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Abstract

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Keywords

land tenure; conservation practice; control function; bivariate probit; Chinese agriculture

Disciplines

Agricultural and Resource Economics

Authors

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20 **JEL Codes:** Q15, Q18, O13

21 **1. Introduction**

22 Land tenure security is crucial in promoting the adoption of various conservation practices,
23 including conservation tillage (Lee and Stewart, 1983; Soule et al., 2000), contour farming
24 (Soule et al., 2000), conservation crops (Fraser, 2004), and stone terraces or soil bunds
25 (Gebremedhin and Swinton, 2003). Arguably, more secure land tenure, which often refers to
26 complete, permanent, or durable ownership of farmland, leads to higher willingness to adopt
27 conservation practices, especially those practices with long-term soil fertility benefits. This is
28 likely because greater land tenure security increases the likelihood of farmers reaping the
29 benefits of land investments, which are often long-term (Feder et al., 1988; Soule et al., 2000;
30 Fraser, 2004; Kabubo-Mariara et al., 2010). Despite the perceived significance of land tenure,
31 there is a lack of evidence of the role of land tenure security in conservation practice adoptions,
32 especially in developing countries such as China. This, in part, results from varying definitions of
33 land tenure security and heterogeneity in the ownership and tenure systems across different
34 countries (Kabubo-Mariara et al., 2010).

35 In China, land tenure security has particular relevance because, under the current Household
36 Responsibility System (HRS), agricultural land is owned by the collectives at the village level,
37 and each eligible farmer household is granted a land contract right to farm a village-allocated
38 land parcel with up to 30 years of tenure (Hu, 1997). The distinct nature of rural tenure systems
39 confronts Chinese farmers with greater land tenure insecurity, which could potentially hinder
40 farmers' investments in production and conservation practices, especially those with a long time

41 horizon. For instance, researchers have found that frequent land reallocation by the village
42 collectives to accommodate a growing rural population often dampens the stability and security
43 of land tenure, resulting in a very uncertain land tenure length with an effective length of much
44 less than 30 years (Liu et al., 1998; Brandt et al., 2002; Tan et al., 2006).

45 In fact, since Jacoby et al. (2002), many researchers have examined the impacts of land
46 tenure insecurity in Chinese farmers' production decisions, with a focus on input use such as
47 organic fertilizer (e.g., Jacoby et al., 2002), land use efficiency (Zhang et al., 2011; Leight,
48 2016), and forest output efficiency (Salant and Yu, 2016). In contrast, evidence of the impacts of
49 land tenure in conservation practice adoption in China is relatively scarce. Wang et al. (2010)
50 investigate the determinants of adopting conservation tillage as well as residue retention;
51 however, they do not consider land tenure as a driving factor. Liu and Huang (2013) were among
52 the first to assess how land tenure security affects conservation practice adoption and show that
53 the ownership of land is slightly positively associated with increased likelihood of using contour
54 cultivation.¹

55 However, to the best of our knowledge, no study has explicitly modeled the role of land
56 tenure in the adoption of straw retention, an increasingly important component of conservation
57 practices (Pittelkow et al., 2015). Straw retention (i.e., returning straw to the field) refers to a
58 residue management strategy of covering the crop straws on the soil surface after harvest, which
59 has been proven to improve long-term soil productivity (Lu, 2015; Wang et al., 2015), and boost

¹ Chinese farmers do not own the farmland. As will be discussed in detail later, the "ownership" of a plot by a farmer household in China is actually represented as the land contract right.

60 yield (Huang et al., 2013; Wang et al., 2015). However, burning straw, which generates large
61 amounts of PM 2.5 (Tao et al., 2013; Shon, 2015; Chen et al., 2017), is still common in China
62 and has become one of its biggest environmental problems despite increased public attention,
63 fines, and penalties. In an attempt to reduce open burning of straw, thus curbing PM 2.5
64 pollution, the Chinese government has recently undertaken various measures supporting
65 sustainable utilization of crop residues. For instance, in May 2015, the government announced a
66 straw retention subsidy pilot project, which offered a cash payment to farmers to encourage straw
67 retention adoption. The project was extended to all of China in 2016.² In addition, we analyze
68 land tenure insecurity in the context of new policies in which China increasingly promotes rural
69 land transfers among farmers through a land rental market. There is a lack of understanding on
70 whether and how farmers make production and conservation decisions differently on rented land
71 obtained through the rental market versus their own-contracted farmland allocated by collectives.

72 This study aims to examine whether and how land rental decisions, which are increasingly
73 prevalent under the new rural land transfer market, affect Chinese crop farmers' adoption of
74 straw retention. We hypothesize that Chinese crop farmers are less likely to adopt straw retention
75 and other conservation practices on land rented from others due to their perceived less secure
76 land tenure arrangement. We argue that farmers on rented fields face less secure land tenure due
77 to the short-term nature of leasing contracts, and thus have lower willingness to undertake a

² The pilot project in 2015 was undertaken in five provinces—Anhui, Shandong, Hunan, Sichuan and Zhejiang. Our study analyzes crop and crop residue choices by farmers in Henan province for the 2015 growing season, which was not included in the pilot project. In addition, the progress on the subsidy project varied dramatically among different regions. Based on the experiences of our interviewers, most farmer households in Henan were not aware of this subsidy program at the time of the survey.

78 conservation practice compared to land formally allocated to them via long-term contracts from
79 the collectives.

80 To test our hypothesis, we use a 2016 rural household survey covering 1,659 crop plots in
81 Henan Province in central China and analyze whether farmers are less likely to adopt straw
82 retention on rented plots compared to own-contracted plots. To address the potential endogeneity
83 of the land tenure variable, we rely on an instrument that proxies the remittance income from the
84 household members who migrated into cities. Arguably, a higher ratio of migrants' income over
85 agricultural profits, conditional on available laborers and farmers' household income, would lead
86 to a smaller likelihood of renting from others but not directly shift conservation practice choices.
87 Following Wooldridge (2010), we employ both a bivariate probit and a control function approach
88 using the above instrument to address the endogenous explanatory variable of land tenure.

89 Our main results confirmed that Chinese crop farmers are less likely to adopt straw
90 retention on fields rented from others compared to own-contracted plots. In particular, the
91 bivariate probit and control functions controlling for the endogeneity of the land tenure variable
92 suggest that on average, the likelihood of Chinese crop farmers adopting straw retention on
93 rented fields are almost only half compared to that for their own-contracted fields. In contrast,
94 simple probit regressions with endogenous land tenure variable show that a rented plot is
95 associated with an eight percent reduction in the probability of adopting straw retention after
96 harvest throughout 2015. Overall, our results confirm our hypothesis of less conservation
97 practice adoption given less secure land tenure arrangements, and are comparable to many

98 studies in other countries.

99 This study contributes to the literature of conservation practice adoption by quantitatively
100 examining the link between land tenure security and straw retention adoption in China for the
101 first time. In particular, our analysis provides evidence that Chinese crop farmers are
102 significantly less likely to adopt straw retention, a critical conservation practice, on rented plots
103 compared to those own-contracted plots. More importantly, our research is of great policy
104 relevance since it reveals the previously overlooked, potentially negative interconnection
105 between two policies promoted by the Chinese government—encouraging the adoption of straw
106 retention and expanding the rural land rental market—and offers insights into how the
107 government can better promote and balance them. Finally, the significant larger average partial
108 effect in the main specifications suggests that one needs to control for the endogeneity of the
109 land tenure variable using the biprobit or control function approach.

110 The rest of this article is organized as follows: Section 2 provides a brief review of China's
111 land system and the development of the land rental market. Section 3 introduces the conceptual
112 framework. Section 4 introduces the empirical implementation strategy. Section 5 describes the
113 data used in this study and empirical implementation. Section 6 discusses the empirical results.
114 Section 7 provides concluding remarks.

115 **2. Land Tenure and Land Rental Market in China**

116 China prohibits private land ownership. The current HRS was introduced in the early 1980s and

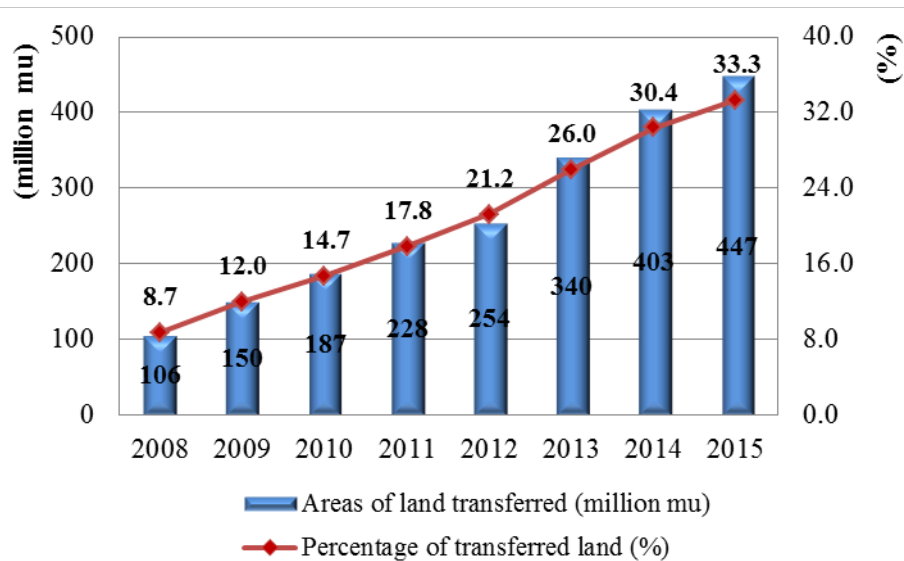
117 allocates a parcel of contracted farmland to each eligible rural household on the basis of
118 household size, which is referred to as the land contract (and use) right. Nevertheless, the
119 allocated land is owned by village collectives represented by villager committee or township
120 government (Hu, 1997). Farmers are free to make their own agricultural production decisions,
121 though they are not permitted to convert the land to non-agricultural use. In the early stages of
122 HRS, land contracts only lasted for a one- or two-year period, which led to significant land
123 tenure insecurity and discouraged farmers from making land improvements (Krusekopf, 2002).
124 Realizing this limitation, the Chinese government lengthened the land contract terms to 15 years,
125 further extending it to 30 years in 1993 (Zhang et al., 2011).

