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Farm and farmer capital foster adoption of improved quality agrochemical inputs in the cotton-wheat zone of the Punjab, Pakistan

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Abstract

Adoption of yield-enhancing agricultural inputs fosters agricultural intensification in low-income countries. In Pakistan, initial adoption of agrochemicals is already widespread; the low quality of much of the inputs contributes to severe health, environmental and enduring pest problems, however. While the positive influence of farm capital and farmer capital on initial adoption is well documented, the adoption of improved quality inputs is little researched. We reduce the knowledge gap investigating smallholder adoption of improved quality agrochemical inputs in the Punjab, Pakistan. Using multi-stage random sampling, a pre-tested and piloted farming household survey was administered to smallholder farming households from 18 villages across three districts of the cotton-wheat zone (N=275). Ordered probit models show that several farming and farm capital variables (cotton crop area, farm machinery, no-tillage farming, adoption in the neighbourhood) as well as several farmer capital variables (age, education, off-farm income, agricultural extension services, source of agricultural credit) influence adoption of improved quality agrochemical inputs. Of these variables, an intensification of agricultural extension service visits appears as the most promising policy option. From a fundamental science point of view, our results provide, for the first time, evidence that adoption of improved quality agrochemical inputs is influenced principally by the same variables as initial adoption.

Keywords: Adoption of agricultural innovations, agrochemical inputs, smallholder farming households, sustainable intensification

1 Introduction

Adoption of yield-enhancing agricultural inputs is a central component of agricultural development through closing frequently existing yield gaps (e.g., Mueller *et al.*, 2012). There is a persisting yield gap among low-income countries of Asia such as Pakistan and India (wheat yield: 2.97 and 3.22 Mg $^{-1}$) compared to, e.g., Germany and the United Kingdom (7.64 and 8.28 Mg $^{-1}$; FAO, 2019). With high rates of population growth in Pakistan (2.4 % a^{-1}, The Government of Pakistan, 2019a) leading to escalating demands for staple food, the adoption of yield-enhancing agricultural inputs appears to be without alternative (Hossain *et al.*, 2006; Khan & Shah, 2011; Salazar *et al.*, 2015; Manlosa *et al.*, 2019). Among these inputs are agrochemicals whose use is positively associated with yield (Pretty & Bharucha, 2014; Koondhar *et al.*, 2018). Adoption of improved quality inputs can be a decisive factor for further sustainable intensification if initial adoption of – low-quality – inputs is already widespread but low productivity persists (Khooharo *et al.*, 2008; Hashmi, 2016).

The adoption of low-quality agrochemical inputs comes along with substantial health and environmental risks. Pesticide exposure may reduce the health of, in particular, the rural poor including the female population resulting in income losses and fatalities (Khan *et al.*, 2002; London *et al.*, 2002; Mrema *et al.*, 2017). Aggressive and inappropriate use of agrochemicals is also responsible for water pollution (Azizullah, 2011) and can endanger ecosystem services from soil microorganisms, fish, birds, and other non-targeted organisms (Aktar *et al.*, 2016). In contrast, using improved quality agrochemical inputs may reduce negative health effects (Abedullah *et al.*, 2015) and environmental risks (Kouser & Qaim, 2014).

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The initial adoption of yield-enhancing inputs has consistently been shown to be positively associated with farm and farmer capital (FFC) variables such as age, education, land, labour, farm mechanisation, as well as use of improved varieties, and fertilisers (Iqbal *et al.*, 2002; Lambert *et al.*, 2015; Koondhar *et al.*, 2018; Harper *et al.*, 1990; Doss & Morris, 2001; Tijani & Sofoluwe, 2012b; Ali & Sharif, 2012; Hailu *et al.*, 2014). Likewise, physical availability of inputs and attributes such as market access and distance to extension service are often positively associated with adoption (Lee, 2005; Mwangi & Kariuki, 2015; Simtowe *et al.*, 2016).

