Brahmaputra, Jamuna and old Brahmaputra Floodplain;
AEZ2: Tista Meander floodplain and Old Himalayan Piedmont Plain;
AEZ3: Low and high Ganges River Floodplain
[a] Used only in the *Boro* season model.

Another variable, constructed by multiplying farm area and off-farm income, was used only in the equation for extent of adoption.