126 However, the increase in duration of land contracts did not necessarily improve the tenure
127 security for rural households for two reasons: (a) village collectives periodically reallocate
128 village land through administrative means to reach egalitarian goals in response to household
129 demographic changes, even in the midst of land contract periods (Liu et al., 1998; Brandt et al.,
130 2002; Tan et al., 2006); and, (b) collective allocations efficiency is negatively impacted by an
131 increasing number of rural migrants going off-farm and working outside the village, which tends
132 to lead to productive inefficiency (Benjamin and Brandt, 2002).

133 In response to the rising need of more secure land tenure, the central government has
134 codified a framework for the protection of land rights and development of a land rental market,
135 including the Land Management Law (1998), the Rural Land Contracting Law (2003), and the
136 Property Law (2007). Subsequently, the land rental market took off rapidly, with a participation

137 rate of about 10 percent in 2001 (Deininger and Jin, 2005), and stayed around that level for
 138 almost a decade. However, in many areas, farmland continued to be illegally reallocated by local
 139 officials (Zhang et al., 2011). With the steady increase in the number of rural workers migrating
 140 to urban regions, more and more rural households no longer have the need to keep all contracted
 141 land due to lack of laborers, which to a large extent stimulates the development of a rural rental
 142 market. Figure 1 shows the national growth of transferred rural land in China. The percentage of
 143 transferred land over the total contracted land to rural households has tripled from less than 10
 144 percent in 2008 to about 33 percent in 2015.

145



146

147 Figure 1. Scale of land Transfers in China, 2008–2015.

148 (Source: Author’s calculation; Ye, 2015; Ministry of Agriculture, 2014, 2015, 2016)

149

150 More recently, the Chinese government has formally announced the intent to protect and
 151 split rural land rights into three parts: ownership, contract, and use. Ensuring permanent

152 collective land ownership, the government allows rural households to lease out the land use right
153 while maintaining the original land contract with the village government, which is largely to
154 stimulate land transfer through the rental market.³ However, the decomposition of rural land
155 rights may raise a further question. The transferred land use right, which depends on how the
156 leasing contract is made between rural households, may not be as secure as the land contract
157 right.

158 While rural land transfer allows more flexible allocation of farmland across farmers,
159 potentially moving from inefficient producers to more efficient producers, it remains uncertain
160 how the tenants, who obtained the farmland via the rural land transfer market for a finite amount
161 of time, would treat these land parcels differently compared to those owned and operated by its
162 original contractees. Enlightened by previous literature on limited investments on rented land
163 (Soule et al., 2000; Fraser, 2004; Kabubo-Mariara et al., 2010), we assume that tenants of rented
164 land would have less incentive to make long-term investments, such as adopting conservation
165 practices (i.e., straw retention) on these parcels.

166 **3. Conceptual Framework**

167 Following previous works by McConnell (1983) and Soule et al. (2000), we develop a
168 three-stage model to analyze the adoption behavior of straw retention under different land tenure
169 arrangements.

³ See the 2014 No. 1 Policy Document available at http://www.moa.gov.cn/zwllm/zwdt/201401/t20140120_3742582.htm (in Chinese).

170 In the first stage, after the crop is harvested for the current growing season, the farmer
171 household decides on the treatment of crop residues (straws), which involves a treatment cost
172 denoted by C_j . In this context, we designate $j = s$ for adopting straw retention and $j = n$ for
173 non-adoption. Straw retention requires straws to be smashed before they are covered and mixed
174 with the soil surface, which takes additional machinery or labor costs and thus $C_s > 0$. If straws
175 are not returned to the fields, farmers can either burn, discard, or use straws for other off-farm
176 purposes such as feed, fuel, and to sell. Any of these treatments may also involve some costs
177 including collecting, storing, and transporting of straws and thus $C_n > 0$. It is difficult to
178 determine which of C_s and C_n is higher, as C_j depends on specific straw treatment as well as
179 the crop type.

180 Straw treatment in the first stage will also affect farming for the next season. Let π_j be the
181 second-season net returns under first-stage straw treatment, j . Although straws can improve soil
182 quality, acting similar to fertilizer, it takes time for straw to decay, which may affect the next
183 cropping given that farmers are often time-pressed between harvesting and sowing (Peng et al.,
184 2016; Zhang et al., 2017), especially during autumn and in double-crop rotation areas like Henan
185 Province. During the process of decaying, it may also lead to insect damage, which potentially
186 increases the cost of pesticide use and hurts crop yields (Cai et al., 2011; Dinardo-Miranda and
187 Fracasso, 2013; Carvalho et al., 2017). Therefore, there are many ways that straw retention may
188 affect short-term profits, as a result it is common that $\pi_s < \pi_n$.

189 For the final stage, the farmer household is concerned with the terminal value of its

190 farmland, denoted by V_j . Research has shown that straw retention can help reduce soil erosion
 191 and improve fertility and productivity over time, thus better retaining the long-term value of the
 192 land. Therefore, $V_s > V_n$.

193 Assume that a farmer household (either contractee or renter) selects a straw treatment
 194 option, j , to maximize the present value, PV_j , of the three terms previously discussed on a
 195 cultivated plot (either own-contracted or rented), as shown by the following equation:

$$196 \quad \max_{(j)} PV_j = \pi_j - C_j + \lambda V_j / (1 + r)^T, \quad (1)$$

197 where r represents the discount rate and T the number of periods. Following Soule et al.
 198 (2000), λ is included as a tenure-security indicator weighting the third term that measures the
 199 farmer household's belief about its ability to use or sell the land in the future. Therefore, the
 200 more secure the land tenure, the higher λ and greater importance of the long-term land value in
 201 the household's decision-making process.

202 Based on equation (1), it is optimal for a rational farmer household to adopt straw retention
 203 when

$$204 \quad \pi_s - C_s + \lambda V_s / (1 + r)^T > \pi_n - C_n + \lambda V_n / (1 + r)^T \quad (2)$$

205 or

$$206 \quad \lambda \Delta V / R > \Delta \Pi, \quad (3)$$

207 where $\Delta \Pi = (\pi_n - C_n) - (\pi_s - C_s)$, $\Delta V = V_s - V_n$ and $R = (1 + r)^T$. Since $V_s > V_n$ and R

208 is positive, condition (3) actually suggests that the adoption of straw retention hinges on whether
209 the potential short-term profit loss (i.e., the right-hand side) can be offset by the perceived gains
210 in long-term land value (i.e., the left-hand side). That is, with higher λ , or more secure land
211 tenure, the farmer household is more likely to undertake long-term improvement activities such
212 as straw retention, as stated in our hypothesis.

213 An empirical estimate of the value of λ is lacking. In countries where private land
214 ownership is well-established, it is plausible to assume that $\lambda = 1$ for a land owner. While in the
215 context of China, the corresponding “owner” of farmland may be the contractee who bears both
216 the land contract and use rights. The value of $\lambda_{contractee}$ is possibly lower than, but close to 1,
217 since land contractees are also confronted with tenure insecurity such as land reallocation. For
218 renters, λ should be much lower since they only possess the land use right and are mainly
219 concerned with short-term profits. However, λ_{renter} could be higher than zero if renters can
220 continually use the land, which depends on the duration of the lease. In this case, more than 90
221 percent of the existing leases in the study region are oral and informal on a one-year basis. Thus,
222 we hypothesize that $\lambda_{renter} < \lambda_{contractee}$ or the probability of adopting straw retention is
223 higher for contractees than for renters, which we test in our empirical model.

224 **4. Empirical Implementation**

225 ***4.1. Base probit model***

226 To test the above hypothesis, we first employ a binary discrete choice model derived from the

227 latent variable approach. Let y denote a farmer household's decision to adopt straw retention or
 228 not, which is generated from a latent variable, y^* , equal to $\lambda \Delta V/R - \Delta \Pi$ from equation (3).
 229 The difference between short-term profits and long-term land values for the farmer household is
 230 unobserved, but one can observe the household's adoption decision. If y^* is positive, straw
 231 retention is adopted and $y = 1$ is observed; otherwise, $y = 0$ is observed if y^* is negative.