In contrast, the adoption of improved quality agrochemical inputs is little researched. Exceptions include a few studies on the association of socio-economic variables with the adoption of recommended agrochemical practices and extent of pesticide use (Tijani & Sofoluwe, 2012a; Issa *et al.*, 2016). In sum, these studies indicate that farmers experience, farmers education, and pesticides price are significantly associated with the extent of given pesticides usage and also with the recommended agrochemical practices. These studies are limited, inter alia, by (i) addressing only one broad category of agrochemicals (pesticides vs. fungicides, herbicides, insecticides, and chemical seed treatment), and (ii) by their focus on recommended practices. Still, they support the hypotheses that the adoption of improved quality agrochemical inputs is positively associated with the same FFC variables as initial adoption.

Initial adoption of low-quality inputs is prevalent in Pakistan where low-quality agrochemicals retard agricultural development (Khan *et al.*, 2013; Hashmi, 2016) as pest problems remain a top of issue impending agricultural development (Oerke, 2006; Khan *et al.*, 2012; Dhaliwal *et al.*, 2015). Likewise, grave environmental (Nafees *et al.*, 2008) and health concerns (Tijani & Sofoluwe 2012b) plague Pakistani agriculture. Thus, investigating the adoption of improved quality agrochemical inputs (fungicides, herbicides, insecticides, and chemical seed treatment) in the agricultural heartland of Pakistan serves two purposes:

(i) improving the regional and national knowledgebase for closing the yield gap in Pakistan,

(ii) contributing to the international debate on factors facilitating sustainable intensification (cf. The Royal Society, 2009; Garnett *et al.*, 2012; USDA, 2016).

Therefore, we use the cross-sectional data collected in 2017 from 275 smallholder farming households of cotton-wheat zone from the Punjab province, Pakistan. We are mainly interested in addressing the following research questions: Do FFC variables of smallholder farming households affect the adoption of improved quality agrochemical inputs?

This paper is part of a more comprehensive study that also investigates the impact of the adoption of improved quality inputs on food security. Respective analyses, in fact, indicate that adoption is not only positively correlated to food security; they also indicate that substantial positive effects of adoption can be documented even if endogeneity effects are taken into account (Bilal *et al.*, in prep.; Bilal & Barkmann, 2018).

The paper is structured as follows. In section 2, we characterise the study area, the agrochemicals market in Pakistan, and the sampled smallholder farming households. Furthermore, the section describes sampling strategy and data analysis. Section 3 provides the results, which are discussed in section 4, focusing on some institutional implications, in particular for the agricultural administration in Pakistan. Section 5 concludes with some policy implications.

2 Research methods

2.1 *Study area*

2.1.1 *Pakistan smallholder agriculture*

In Pakistan, 58 % of farms are categorised as "small farms" (national definition: area ≤ 5 acres [2.02 ha]; The government of Punjab, 2010). The smallholders operating these farms use less advanced technological inputs due to socio-economic constraints (Thapa & Gaiha, 2011). Smallholder production systems, among others, tend to lack access to water, authorised and/or improved quality seeds, easy access to input and output markets and to agricultural credit; in contrast, use of adulterated and inferior quality of agrochemical inputs are widespread (Khan *et al.*, 2013; Bilal *et al.*, 2015). This is a serious issue as the potential yield loss due to weeds in cotton may vary from 33–50 % and from 24–40 % in wheat (Ali *et al.*, 2013; Oad *et al.*, 2007). The potential yield loss due to pests in cotton may vary from 29–40 % and from 35–40 % in wheat (Khan *et al.*, 2012; Rehman *et al.*, 2015).