232 For each household, i , the latent variable y_i^* is assumed to be a linear function of the
 233 vector of observable household, plot, and regional characteristics (\mathbf{X}_i) as follows:

$$234 \quad y_i^* = \boldsymbol{\beta} \mathbf{X}_i + \varepsilon_i, \quad (4)$$

235 where $\boldsymbol{\beta}$ is the coefficient vector and ε_i a random error term. The linkage between y_i^* and y_i
 236 is as follows:

$$237 \quad y_i = \begin{cases} 1, & \text{if } y_i^* > 0 \\ 0, & \text{if } y_i^* < 0 \end{cases} \quad (5)$$

238 then the probability that household i adopts straw retention ($y_i = 1$) is given by

$$239 \quad \begin{aligned} Pr[y_i = 1] &= Pr[y_i^* > 0] & (6) \\ &= Pr[\boldsymbol{\beta} \mathbf{X}_i + \varepsilon_i > 0] \\ &= 1 - Pr[\varepsilon_i \leq -\boldsymbol{\beta} \mathbf{X}_i] \\ &= F(\boldsymbol{\beta} \mathbf{X}_i), \end{aligned}$$

243 where $F(\cdot)$ is the cumulative distribution function of the error term ε_i . We assume that ε_i
 244 follows the standard normal distribution and equation (6) is estimated by probit regression.

245 Empirically, the straw retention adoption equation, for each household i and cultivated plot
246 k , is assumed to be written as:

$$247 \quad Pr[adopt_{ik} = 1] = \theta rent_{ik} + \beta \mathbf{X}_{ik} + u_{ik}, \quad (7)$$

248 where $adopt_{ik}$ represents the adoption dummy, which equals unity if the household i adopts
249 straw retention on plot k ; $rent_{ik}$ is a land tenure dummy, which equals unity if the plot is
250 rented from others, and is designed to capture the land tenure insecurity denoted earlier as
251 λ_{renter} ; \mathbf{X}_{ik} is the vector of other plot-level and household-level control variables; and, u_{ik} is
252 the error term. $\hat{\theta}$ is of primary interest because it measures the marginal effect of renting from
253 others on the adoption of straw retention.

254 The land tenure dummy may be endogenous to adoption decisions for several reasons. First,
255 growers on rented plots may self-select into non-conservation activities. For instance, renters
256 could be large-scale producers who are keener to maximize profits on all grounds (including
257 rented plots) and thus are more cognizant of all possible cost savings and prone to select the
258 profit-maximizing practice.⁴ Given that air quality impacts from straw burning is currently
259 external to a producer's decision process, the renters are more likely to adopt the least costly
260 option as opposed to more costly straw retention. In this case, the naïve probit estimate of the
261 rental dummy may be underestimated. In addition, there may be unobserved characteristics that

⁴ As indirect evidence to support the claim that renters are probably large-scale producers, we make a simple statistic for our surveyed sample. Of all 670 valid households, 588 households are purely own-contractees, which means they only cultivate on their own contracted plots throughout 2015; the remaining 82 households have rented plots to cultivate besides their own-contracted plots. The average area of cultivable land in 2015 for 82 renters is 16.06 Mu, about four times larger than that of 588 purely own-contractees, which is only 4.86 Mu.

262 are correlated with both adoption choices and rental decisions, including on-farm characteristics
263 such as land shapes, soil quality and machinery use, and off-farm factors such as
264 government-supported agricultural policies.

265 Technically, the endogeneity arises due to the presence of correlation between $rent_{ik}$ and
266 u_{ik} , which may bias the estimate of $\hat{\theta}$. In order to obtain a consistent $\hat{\theta}$, we further consider two
267 approaches separately dealing with the endogeneity issue, a bivariate probit model and a control
268 function method.

269 **4.2. Bivariate probit model**

270 The bivariate probit model is frequently used in estimating the effect of an endogenous binary
271 treatment on a dichotomous outcome, while accounting for unobserved confounders
272 (Wooldridge, 2010). For expositional purposes, we rewrite the adoption equation and construct
273 the two-equation latent variable framework as follows:

$$274 \quad y^* = x'\beta + \theta d^* + u, \quad y = 1 \text{ if } y^* > 0; \quad (8)$$

$$275 \quad d^* = z'\gamma + \varepsilon, \quad d = 1 \text{ if } d^* > 0; \quad (9)$$

276 where y^* and d^* represent the latent outcome (i.e., adoption) and treatment (i.e., renting)
277 variables, respectively; x and z are covariates in each equation; and, u and ε are
278 corresponding errors. We assume that households' rental decisions are endogenous to straw
279 retention adoption, thus ε is correlated with u . The bivariate probit builds on the assumption
280 that (u, ε) follows a bivariate standard normal joint distribution with zero means, unit

281 variances, and correlation coefficient ρ (i.e., $\rho = \text{corr}(u, \varepsilon)$):

$$282 \quad (u, \varepsilon) \sim N \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \rho & 1 \\ 1 & \rho \end{bmatrix} \right). \quad (10)$$

283 To identify the parameters θ and β in the adoption equation, the covariates z in equation
284 (9) must contain at least one variable as an instrument for d^* (or exclusion restriction) not
285 included in covariates x in equation (8). Otherwise, simply relying on nonlinearities without
286 excluded instruments will lead to ill specification and the estimated partial effects may also be
287 biased (Altonji et al., 2005; Wooldridge, 2010).

288 In particular, we construct a ratio of annual income for a family's migrant workers to annual
289 agricultural profits for the farmer household as the instrument for the rental variable. The higher
290 the ratio, the higher the remittances the family receives from migration than from farming, and
291 thus a smaller likelihood that the household would rent more farmland from other contractees.
292 The idea is that the ratio serves as a proxy of a household's ability to earn additional income
293 from urban employment and thus is directly associated with household's rental decisions. It is
294 possible that the migrants' income ratio is still endogenous to adoption because higher
295 remittances means a lack of labor supply available for agricultural production, or more money to
296 potentially buy straw retention machinery. In other words, the ratio may affect the adoption
297 choice through laborer numbers or gross household income. Empirically, this can be overcome
298 by including these two variables as controls.⁵ That way, the ratio variable is exogenous to

⁵ In our empirical models, as will be noted later, the number of laborers that engaged in farming activities and annual family income will be included as control variables in all regressions.

299 adoption conditional on available laborers and household income.

300 **4.3. Control function method**

301 The control function method addresses the endogeneity problem by directly augmenting the
302 generalized residuals in the outcome equation, which accounts for any correlation between d^*
303 and u . Specifically, we can rewrite equation (8) as:

$$304 \quad y^* = x'\beta + \theta d^* + \mu \tilde{\varepsilon} + \nu, \quad (11)$$

305 where $\tilde{\varepsilon}$ is the fitted residuals from equation (9) and identified as the inverse Mills ratio for the
306 whole sample, which takes the form (Gourieroux et al., 1987; Vella, 1998):

$$307 \quad \tilde{\varepsilon} = d * \left[\frac{\phi(z'\hat{\gamma})}{\Phi(z'\hat{\gamma})} \right] + (1 - d) * \left[\frac{-\phi(z'\hat{\gamma})}{1 - \Phi(z'\hat{\gamma})} \right] \quad (12)$$

308 where d is the rental dummy; $\hat{\gamma}$ denotes the estimated parameter vector for the probit
309 estimation of equation (9); and, $\phi(\cdot)$ and $\Phi(\cdot)$ are normal density and normal distribution
310 functions.

311 Following Vella (1998), a consistent estimate of $\hat{\theta}$ can be obtained from regressing
312 equation (11) by linear probability model (LPM), assuming the generalized residuals, $\tilde{\varepsilon}$, has
313 fully removed any correlation between d^* and the new error ν .⁶ Although technically one
314 could rely on the nonlinearity of the probit model in the first stage of the control function
315 approach, Wooldridge has forcefully argued that it is better to have more independent variation
316 in the generalized residuals with inclusion of instrumental variables (Wooldridge, 2010, p.599).

⁶ For detailed discussions about why equation (11) is required being estimated by LPM and characteristics of the generalized residuals, see Vella (1998).

317 As a result, we rely on the migrants' income ratio in the first stage of the control function
318 approach when generating the generalized residuals. It is important to note that the control
319 function method with binary endogenous explanatory variables in nonlinear models is more
320 controversial, because it requires nonstandard assumptions including that the generalized
321 residuals act as a kind of sufficient statistic for capturing the endogeneity of the land tenure
322 variable (Wooldridge, 2015). However, these assumptions are no more or less general than the
323 bivariate probit assumptions (Wooldridge, 2015). In addition, equation (11) itself can serve as an
324 endogeneity test of the binary treatment variable, the rental dummy in our model, and as an
325 analogue of the Rivers-Vuong approach, which deals with a continuous endogenous variable in a
326 binary response model (Rivers and Vuong, 1988).⁷ Specifically, rejection of the null hypothesis
327 that $\mu = 0$ in equation (11) implies that d is endogenous.

328 Empirically, we provide the estimation results of the two approaches—a bivariate probit and
329 a control function method—to quantify the marginal effect of rental decision on straw retention
330 adoption after controlling for the endogeneity of the land tenure variable.

331 **5. Data Description**

332 The data used in this study is drawn from a rural household survey conducted by Henan
333 Agricultural University in 2016 in Henan Province, a major grain production province in central

⁷ In Rivers-Vuong's two-step approach, first run an OLS of the endogenous continuous variable, say y_2 , on covariates z_2 and obtain the residuals \hat{v} ; then run the probit of the binary outcome variable, say y_1 , on covariates z_1 , y_2 and \hat{v} . While in our model, the first-stage regression is probit and the second-stage is OLS but with generalized residuals.