2.1.2 *Pakistani agrochemical inputs market*

In Pakistani agrochemical inputs market currently available agrochemicals on the basis of specific formulation consists of 108 insecticides, 39 herbicides, and 30 fungicides with glyphosate being the most common active ingredient in herbicides in Pakistan (Hameed *et al.*, 2017; Khan *et al.*, 2010). Farm productivity-enhancing inputs including agrochemical inputs and fertilisers worth ∼ 735 million USD were imported to fulfil the domestic needs during the fiscal year 2017-2018. The agrochemical inputs market import share in Pakistan is estimated to be worth ∼ 120 million USD during the fiscal year 2017-2018 (The Government of Pakistan, 2019b). The proportions of agrochemicals input types in the Pakistani agrochemicals market in recent past are as follows: insecticides 42 %, herbicides 23 %, fungicides 10 %, granules 16 %, and crop supplement 9 %. Among the major crops of Pakistan, most agrochemical inputs by the value are mainly used for cotton and wheat (47 %/160 million USD; 18 %/60 million USD (Pakistan Crop Protection Associate, 2016).

We differentiated between three tiers ('types') of agrochemical input quality following the Department of Plant Protection of the Pakistani national Ministry of National Food Security and Research. We designated these types A to C (The Government of Pakistan, 2018):

- type A (improved quality) inputs are legally imported based upon their successful registration in an OECD (Organization for Economic Cooperation & Development) listed country or in China.
- type B (intermediate quality) inputs receive a marketing permission based on efficacy trials and field experiments prior to registration. The field trials are conducted over two crop seasons before allocating the trade name.
- type C (base quality) receive a marketing permission without any field trials only based on a sample analysis.

2.2 Survey area and administration of the survey

Pakistan is the confederation of four provinces. Punjab province is the largest with respect to population size (53 %) and the total net area under arable agriculture (69 %) (Pakistan Bureau of Statistics, 2019). There are nine divisions in Punjab province (division is the highest administrative unit). Of these, three divisions (Bahawalpur, Multan, and Sahiwal division) constitute the cotton-wheat zone of Pakistan. Using a multi-stage random sample, households from 18 villages in the cotton-wheat zone of Punjab province (Fig. 1) were surveyed from September to December 2017.

At the first stage, one district[1] (Pakpattan, Rahim Yar Khan, Vehari) was selected from each division with type A to C inputs being widely available using a population proportional random selection, and one *tehsil*[2] (Burewala, Pakpattan[3], Sadiqabad) was randomly selected from each district. In a second stage, five to six union councils[4] were randomly selected from each tehsil (total of 17 union councils). In the third stage, a selection of one to two villages from each union council resulted in a total of 18 villages. In the last stage, we randomly selected 11–20 smallholder farms from each village. Thus, the final sample size yields N=275 smallholders who were interviewed in person by the first author and two advanced student assistants.

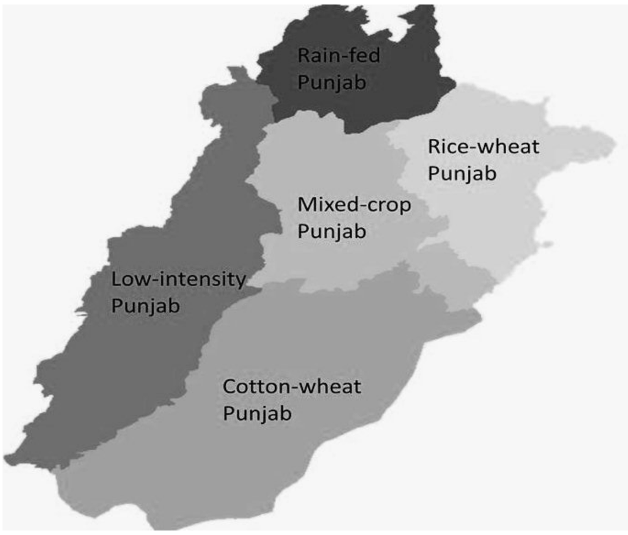

Fig. 1: *Agro-ecological zone of the Punjab province, Pakistan (source: Ahmad et al., 2016).*

2.3 Questionnaire

In January 2017, a preliminary version of the questionnaire was piloted in the research area (N=45), and subsequently improved. The final questionnaire included sections on FFC variables, beliefs of respondents on the quality of agrochemical inputs available in local markets, perceptions on the importance of dosage, time of spraying, and recommended instructions for spraying. The questionnaire was originally designed in English, and translated to Urdu by the first author. A copy of the questionnaire is available from the first author upon request.

2.4 Data analysis

To determine influences on input adoption, we used discrete response models with more than two responses. As the input types have a natural quality order, we employed ordered probit models (Verbeke & Ward, 2006). To further rationalize the ordering of the agrochemicals quality, we showed and asked all smallholder farming households

[1]District is the subsequent administrative unit with a formal government after division in context to Pakistan.

[2]Tehsil is below district administrative unit.

[3]Pakpattan is a district and consists of two *tehsils*; one of its *tehsil* bears the same name 'Pakpattan'.

[4]Union council is the lowest administrative unit with a formal government.

about their opinion/knowledge about typical examples of products belonging to the three quality tiers (see introduction). The subjective quality assessment of the farmers about qualitative aspects of agrochemicals being practised at their farms and their knowledge/opinion about other available agrochemicals which in principle not being practised at their farms, closely matched the quality ordering used in this study (see Table 1). In particular, the most (83 %) of exclusive users of agrochemicals input type A assessed it as improved quality, to the contrary, only a minuscule percentage (14 %) of exclusive users of agrochemicals input type C assessed it as improved quality. Since ordered probit coefficients lack an immediately meaningful interpretation, we report marginal effects for each explanatory variable. Using type A, type intermediate, and type C as responses, each response had a minimum of 50 data points (cf. Sudman, 1976; see Table 2). Several farm capital and farmer capital variables for which literature suggested an influence (see introduction), were used as independent variables (see Table 4). In detail, our ordered response model assumed the following form (Wooldridge, 2010):

Table 1: *Farmer's opinion about the quality of adopted agrochemicals inputs types.*

Response	*Full sample (N=275)*	*User type (%)*		
		A	*B*	*C*
Improved quality	51	83	42	14
Low quality	23	17	50	62
Poor quality	26	0	8	24
Total	100	100	100	100

$$y_i^* = x_i'\beta + \varepsilon_i, \quad \varepsilon_i \sim NID\,(0,1)$$

y_i^* = unobserved or latent variable,

y_i = observed variable not in the equation,

$y_i = 0$ if $y_i^* \leq y_1$,

$y_i = 1$ if $y_1 < y_i^* \leq y_2$,

$y_i = 2$ if $y_2 < y_i^*$.

Where x_i' is set of explanatory variables and β are the estimated parameters for the corresponding explanatory variables, the stochastic disturbance term ε_i is assumed to be normally and independently distributed (0, 1). Here y is an unknown cut point (or threshold parameter, if y takes three adoption responses, then there will be two cut points, y_1 and y_2. Therefore, y is jointly estimated with β.

Consequently, the ordered probit model for three agrochemical input types is given as under:

$$ACQ_{ij} = \alpha + \beta X_i + \delta Z_i + \varepsilon_i, \quad \varepsilon_i \sim NID\,(0,1)$$

where ACQ is the adopted agrochemicals input quality, subscript i represents a smallholder farming household, and j represents the agrochemicals input category respondents adopted (j=0,1,2). In particular, j=0 indicates that a household adopted agrochemicals input C category, j=1 whether or not a respondent adopt agrochemicals input type intermediate category, and j=2 whether or not a respondent adopt agrochemicals input type A category (see section 3.1, Table 3); X and Z are the FFC variables thought to determine ACQ. α, β, δ, and ε estimated using maximum likelihood procedures. We made a robust standard error calculation for an ordered probit model to address the heteroscedasticity (Greene, 2002). We employed Pregibon's link test for model specification (Pregibon, 1980), which basically implies that when we regress explanatory variables on the predictions squared, the null hypothesis is that predictions squared have no explanatory power. The data were analysed using STATA version 11.

3 Results

3.1 Smallholder farming households' proportions with respect to input types

Compared to exclusive users of input types A and C, exclusive users of type B as well as users of more than one type are relatively infrequent (Table 2). For subsequent analyses, we designated all respondents who did not exclusively use type A (52 %) or type C inputs (29 %) as users of an intermediate type (Table 3).