334 China. Henan is also a big crop straw producer, accompanied by severe air pollution resulting
335 from straw burning in open fields (Fu et al., 2017).

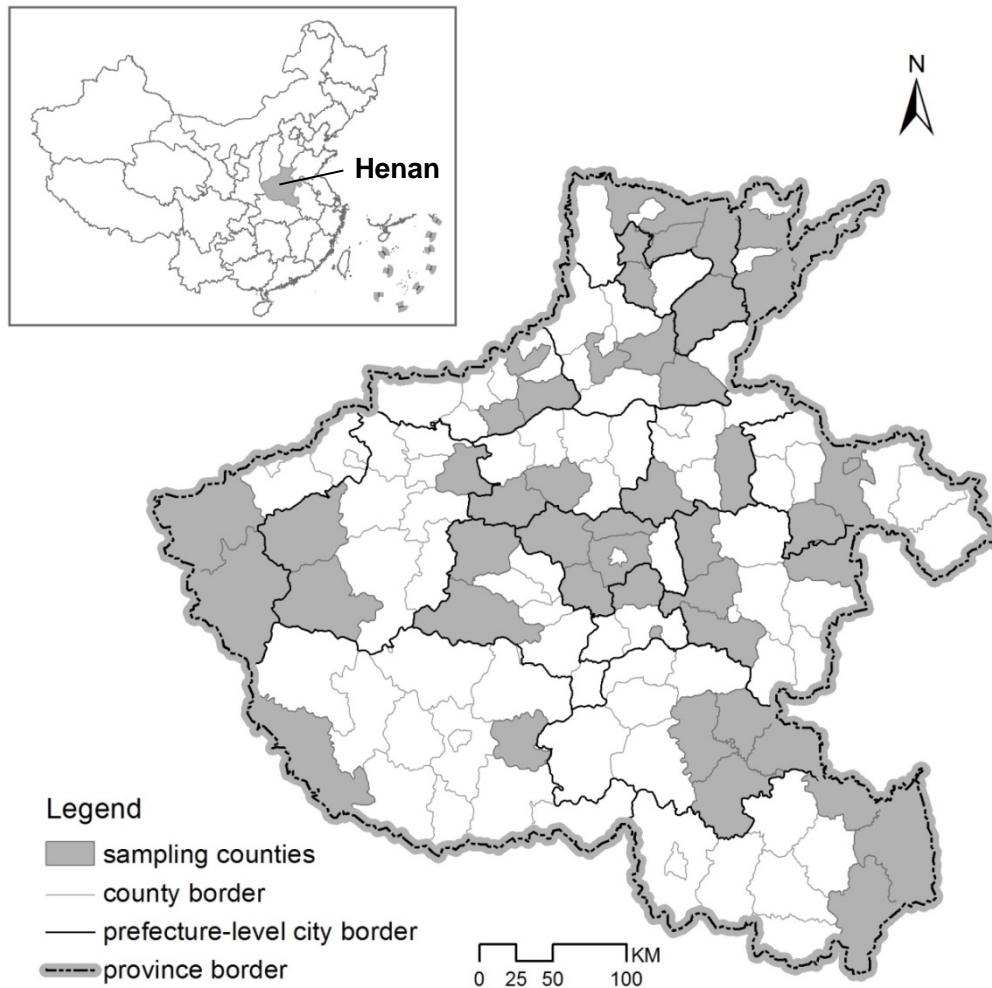
336 We have followed a stratified sampling approach in collecting our sample: for each of the
337 17 prefecture cities in Henan province, we randomly selected two to four counties, and within
338 each county, we randomly selected one or two villages among the agriculturally significant
339 counties based on historical planting area. About 50 trained undergraduate research assistants
340 went to these sampled villages for face-to-face interviews of farmers. With the help of local
341 village and county officials, we randomly selected 10 percent of rural households within each
342 village based on the household registry roster. In total, our sample consists of 670 valid rural
343 household responses spanning across 175 villages in 47 counties (see Figure 2).

344 The household-level data covers detailed information about agricultural production and
345 operation throughout 2015, as well as household and personal characteristics (see Appendix 1 for
346 the full version of the questionnaire). We also supplement the survey data with climatic
347 information obtained from the National Meteorological Information Center (NMIC), which
348 reports county-level historical averages for climate variables from 1981 to 2000 in Henan
349 Province.⁸

350 In our study area, many farmers grow at least two crops every year, typically corn during
351 the autumn season (from June to October) and winter wheat during the winter season (from
352 October to June). As a result, farmers face two annual straw retention choices. To better identify

⁸ As mentioned earlier, since Henan province is not included in the pilot project for a straw retention subsidy, in our study area for the 2015 crop year, there is no subsidy available for farmers specifically targeted to incentivize straw retention.

353 the impact of tenure, we treat straw retention choices for these crops separately and our unit of
354 observation is at the plot-level for each season, with each representing a particular crop for a
355 particular growing season.
356



357
358 Figure 2. Map of Henan Province in China, the sampled region.

359
360 For each specified plot, the farmer is asked how he or she dealt with the straws after harvest
361 and asked to choose among the following options: straw retention, burn, use for fuel, use for

362 feed, sell, and discard. We assume that straw retention is adopted for a particular plot if straw
363 retention is chosen, no matter whether there are other selected options as well and regardless of
364 the specific share of straws being returned to the field (retention).⁹ Of all observations, 9.3
365 percent of plots are rented and 90.7 percent are own-contracted, but the areas of rented plots
366 account for 20.3 percent of total cultivated land areas in our sample. In addition, 70.8 percent of
367 plots adopted straw retention, 44.1 percent are wheat plots, 38.4 percent are corn plots, and 17.5
368 percent are other crops including rice, soybean, peanuts, cotton, etc.

369 All plots are classified by a binary land tenure variable: own-contracted versus rented from
370 others. Own-contracted refers to plots with current growers that are the original contractees of
371 land allocated directly from the village collectives and who hold both the land contract and use
372 rights. Rented plots are those which current growers rented from original contractees and thus
373 only hold the land use rights. After eliminating (a) all plots that are not cultivated in 2015; and,
374 (b) plots where the planted crops do not generate straws, and thus do not involve any treatment
375 of straw, we have 1,659 plot-level observations from 670 farmer households for analysis.¹⁰

376 As mentioned above, we form our instrument by constructing a ratio of annual income for
377 family's migrant workers to annual agricultural profits for the farmer household.¹¹ More

⁹ The survey does not collect information about the shares of straws for different straw treatments.

¹⁰ Due to widely used informal contracts between farmer households in most cases, it is not clear how the decision is made on a rented plot in this context. The decision-making process has been shown crucial in affecting adoption of conservation practices (Soule et al., 2000; Kurkalova et al., 2006). For instance, in the United States, there are two types of land renter: share-renters' decisions may be affected by land owners because both the owners and renters share the revenues and costs of production; cash-renters, however, may behave more independently since they only pay a fixed rent to the landlords while the owners do not participate in any activities. Failure to consider the differences in decision-making process may obscure the effect of land tenure on adoption.

¹¹ Besides migrant income and agricultural profits, the annual household income also includes income from off-farm business or employment, transfer income such as pensions and government subsidies, etc. Statistics from our survey reveals that migrants'

378 specifically, the annual migrant income is calculated by the number of family migrant members
379 working outside the village, times the average working months, times the average monthly
380 wages. The annual agricultural profits are simply the profits of planting crops for the whole
381 family. All this information has been collected through the survey.

382 We follow the extant literature of soil conservation practices in selecting other control
383 variables of farmer and field characteristics (Feder et al., 1988; Fox et al., 1991; Knowler and
384 Bradshaw, 2007; Baumgart-Getts et al., 2012; Zhang et al. 2016). Table 1 shows the descriptions
385 of selected variables. First, we include three farmer characteristics of the household head (who is
386 also the main operator): age, years of farming, and risk preference.¹² Farmers with more
387 experience and more risk-taking attitudes are expected to have a higher likelihood of adopting
388 conservation practices. A second set of variables control for household-level characteristics,
389 which include highest years of education of all household members, number of laborers, family
390 income, participation in agricultural economic organization, and purchase of agricultural
391 insurance. We hypothesize that a richer, well-connected farmer household with better education,
392 more laborers, and insurance coverage is more likely to adopt straw retention. In addition, July
393 temperature and July precipitation are two weather variables included as controls of local climate
394 effect on farmer's adoption choice. Finally, at the plot level, we consider plot size, a season
395 dummy, and crop dummies to control for possible scale and seasonal effects, and heterogeneous

income and agricultural profits jointly account for about 75 percent of gross household income on average.

¹² The household head's attitude towards risk is measured through response to a binary question "whether you will utilize a newly developed fertilizer that may increase yields but has not been used yet" and is assigned "risk-seeking" if answering "yes" and "risk averse" otherwise.

396 impacts of crop types. We do not consider other topographic features, such as plot slope, because
 397 most of our study area is flat and thus we do not expect significant within-province variation.