3.2 Farmer and farm capital

The descriptive summary of FFC variables of smallholder farming households is presented in Table 4. Most notably, less than a quarter of all farms own farm machinery (23 %), few have access to quality source of agricultural information (16 %) and even less have their own tube well for irrigation (15 %) or are members of a local farmer association (10 %).

While the total farm size of farms exclusively using improved agrochemical inputs (type A) is not necessarily bigger than intermediate and type C farms, they have a higher mean area under cotton (Fig. 2 (a)/(b)). Ownership of farm machinery and no-tillage cropping also tends to be higher for type A farms (Fig. 2(c)/(d)). The same trend can be seen for education of the household head, visits by agricultural extension service agents/month, and number of adopters in the

Table 2: *Use of agrochemical input types A (improved quality), B (national level quality), and C (base quality) by surveyed smallholder farming households.*

	Input type						
District	*A*	*A+B*	*A+C*	*B*	*B+C*	*C*	*Total*
District Pakpattan	32	9	11	5	6	26	89
District Rahim Yar Khan	59	1	3	11	1	31	106
District Vehari	52	2	2	1	1	22	80
Total	143	12	16	17	8	79	275

Table 3: *Smallholder farming households' distribution with respect to input types.*

Agrochemicals input type	*Ordered*	*Frequency*	*Percent*
Agrochemicals input type A only	2	143	52
Agrochemicals input type Intermediate	1	53	19
Agrochemicals input type C only	0	79	29
Total		275	100

neighbourhood (Fig. 3a/b/c). In contrast, the distance to the home of the village head decreases (Fig. 3(d)). For all farm variables, ANOVA with post hoc Scheffé test indicates that type C farms differ from type A farms.

3.3 Determinants adoption: ordered probit model

Table 5 reports regression estimates of the adoption of agrochemicals input types from an ordered probit model. The area sown under cotton positively influences the probability of adoption of improved inputs by 13 % per hectare; the probability of using intermediate quality (-4 %) and base quality (-9 %) decreases. Owning farm machinery tends to promote type A adoption strongly (+15 %), while farms are less likely to use exclusively type C base quality inputs (-9 %). Smallholder farming households practicing no-tillage are (20 %) more likely to exclusively adopt type A inputs – with correspondingly decreasing probabilities for intermediate quality (-6 %) and base quality (-13 %) inputs. Struc-

Table 4: *Descriptive summary of farm capital and farmer capital (FFC) variables (N=275).*

Definition of variables	*Mean*	*Std. Dev.*	*Min*	*Max*
Farm capital variables				
Area in ha	1.30	0.55	0.4	2.02
Area in ha (cotton)	0.77	0.58	0	2.02
Farm machinery (yes=1; no=0)	0.23	0.42	0	1
Farm distance to the farm of village head (km)	1.32	1.32	0	7
Tube well (own=1; otherwise=0)	0.15	0.36	0	1
No-tillage (yes=1; no=0)	0.45	0.49	0	1
Neighbourhood adopters (numbers)*	2.46	2.32	0	12
Farmers Capital variables				
Age (years)	43.5	12.92	17	73
Education in years	5.7	4.41	0	16
Off-farm income (yes=1; no=0)	0.45	0.49	0	1
Membership of local farmers union (yes=1; no=0)	0.10	0.31	0	1
Number of visits by government agriculture extension service/month	0.80	0.94	0	4
Source of agricultural-credit (government bank: yes= 1; no = 0)	0.16	0.36	0	1
Source of agriculture information (agriculture-extension, village committee, newspaper/TV/Radio=1; otherwise=0)	0.16	0.37	0	1

* number of adopters of improved quality inputs (type A) in the respondent neighbourhood.

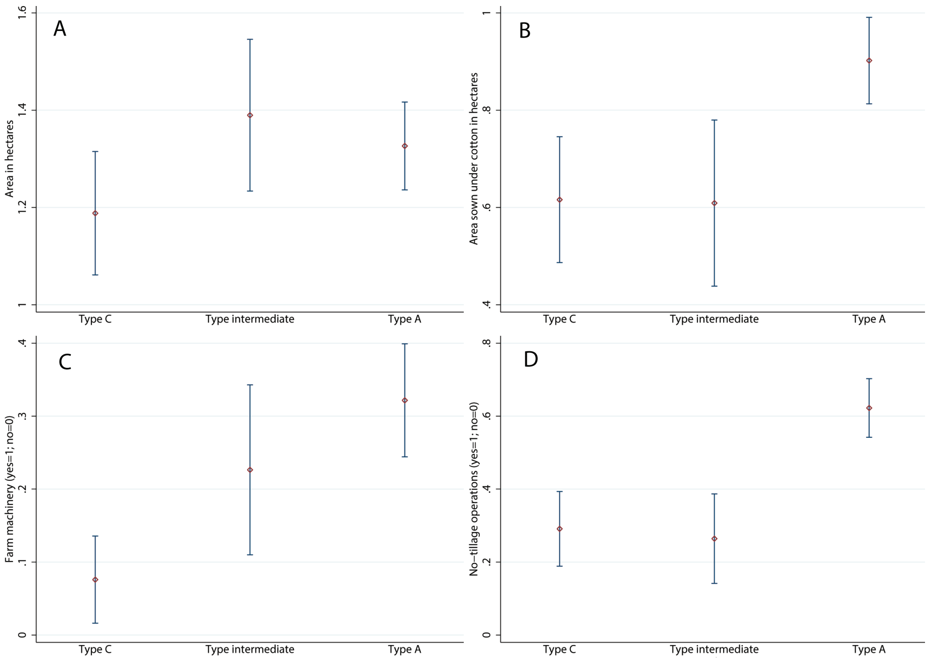

Fig. 2: *(a)/(b)/(c)/(d): Confidence interval plots of farm capital variables with respect to agrochemicals input types.*

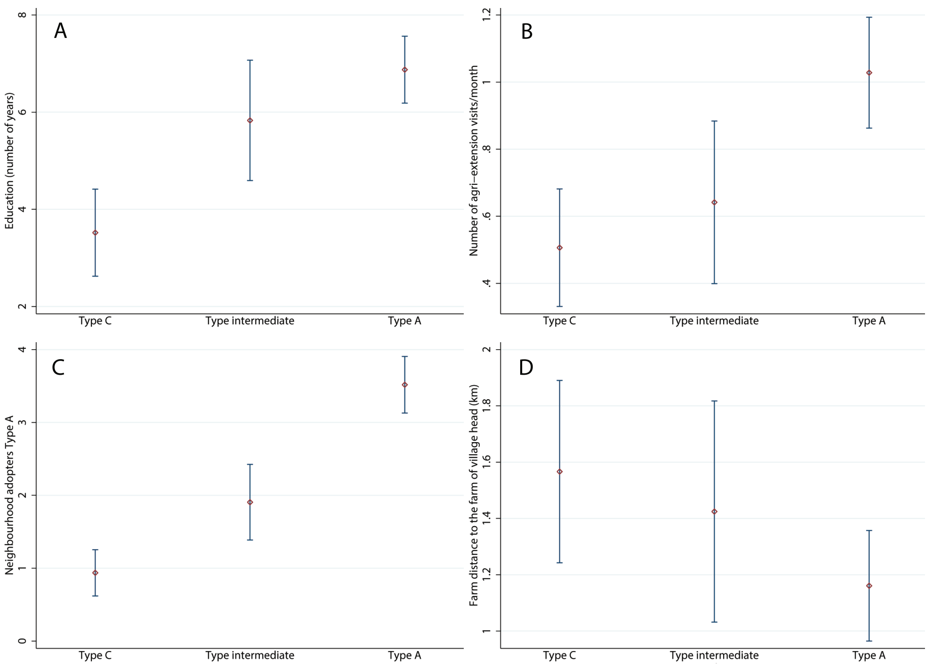

Fig. 3: *(a)/(b)/(c)/(d): Confidence interval plots of farmers' capital variables with respect to agrochemicals input types.*