398

399 Table 1. Descriptions of Selected Variables

Variable	Description
Straw retention	Straw retention is adopted in the plot (1=yes, 0=no)
Rented plot	The plot is rented from other contractees (1=yes, 0=no)
Age	Age of the household head
Farming experience	Number of farming years of the household head
Risk preference	Risk preference of the household head (1=risk seeking, 0=risk averseness)
Education	Highest years of education of all household members
Number of laborers	Number of laborers that engaged in farming activities in 2015
Income	Household annual income in 2015 (10,000 Yuan)
Organization	The household has participated in rural economic organization (1=yes, 0=no)
Insurance	The household has purchased agricultural insurance (1=yes, 0=no)
Plot size	Plot area ($\mu=0.0667$ hectares)
Mig-ag ratio	Ratio of annual income for family's migrant workers to annual agricultural profits for the farmer household in 2015
July temperature	Average daily temperature of July days from 1981 to 2000 of the county that the household locates ($^{\circ}\text{C}$)
July precipitation	Average annual daily precipitation of July days from 1981 to 2000 (mm)
Winter season	The plot is cultivated in the winter season (1=winter season, 0=autumn season)
Wheat	The plot is planted wheat (1=yes, 0=no)
Corn	The plot is planted corn (1=yes, 0=no)
Other crop	The plot is planted other crops (1=yes, 0=no)

400

401 Table 2 shows summary statistics for the selected variables used in our model by tenure
 402 type. The last column reports the sample t-test results of mean differences (rented minus
 403 own-contracted) of each of the variables. Basically, the raw descriptive adoption rate for straw
 404 retention on rented plots is about five percent lower, though insignificantly, compared to

405 own-contracted plots, confirming our general expectation. It is worthwhile to note that the
 406 instrumental variable—the migrants’ income ratio on rented plots—is significantly less than that
 407 on own-contracted plots, which is in line with our assumption that higher remittances from
 408 migration decrease the probability of renting. Another notable fact is that rented plots are
 409 generally (3.56 mu) larger in size, which provides partial evidence that renters are probably
 410 large-scale producers. Other factors with significant differences include age, education,
 411 household income, etc.

412

413 Table 2. Summary Statistics of Selected Variables by Tenure Type

Variable	All plots		Own contracted plots		Rented plots		T-test of mean diff
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Straw retention	0.708	0.45	0.712	0.45	0.665	0.47	-0.048
Rented plot	0.093	0.29	-	-	-	-	-
Age	44.28	11.76	44.08	11.93	46.28	9.71	2.20**
Farming experience	28.28	13.59	28.32	13.55	27.92	14.04	-0.40
Risk preference	0.679	0.47	0.676	0.47	0.710	0.46	0.034
Education	12.40	3.58	12.32	3.59	13.20	3.47	0.88***
Number of laborers	2.611	1.26	2.620	1.27	2.516	1.21	-0.104
Income	4.201	3.15	4.087	2.96	5.351	4.48	1.26***
Organization	0.041	0.20	0.041	0.20	0.039	0.19	-0.003
Insurance	0.129	0.34	0.116	0.32	0.258	0.44	0.14***
Plot size	4.135	4.25	3.802	2.61	7.363	10.80	3.56***
Mig-ag ratio	6.703	11.54	6.896	11.83	4.829	8.02	-2.07**
July temperature	26.98	0.36	26.97	0.36	27.05	0.34	0.08***
July precipitation	337.6	70.4	336.5	67.7	348.2	92.0	-11.74**
Winter season	0.461	0.50	0.463	0.50	0.439	0.50	-0.024
Wheat	0.441	0.50	0.443	0.50	0.413	0.49	-0.031
Corn	0.384	0.49	0.387	0.49	0.355	0.48	-0.032
Other crop	0.175	0.38	0.170	0.38	0.232	0.42	0.06*
Observations	1659		1504		155		

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively.

414 **6. Empirical Results**

415 ***6.1. Base probit regressions with an endogenous regressor***

416 We first report the results of several simple probit regressions in which we test whether the
417 probability of adopting straw retention is higher in own-contracted plots than rented plots. That
418 is, we test the null hypothesis that $\beta = 0$, where $\beta = \lambda_{renter} - \lambda_{contractee}$ is the coefficient on
419 the tenure dummy and represents the difference of tenure-security indicator between
420 own-contracted and rented plots. Table 3 presents the resulting estimated average partial effects.

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434 Table 3. Results of the Binary Probit Regressions (Dependent: Adoption=1)

Variable	(1) Full sample Marg. eff.	(2) Own contracted Marg. eff.	(3) Rented Marg. eff.
Rented plot	-0.0819**		
Age	-0.0021	-0.0036*	0.0068
Farming experience	0.0002	0.0013	-0.0035
Risk preference	0.0349	0.024	0.0903
Education	0.0166***	0.0147***	0.0274**
Number of laborers	0.0659***	0.0635***	0.1041***
Income	0.0054	0.0056	-0.0013
Organization	0.1853**	0.1986**	0.1909
Insurance	0.1239***	0.1380***	0.0842
Plot size	0.0093**	0.0122**	0.0027
July temperature	-0.0792*	-0.1153	0.1766
July precipitation	0.0013***	0.0013***	0.0011**
Winter season	0.1284**	0.1600**	0.0176
Crop dummies	Yes	Yes	Yes
Observations	1659	1659	1659
% correctly predicted	0.8005	0.8005	0.8005
LR test (p-value)		$\chi^2(14)=30.06 (0.0075)$	

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level. The marg. eff. columns report the average partial effects across all individuals in the sample. The null of the likelihood ratio test is no systematic difference in coefficients across tenure types.

435
 436 Column (1) in Table 3 displays the results using the full sample. The marginal effect of the
 437 “rented plot” dummy is negative and significant at the five percent level, and shows that a rented
 438 plot is associated with about eight percent lower probability of adopting straw retention than an
 439 own-contracted plot, ceteris paribus. The result confirms our hypothesis and is consistent with
 440 previous studies regarding the impacts of land tenure on conservation practice adoption (Soule et
 441 al., 2000; Fraser, 2004; Kabubo-Mariara et al., 2010). The household-level characteristics appear

442 to be more important in the adoption decision—higher educational attainment, greater number of
443 laborers, participation in an agricultural economic organization, and purchase of agricultural
444 insurance are significantly and positively related to increased likelihood of adoption. More
445 specifically, each extra year of education increases the probability of adoption by about two
446 percent and one more laborer leads to an increase of the likelihood of adoption by about seven
447 percent. Participation in agricultural economic organization and purchase of agricultural
448 insurance have a larger effect on adoption, with values of about 19 percent and 12 percent,
449 respectively. Two climate variables are significant, suggesting that straw retention occurs more
450 frequently where the climate is warmer and wetter (more rain). The estimated coefficient of plot
451 size indicates that one more unit increase of plot size results in an about one percent increase of
452 the likelihood of adoption, which reflects that larger farmland in fact lowers the average cost of
453 adoption. The positive and significant winter dummy verifies the existence of seasonal effect on
454 residue management.

455 We also examine whether the estimated coefficients systematically differ by tenure type. We
456 conduct separate probit regressions for each of the two tenure categories, own-contracted and
457 rented plots, with all other independent variables the same as those in the full-sample regression.
458 A Chi-square statistic of 30.06 in the likelihood ratio test rejects the null hypothesis that the
459 coefficients are identical across tenure types, implying that the impact of all other characteristics
460 on adoption of straw retention relies on the specific tenure status of the plot.¹³ The resulting

¹³ In conducting the likelihood ratio test, we do not specify clustered standard errors at any level in the regressions.

461 coefficients and average partial effects by tenure type are reported in columns (2) and (3) in
462 Table 3, which shows that despite similarity in other variables, the age of household head,
463 organization participation, purchase of insurance, plot size, and seasonal effect only matter for
464 own-contracted plots, while they have no effect on adoption for rented plots. The sharp disparity
465 reflects a significantly different decision mechanism for a renter in adopting straw retention.
466 Although the simple probit models shown in Table 3 provide suggestive evidence of the negative
467 impacts of land rental decisions on straw retention adoptions, it is important to note that the key
468 variable of interest, the land rental variable, is potentially endogenous and thus the estimates
469 might be biased.

470 ***6.2. Results of bivariate probit model and control function method***

471 To control for or mitigate the endogeneity of the rental variable, we also employ two alternative
472 approaches—a bivariate probit and a control function method with a linear probability model. In
473 both models, the ratio of migrants' income to agricultural profits for the farmer household is used
474 as the instrument.¹⁴ Results are reported in Tables 4 and 5, respectively.

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¹⁴ We have also tried “migrants' income in levels” and “relative share of migrants' income” as exclusion restrictions. Results are very similar, but using the ratio variable as the restriction has the best fits. Regression results for bivariate probit and control function method using the other two restrictions are available from authors upon request.

480 Table 4. Results of Bivariate Probit Model

Variable	Adoption Equation		Renting Equation	
	Marg. eff.	p-value	Coef.	p-value
Rented plot	-0.5113***	0.000		
Age	-0.0008	0.547	0.0187***	0.004
Farming experience	-0.0006	0.603	-0.0107**	0.034
Risk preference	0.0353*	0.070	-0.0377	0.699
Education	0.0165***	0.000	0.0276**	0.037
Number of laborers	0.0585***	0.000	-0.0597	0.119
Income	0.0064**	0.043	0.0301**	0.021
Organization	0.1650***	0.001	0.0321	0.888
Insurance	0.1425***	0.000	0.5818***	0.000
Plot size	0.0149***	0.000	0.0804***	0.000
July temperature	-0.0610*	0.064		
July precipitation	0.0011***	0.000		
Winter season	0.1058*	0.071		
Mig-ag ratio			-0.0110**	0.042
ρ (p-value)		0.7100** (0.0108)		
Crop dummies	Yes		No	
Observations		1659		

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level. The marg. eff. column reports the average partial effects across all individuals in the sample.

481

482 As seen in the bivariate probit model, the rental dummy is still negatively significant at the
 483 one percent level, but with a much higher average partial effect of 0.5113, meaning that being on
 484 a rented plot would lower the probability of adoption of straw retention by half. The signs and
 485 significance of most of other explanatory variables remain nearly unchanged when compared
 486 with the base model, except that household head’s risk preference and household income become
 487 significant in the bivariate probit model.

488

489 Table 5. Results of Control Function with LPM¹⁵

Variable	LPM		Probit	
	Coef. (Marg. eff.)	p-value	Coef.	p-value
Rented plot	-0.5251*	0.054		
Age	-0.0004	0.863	0.0218***	0.005
Farming experience	-0.0012	0.512	-0.0122*	0.081
Risk preference	0.0386	0.241	0.0188	0.893
Education	0.0210***	0.000	0.0310*	0.091
Number of laborers	0.0607***	0.000	-0.0508	0.400
Income	0.0082	0.170	0.0274	0.152
Organization	0.1427**	0.043	-0.0117	0.974
Insurance	0.1718***	0.000	0.5829***	0.000
Plot size	0.0137***	0.003	0.0772***	0.000
July temperature	-0.0821	0.121		
July precipitation	0.0015***	0.000		
Winter season	0.1696**	0.030		
Generalized residual	0.2293	0.109		
Mig-ag ratio			-0.0048	0.517
Intercept	1.9038	0.165	-2.7877***	0.000
Crop dummies	Yes		No	
Observations	1659			

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level.

490
491 As for the control function method, the marginal effect of the rental dummy is -0.5251 and
492 significant at the ten percent level. It is noteworthy that the generalized residual term appears
493 insignificant at any significance level but with a very close p-value of 0.109, which fails to reject
494 the null hypothesis that renting is exogenous, suggesting that at least the endogeneity may not be
495 that apparent in our case. However, it is important to note that one could not fully rely on a

¹⁵ In an identical model but without exclusion restriction variable (i.e. “mig-ag ratio” is excluded in the probit regression), whose identification of the endogenous rental variable simply relies on the nonlinearity nature of the generalized residual, the coefficient (marginal effect) of the rental dummy is -0.3707 but insignificant with a p-value of 0.16.

496 marginally insignificant test statistic to claim full exogeneity.¹⁶ We argue that our control
497 function approach at least mitigated, if not fully addressed, the endogeneity concerns. We also
498 want to caution readers that alternative specifications of our control function approach, using
499 alternative set of instruments such as migrants' income in levels or without any instrumental
500 variables in the first stage, lead to statistically insignificant coefficient for the land tenure
501 variable. This suggests further research is needed to examine the robustness of these results but
502 even in these alternative specifications the coefficient for land tenure on straw retention is still
503 negative.

504 Contrary to the results in the adoption regression, characteristics of the household head,
505 including age and farming experience, appear to play an important role in driving land rental
506 decisions. Higher family education level, higher family income, and purchase of insurance are
507 positively related to the probability of renting more farmland. In addition, the positive and
508 significant coefficient of plot size confirms our conjecture that renters are more likely to rent
509 larger fields or more farmland. The exclusion restriction variable (migrants' income ratio) is
510 negatively significant in the bivariate probit model, which confirms our expectation that
511 households with higher remittances from migrant members are less willing to rent from other
512 contractees. This variable has negative coefficient in the control function approach as well but it
513 is statistically insignificant.

514 ***6.3. Discussion***

¹⁶ We thank an anonymous reviewer for pointing this out.

515 Our empirical results provide evidence that land tenure insecurity, as proxied by rented plots,
516 tend to negatively impact farmers' decisions to adopt straw retention in China. Combining results
517 of all three regression models, we discover that after dealing with the potential endogeneity
518 issue, there is a dramatic increase in magnitude of the average marginal effect of renting on
519 conservation practice adoption, from about -0.08 in the base model to around -0.50, which is
520 much higher than that in the existing literature (Soule et al., 2000; Gebremedhin and Swinton,
521 2003; Kabubo-Mariara et al., 2010; Baumgart-Gets et al., 2012). This increase is intuitive in the
522 sense that the base probit model may be underestimated, either due to renters' self-selection
523 behaviors or omission of some important covariates. More specifically in our data analysis, the
524 omitted unobservables could be positively related to both farmers' rental decisions and adoption
525 choices. Evidence includes the positive coefficient on the residual term (although insignificant)
526 from the second-stage regressions in two control function models and the positive and significant
527 ρ in the bivariate probit that measures correlation between adoption and renting equations.

528 Availability of machinery and agricultural subsidies from local government may be two
529 omitted factors and unfortunately they were not covered in our survey data.¹⁷ Use of machinery
530 can facilitate straw retention and save laborers to a large extent, so households who own relevant
531 machines, or are able to rent machines from outside supplies, are more likely to adopt straw
532 retention. Meanwhile, machinery availability may further lead to an increased likelihood of

¹⁷ We thank an anonymous review for pointing out that these two factors may be correlated, though slightly, with the instrument variable, the migrants' income ratio. We acknowledge that the constructed ratio variable may not fully solve the endogeneity of the rental dummy. While in this sense, the use of control function method could mitigate the endogeneity problem to a large extent.

533 renting more farmland to gain economies of scale and enhance productivity. China's central
534 government has granted rural farmers four categories of agricultural subsidies for many years to
535 boost grain production.¹⁸ Although these subsidies do not directly target conservation, it is
536 reasonable to infer that households receiving more subsidies are less vulnerable to uncertain
537 short-term profit loss from adopting straw retention. Moreover, households residing in areas
538 where the subsidies are available are more willing to grow crops and thus more likely to rent
539 more farmland simply to increase income. Recent studies in China also support the claim that
540 machinery use and subsidies play an important and positive role in inducing straw retention
541 behaviors, and their effects warrant further research.¹⁹

542 Furthermore, the descriptive data from our sample seems to suggest that current land rental
543 arrangements may be significantly insecure. Of all 82 surveyed households (out of a total of 690)
544 who rent land from others, 75 households (about 95 percent) are based on oral land leases
545 without legal validity; only four households (about five percent) have signed formal and written
546 contracts, and 65 households' leases (about 82 percent) are on a one-year-tenure basis. The
547 figures reflect that the tenure of a rented plot, or the transferred land use right, may be far less
548 secure than land contract rights in Henan province.²⁰

¹⁸ Four categories of subsidies include direct grain subsidy, superior grain varieties subsidy, agricultural machinery and tools subsidy, and general agricultural suppliers subsidy. Unlike the straw retention subsidy that is about to take effect in recent years, these subsidies have been available since 2004 in most areas of China.

¹⁹ See Qi et al. (2016) and Tong and Liu (2017) as examples.

²⁰ To test the potential effects of contract type and lease term on adoption, we have also run several probit regressions for only the 155 renters in our sample. Results are reported in Table A.1 in Appendix 2, where we list four specifications with column (1) the base model and columns (2)–(4) with one or two of the contract variables augmented. However, results reveal that neither of the two contract variables is significant in any specification. Therefore, we are unable to identify the effect of contract type and renewal frequency in this study.

549 **7. Concluding Remarks**

550 Based on data from a 2016 farmer household survey in Henan Province in central China, we
551 apply several probit regressions, including a bivariate probit model and a control function
552 method, to examine how land tenure arrangements especially land rental decisions affect the
553 probability of adopting crop straw retention. We employ an instrument that relies on the
554 remittance income from household members who migrate to cities to address the potential
555 endogeneity of the land tenure variable. Empirical results show that farmer households are more
556 likely to adopt straw retention after harvest on own-contracted than rented plots, which is
557 consistent with previous literature that shows insecure land tenure often hinders adoption of
558 conservation practices. This study provides some of the first evidence in assessing the negative
559 impact of land tenure insecurity on the adoption of a long-term land improvement practice, straw
560 retention.

561 Our findings have important and valuable policy implications. The Chinese government is
562 currently encouraging participation of market-based rural land transfer as an alternative to
563 committee-intervening land reallocation to improve agricultural production efficiency. However,
564 our results imply that more careful deliberation or monitoring is warranted regarding the
565 potential impediments to less-sustainable farming practices on the growing acres of rented
566 grounds. Our results also suggest that the air quality and other environmental benefits from
567 encouraged straw retention could be impacted without further efforts to boost adoption on rented
568 land. Due to less secure land tenure, farmers on rented plots may have lower incentives to adopt

569 conservation practices, causing environmental problems such as more PM 2.5 emissions from
570 straw burning and more severe soil degradation. Improving the land tenure security, especially
571 for rented plots, may be one effective measure. For instance, the government could regulate the
572 rental market by enforcing the use of a more stable and formal written contract, which
573 incorporates specific requirements on conservation practices and residue management. On the
574 other hand, it may also be helpful to extend the current range of land contract rights transfer from
575 within-village to cross-village or within-township, in order to allow farmer households to own
576 more contracted land and stimulate long-run land improvements.