turally similar effects are found for the numbers of neighbourhood adopters, age, education, availability of off-farm income, and the number of agricultural extension visits. Of these, the last two have the strongest positive impact on the probability of exclusive type A adoption. Most importantly, one additional visit of an extension agent increases the probability of exclusive type A adoption by 10 % while decreasing the adoption probabilities for both other input quality types. Having agricultural credit from a government bank tends to reduce the probability of exclusive type A adoption (-14 %). As far as the model's accuracy is concerned, we failed to reject the null hypothesis that predictions squared have no explanatory power because of the probability value greater than 10 %, we conclude that our model accurately fit the data as presented in Table 5

Table 5: *Regression estimates of agrochemicals input categories from an ordered probit model.*

			Marginal effects		
Explanatory variables	*Coefficients*	*Robust SE*	y_1=0	y_1=1	y_1=2
Area in ha (total crop area)	− 0.08	0.17	0.02	0.01	− 0.03
Area in ha (cotton)	0.34**	0.15	− 0.09**	− 0.04**	0.13**
Farm machinery	0.39*	0.22	− 0.09**	− 0.05	0.15*
Tube well	− 0.24	0.25	0.07	0.02	− 0.09
No−tillage	0.50***	0.18	− 0.13***	− 0.06***	0.19***
Neighbourhood adopters	0.31***	0.05	− 0.08***	− 0.04***	0.12***
Age	0.01*	0.00	− 0.00*	− 0.00*	0.00*
Education in years	0.04**	0.02	− 0.01**	− 0.00*	0.01**
Off−farm income	0.33**	0.17	− 0.08**	− 0.04*	0.13**
Membership	0.11	0.28	− 0.02	− 0.01	0.04
Agriculture information quality	− 0.18	0.23	0.05	0.02	− 0.07
Agricultural extension visit	0.25***	0.10	− 0.06***	− 0.03**	0.10***
Source of agricultural credit	− 0.36*	0.21	0.10	0.03**	− 0.14*
Farm distance from village head	− 0.07	0.06	0.01	0.00	− 0.02
Threshold parameters					
y_1	1.25***	0.42			
y_2	2.01***	0.43			
Model summary					
No. of observations	275				
Pseudo R2	0.25				
Wald (14 d.f.)	119.47 ***				
Linktest hatsq p value	0.263				
Log−likelihood	−209.76				

Notes: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

4 Discussion

Most of the variables incorporated in this study are consonant to previous studies regarding technology adoption in developing countries of South Asia and Africa (Qaim & Kouser, 2013; Abdulai & Huffman, 2014). As the study confined to smallholder farming households, they lack tendency to ownership of farming capital stock (Mottaleb *et al.*, 2017) and we have found a similar trend of that particular variable (e.g., less ownership of farm machinery and tube well). Small farmers are rarely members to farming community groups (Shikuku *et al.*, 2017) also this may be a potential reason of not having a good representation for the membership of local farmers unions (see Table 4).

Differentiating three quality types in the adoption of agrochemical inputs by smallholders' famers in Punjab Province, Pakistan, we estimated the econometric influence of several farm capital and farmer capital variables on the adoption of improved quality inputs using an ordered probit model. As expected, farm capital variables such as cotton farm size, ownership of farm machinery, but also off-farm income increased the probability for exclusive adoption of improved quality inputs. Positive technology adoption effects were shown, for instance, for farm size (Bonabana-Wabbi, 2002), area under cotton (Lambert *et al.*, 2015), farm machinery (Morris *et al.*, 1999; Ayandiji & Olofinsao, 2015), and off-farm income (Hailu *et al.*, 2014). These results follow the general pattern that potentially beneficial rural innovations are not first adopted by those most in need but by those able to afford the innovation.