577 The importance of our findings notwithstanding, they are limited by the fact that some of
578 important factors such as availability of machinery and agricultural subsidies were not covered in
579 our survey. Moreover, the effects of different aspects of tenure security need further
580 investigation. For instance, the duration of tenure, another important dimension of tenure
581 security either for own-contracted or rented land, may also play a role in affecting the adoption
582 rate. In addition, with a panel dataset, one can examine whether the adoption rate of straw
583 retention varies over time under different policy scenarios, such as varying strictness on
584 restricting the burning of straws and the forthcoming straw retention subsidy. It is possible that
585 the higher adoption rate is mainly due to the prohibition of straw burning.

586 Another caveat is that our empirical results may not always be robust in terms of the
587 significance and magnitude of the land rental variable when we rely on alternative instruments in
588 both the biprobit and control function models. For instance, using migrant income in levels or

589 relative share of migrants' income could lead to differing estimated marginal effects of rental
590 ranging from 38 percent to 51 percent. However, it is important to note that the rental variable
591 has been shown consistently to negatively impact the adoption of straw retention, even in cases
592 of statistical insignificance. This could result from our data limitation of only relying on one
593 year's data, or lack of information about some important omitted factors, which suggests
594 additional research to examine the role of land tenure in conservation practice adoptions.

595

596

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603

604 **References**

- 605 Altonji, J.G., T.E. Elder, C.R. Taber. 2005. “An Evaluation of Instrumental Variable Strategies
606 for Estimating the Effects of Catholic Schooling.” *The Journal of Human Resources*
607 40(4): 791–821.
- 608 Baumgart-Getz, A., L.S. Prokopy, and K. Floress. 2012. “Why Farmers Adopt Best Management
609 Practice in the United States: A Meta-analysis of the Adoption Literature.” *Journal of*
610 *Environmental Management* 96(1): 17–25.
- 611 Benjamin, D. and L. Brandt. 2002. “Property Rights, Labour Markets, and Efficiency in a
612 Transition Economy: the Case of Rural China.” *Canadian Journal of Economics* 35(4):
613 689–716.
- 614 Brandt, L., J. Huang, G. Li, and S. Rozelle. 2002. “Land Rights in Rural China: Facts, Fictions
615 and Issues.” *The China Journal* 47: 67–97.
- 616 Cai, Y., H. Qiu, Z. Xu. 2011. Evaluation on Potentials of Energy Utilization of Crop Residual
617 Resources in Different Regions of China [Zhong Guo Ge Qu Yu Jie Gan Zi Yuan Ke
618 Neng Yuan Hua Li Yong De Qian Li Fen Xi]. *Journal of Natural Resources* 26(10):
619 1637 – 1646. (In Chinese)
- 620 Carvalho, J., R. Nogueirol, L. Menandro, R. Bordonal, C. Borges, H. Cantarella, H. Franco. 2017.
621 “Agronomic and Environmental Implications of Sugarcane Straw Removal: A Major
622 Review.” *Global Change Biology Bioenergy* 9: 1181–1195.
- 623 Chen, J., Li, C., Ristovski, Z., Milic, A., Gu, Y., Islam, M.S., Wang, S., Hao, J., Zhang, H., He, C.,
624 Guo, H., Fu, H., Miljevic, B., Morawska, L., Thai, P., LAM, Y.F., Pereira, G., Ding, A.,
625 Huang, X., Dumka, U.C. 2017. “A review of biomass burning: Emissions and impacts on
626 air quality, health and climate in China.” *Science of the Total Environment* 579: 1000–
627 1034.

628 China, People's Republic of, Ministry of Agriculture. 2014. *26% Contracted Land Has Been*
629 *Transferred, Ministry of Agriculture Required No Forced Commands* [Quan Guo 26%
630 *Cheng Bao Di Yi Liu Zhuan, Nong Ye Bu Yao Qiu Bu Neng Gao Qiang Po Ming Ling*].
631 Available at http://news.xinhuanet.com/fortune/2014-02/23/c_119460477.htm. (in
632 Chinese)

633 China, People's Republic of, Ministry of Agriculture. 2015. *The Transferred Land Has*
634 *Accounted for More Than 30% of the Total Contracted Land* [Quan Guo Geng Di Liu
635 *Zhuan Mian Ji Zhan Zong Cheng Bao Geng Di Bi Zhong Chao Guo San Cheng*].
636 Available at http://news.xinhuanet.com/fortune/2015-08/27/c_1116397151.htm. (in
637 Chinese)

638 China, People's Republic of, Ministry of Agriculture. 2016. *Ministry of Agriculture: The*
639 *Transferred Land Areas Have Been 447 Million Mu by the End of Last Year* [Nong Ye Bu:
640 *Jie Zhi Qu Nian Di, Quan Guo Jia Ting Cheng Bao Geng Di Liu Zhuan Mian Ji 4.47 Yi*
641 *Mu*]. Available at <http://www.chinanews.com/cj/2016/08-10/7967918.shtml>. (in Chinese)

642 Dinardo-Miranda, L.L., J.V. Fracasso. 2013. "Sugarcane Straw and the Populations of Pests and
643 Nematodes." *Scientia Agricola* 70(5): 305–310.

644 Deininger, K. and S. Jin. 2005. "The Potential of Land Rental Markets in the Process of
645 Economic Development: Evidence from China." *Journal of Development Economics*
646 78(1): 241-270.

647 Feder, G., T. Onchan, Y. Chalamwong, and C. Hongladarom. 1988. *Land Policies and Farm*
648 *Productivity in Thailand*. Baltimore and London: Johns Hopkins University Press for the
649 World Bank.

650 Fox, G., A. Weersink, G. Sarwar, S. Duff, and B. Deen. 1991. "Comparative Economics of
651 Alternative Agricultural Production Systems: A Review." *Northeastern Journal of*
652 *Agricultural and Resource Economics* 20(1): 124–142.

- 653 Fraser, E.D.G. 2004. "Land Tenure and Agricultural Management Soil Conservation on Rented
654 and Owned Fields in Southwest British Columbia." *Agriculture and Human Values* 21(1):
655 73–79.
- 656 Fu, L., S. Wang, Z. Wu, S. Liu, S. Yang, and R. Zhang. 2017. "Estimation of Air Pollutant
657 Emissions from Straw Residues Open Burning in Henan Province [He Nan Sheng Jie
658 Gan Lu Tian Fen Shao Da Qi Wu Ran Wu Pai Fang Liang De Gu Suan Yu Fen Xi]." *Journal of Agro-Environment Science*, 36(4): 808–816. (in Chinese)
- 659
- 660 Gourieroux, C., A. Monfort, E. Renault, A. Trognon. 1987. "Generalised Residuals." *Journal of*
661 *Econometrics* 34(1-2): 5–32.
- 662 Gebremedhin, B. and S.M. Swinton. 2003. "Investment in Soil Conservation in Northern
663 Ethiopia: The Role of Land Tenure Security and Public Programs." *Agricultural*
664 *Economics* 29(1): 69–84.
- 665 Hu, W. 1997. "Household Land Reform in China: Its Impact on Farming Land Use and
666 Agro-environment." *Land Use Policy* 14(3): 175–186.
- 667 Huang, S., Y. Zeng, J. Wu, Q. Shi, and X. Pan. 2013. "Effect of Crop Residue Retention on Rice
668 Yield in China: A Meta-analysis." *Field Crops Research* 154: 188–194.
- 669 Jacoby, H.G., G. Li, and S. Rozelle. 2002. "Hazards of Expropriation: Tenure Insecurity and
670 Investment in Rural China." *The American Economic Review* 92(5): 1420–1447.
- 671 Kabubo-Mariara, J., V. Linderhof, and G. Kruseman. 2010. "Does Land Tenure Security Matter
672 for Investment in Soil and Water Conservation? Evidence from Kenya." *African Journal*
673 *of Agricultural and Resource Economics* 4(2): 123–139.
- 674 Knowler, D. and B. Bradshaw. 2007. "Farmers' Adoption of Conservation Agriculture: A Review
675 and Synthesis of Recent Research." *Food policy* 32(1): 25–48.

- 676 Krusekopf, C.C. 2002. "Diversity in Land-tenure Arrangements under the Household
677 Responsibility System in China." *China Economic Review* 13(2): 297–312.
- 678 Kurkalova, L., C. Kling, and J. Zhao. 2006. "Green Subsidies in Agriculture: Estimating the
679 Adoption Costs of Conservation Tillage from Observed Behavior." *Canadian Journal of*
680 *Agricultural Economics* 54(2): 247–267.
- 681 Lee, L.K. and W.H. Stewart. 1983. "Landownership and the Adoption of Minimum Tillage."
682 *American Journal of Agricultural Economics* 65(2): 256–264.
- 683 Leight, J. 2016. "Reallocating Wealth? Insecure Property Rights and Agricultural Investment in
684 Rural China." *China Economic Review* 40: 207–227.
- 685 Liu, S., M. Carter, and Y. Yao. 1998. "Dimension and Diversity of Property Right in Rural China:
686 Dilemmas on the Road to Further Reform." *World Development* 26(10): 1789–1806.
- 687 Liu, H. and Q. Huang. 2013. "Adoption and Continued Use of Contour Cultivation in the
688 Highlands of Southwest China." *Ecological Economics* 91: 28–37.
- 689 Lu, F. 2015. "How Can Straw Incorporation Management Impact on Soil Carbon Storage? A
690 Meta-analysis." *Mitigation and Adaptation Strategies for Global Change* 20(8): 1545–
691 1568.
- 692 McConnell, K.E. 1983. "An Economic Model of Soil Conservation." *American Journal of*
693 *Agricultural Economics* 65(1): 83–89.
- 694 Peng, L., Q. Zhang, K. He. 2016. "Emission inventory of atmospheric pollutants from open
695 burning of crop residues in China based on a national questionnaire [Ji Yu Diao Cha De
696 Zhong Guo Jie Gan Lu Tian Fen Shao Wu Ran Wu Pai Fang Qing Dan]." *Research of*
697 *Environmental Sciences* 29(8): 1109–1118. (in Chinese)