Furthermore, our results showed that age is positively associated with input type A adoption. Smallholder age may act as proxy for farming experience, and as such fosters adoption. Asfaw *et al.* (2012) find the same positive influence of age on adoption of agricultural technologies. Years of education is a farmer capital variable with five additional years resulting in a high probability of exclusive type A adoption. Years of education have frequently been shown to be positively correlated with adoption of improved quality inputs (cf., Willy & Holm-Müller, 2013).

All of the above variables are characterised by a small or absent short-term ability of the government of a low-income country such as Pakistan to improve variable values. Thus, it is one of the most striking results of our study that the number of contacts of smallholders with agricultural extension service agents has a very strong positive influence on the adoption of improved quality agrochemical inputs: One additional visit per month is associated with a 10 % increase in the probability of exclusively adopting quality type A inputs. This result is in line with findings, e.g., by Handschuch & Wollni (2016) showing that extension contacts promote the adoption of improved farm practices. Agricultural extension services help farmers to diversify their knowledge and experience new technologies resulting in a generally positive association with the adoption of new agricultural technologies (Mwangi & Kariuki, 2015; Simtowe *et al.*, 2016). In particular, underprivileged and uneducated farmers can benefit from extension field staff and farmer field schools in association with adult education (Ashraf *et al.*, 2015). Although implementing a well-run and effective nationwide agricultural extension service has its own challenges (Abbas *et al.*, 2003; Aldosari *et al.*, 2017), this is clearly an area deserving prime government attention for short and medium term improvements. With positive neighbourhood effects clearly shown in our data (cf. Wilson, 1987; Holloway *et al.*, 2007), improved agricultural extension may have self-enhancing effects on adoption.

Access to agricultural credit is another area of government activity believed to foster technology adoption (Hailu *et al.*, 2014). One of these institutions in Pakistan is Zarai Taraqiati Bank Limited (ZTBL). Surprisingly, having credit from a government bank reduces the exclusive adoption of type A inputs in our study. One set of reasons may relate to bureaucratic hurdles to government credit (Bilal *et al.*, 2015). In effect, the more successfully adopting farmers eschew government lending institutions. Because of the lack of a positive influence of government credit on adoption, we cannot recommend easier access to government banks as a means to higher adoption. Still, the unusual result may hint at specific problems with the lenders in the project area.

Farmers who perceive that technology meets their needs are likely to adopt the technology (Doss, 2003; Mignouna *et al.* 2011). Particularly, no-tillage systems are efficient for soil conservation and reduce labour and energy input as ploughing/tillage is avoided (Barbera *et al.*, 2012). No-tillage systems are frequently based on the use of glyphosate formulations – often imported from China or OECD countries and, thus, categorised as improved quality type A agrochemical inputs in our application of official Pakistani classifications. We suggest that the strong influence of no-tillage cropping on adoption is based on the associated use of imported herbicides based on glyphosate or similar ingredients. A discussion of the pros and cons of the joint adoption of no-tillage systems with glyphosate formulations is beyond the scope of this study (see, e.g., Fernandez-Cornejo *et al.*, 2012; Brookes *et al.*, 2017; Danne *et al.*, 2019).

From scientific point of view, this study conforms – to the best of our knowledge – for the first time that the adoption of improved quality agrochemical inputs follows the same patterns as the initial adoption of agrochemical inputs. This result also holds with respect to influences on the adoption of agricultural innovations at large.

5 Conclusions

The results demonstrate that several FFC variables significantly impact decisions of smallholders in the cotton-wheat zone of the Punjab to adopt improved quality agrochemicals inputs. The results are broadly in line with previous research investigating initial adoption of agrochemical inputs and/or adoption of improved agricultural technologies at large. Of the variables tested, the number of visits by agents of the agricultural extension service had a very strong impact on adoption. Because this is a variable under rather direct and government control that can be improved at moderate cost, we suggest that Pakistani and Punjabi agricultural administrations focus on improvements here.

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Conflict of interest

Authors state they have no conflict of interests.

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