- 698 Pittelkow, C.M, X. Liang, B.A. Linqvist, K.J. van Groenigen, J. Lee, M.E. Lundy, N. van Gestel,
699 J. Six, R.T. Venterea, and C. van Kessel. 2015. “Productivity Limits and Potentials of the
700 Principles of Conservation Agriculture.” *Nature* 517(7534): 365–368.
- 701 Qi, J., L. Zhu, L. Chen, Q. Li. 2016. “Research on the farmers’ behavior of straw processing in
702 Jiangsu, Zhejiang and Anhui [Su Zhe Wan Nong Hu Jie Gan Chu Li Xing Wei Fen Xi].”
703 *Resources Science* 38(6): 1099–1108. (in Chinese)
- 704 Rivers, D., Q.H. Vuong. 1988. “Limited Information Estimators and Exogeneity Tests for
705 Simultaneous Probit Models.” *Journal of Econometrics* 39: 347–366.
- 706 Salant, S.W. and X. Yu. 2016. “Forest Loss, Monetary Compensation, and Delayed Re-planting:
707 The Effects of Unpredictable Land Tenure in China.” *Journal of Environmental*
708 *Economics and Management* 78: 49–66.
- 709 Shon, Z.H. 2015. “Long-term variations in PM 2.5 emission from open biomass burning in
710 Northeast Asia derived from satellite-derived data for 2000-2013.” *Atmospheric*
711 *Environment* 107: 342–350.
- 712 Soule, M.J., A. Tegene, and K.D. Wiebe. 2000. “Land tenure and the adoption of conservation
713 practices.” *American Journal of Agricultural Economics* 82(4): 993–1005.
- 714 Tan, S., N. Heerink, and F. Qu. 2006. “Land Fragmentation and Its Driving Forces in China.”
715 *Land Use Policy* 23(3): 272–285.
- 716 Tao, J., L. Zhang, G. Engling, R. Zhang, Y. Yang, J. Cao., C. Zhu, Q. Wang, and L. Luo. 2013.
717 “Chemical Composition of PM2.5 in an Urban Environment in Chengdu, China:
718 Importance of Springtime Dust Storms and Biomass Burning.” *Atmospheric Research*
719 122: 270–283.
- 720 Tong, H., W. Liu. 2017. “Empirical Study on Factors of Farmers’ Straw Returning Technology
721 Adoption: Based on Survey Data of 311 Households [Nong Hu Jie Gan Huan Tian Ji Shu

- 722 Cai Na Xing Wei Ying Xiang Yin Su Shi Zheng Yan Jiu: Ji Yu 311 Hu Nong Hu De Diao
723 Cha Shu Ju].” *Rural Economy* 4: 108–114. (in Chinese)
- 724 Vella, F. 1998. “Estimating Models with Sample Selection Bias: A Survey.” *The Journal of*
725 *Human Resources* 33(1): 127–169.
- 726 Wang, J., J. Huang, L. Zhang, S. Rozelle, and H.F. Farnsworth. 2010. “Why is China's Blue
727 Revolution So Blue? The Determinants of Conservation Tillage in China.” *Journal of Soil*
728 *and Water Conservation* 65(2): 113–129.
- 729 Wang, J., X. Wang, M. Xu, G. Feng, W. Zhang, and C. Lu. 2015. “Crop Yield and Soil Organic
730 Matter after Long-term Straw Return to Soil in China.” *Nutrient Cycling in*
731 *Agroecosystems* 102(3): 371–381.
- 732 Wooldridge, J.M. 2010. *Economic Analysis of Cross Section and Panel Data*, 2nd. ed.
733 Cambridge MA: The MIT Press.
- 734 Wooldridge, J.M. 2015. “Control Function Methods in Applied Econometrics.” *Journal of*
735 *Human Resources* 50(2): 420–455.
- 736 Ye, J. 2015. “Land Transfer and the Pursuit of Agricultural Modernization in China.” *Journal of*
737 *Agrarian Change* 15(3): 314–337.
- 738 Zhang, G., F. Lu, H. Zhao, G. Yang, X. Wang, Z. Ouyang. 2017. “Residue usage and farmers’
739 recognition and attitude toward residue retention in China’s croplands [Wo Guo Nong
740 Zuo Wu Jie Gan Zi Yuan Hua Li Yong Xian Zhuang Ji Nong Hu Dui Jie Gan Huan Tian
741 De Ren Zhi Tai Du].” *Journal of Agro-Environment Science* 36(5): 981–988. (in Chinese)
- 742 Zhang, Y., X. Wang, T. Glauben, and B. Brümmer. 2011. “The Impact of Land Reallocation on
743 Technical Efficiency: Evidence from China.” *Agricultural Economics* 42(4): 495–507.

744 Zhang, W., R.S. Wilson, E. Burnett, E.G. Irwin, J.F. Martin. 2016. “What Motivates Farmers to
745 Apply Phosphorus at the “Right” Time? Survey Evidence from the Western Lake Erie
746 Basin.” *Journal of Great Lakes Research* 42(6): 1343–1356.
747

748 **Appendix 1: Translated Version of Survey Questionnaire**

749 **Survey on Farmers' Planting Behavior in Henan Province 2015**

750 _____City_____County_____Town_____Village Date_____

751 Name of interviewee_____Contact number_____ Name of interviewer_____

752

753 **A. On-farm Operation of Tillage and Straw Return in 2015**

754 **A1** In 2015, total areas of family cultivable land is _____Mu; # of plots _____; the
755 area of the biggest plot is _____Mu.

A2 Land area for each property type (Mu)	Own-contracted_____				Rented-in_____				Trusteeship_		
	Plot Index	X1	X2	X3	X4	Y1	Y2	Y3	Y4	Z1	Z2
A3 Plot area (Mu)											
A4 Contract type	NA	NA	NA	NA						NA	NA
A5 Lease term (ys)	NA	NA	NA	NA						NA	NA
Season 1: Autumn											
A6a Crop											
A7a Straw treatment											
A8a Reasons for SR adoption											
A9a Reasons for SR non-adoption											
Season 2: Winter-Summer											
A6b Crop											
A7b Straw treatment											
A8b Reasons for SR adoption											
A9b Reasons for SR non-adoption											

756 Note:

757 1. **Plot division:** Plots with the same property type and identical planted crops for both seasons is treated as
758 ONE plot (no matter whether the plot(s) is(are) connected).

759 2. **A4 Contract type:** 1=oral; 2=written.

760 3. **A6 Crop:** 0=not planted; 1=wheat; 2=corn; 3=rice; 4=soybean; 5=peanut; 6=cotton; 7=inter-planting;
761 8=others.

762 4. **A7 Straw treatment (multiple choices):**1=straw return (SR); 2=burn; 3=use as feed; 4=use as fuel; 5=for

- 763 sale; 6=discard; 7=no straw; 8=others.
- 764 5. **A8 Reasons for SR adoption (multiple choices):** 1=soil improvement; 2=fertilizer saving; 3=policy
- 765 factors; 4= increasing production/income; 5=unable to handle; 6=environmental protection; 7=others.
- 766 6. **A9 Reasons for SR non-adoption (multiple choices):** 1=affecting planting; 2=cost saving; 3=policy
- 767 factors; 4=lack of laborers; 5=lack of machinery; 6=feeling troublesome; 7= avoiding infected by pests
- 768 and diseases; 8=others.

769

770

B. Production and Operation of Crop Planting in 2015

771 **B01 Purpose of farming ()**

772 1=to increase income; 2=to hold land property; 3=to eat; 4=without other job opportunities if not

773 farming; 5=scale management; 6=others.

774 **B02 What do you think is the most currently necessary technology for farming ()**

775 1=new varieties; 2=new fertilizers; 3=new pesticides; 4=new machinery; 5=new irrigation facilities;

776 6=others.

777 **B03 What do you think is the harm of excessive use of chemical fertilizer and pesticide**

778 **()**

779 1=causing residues harmful to human; 2=soil compaction; 3=waste of resources; 4=pollution; 5=have

780 to gradually increase the input of chemical fertilizer and pesticide; 6=reducing soil fertility; 7=no

781 harm; 8=others.

782

Crop index	W1 Wheat	W2 Corn	W3 Rice	W4 Soybean	W5 Other ()
B1 Sown area (Mu)					
B2 Yield (kg/Mu)					
B3 Sale price (¥/kg)					
B4 Seed price (¥/Mu)					
B5a Base fertilizer cost (¥/Mu)					
B5b Top-dressing cost (¥/Mu)					
B6 Pesticide cost (¥/Mu)					
B7 Irritation cost (¥/Mu)					
B8 Machinery cost (¥/Mu)					
B9 Labor cost (¥/Mu)					
B10 Other cost (¥/Mu)					

783 Note:

- 784 1. In this table, only record crops that involve straw treatment; for those without straws (e.g. watermelon,
- 785 pepper, vegetables, etc.), no need to fill in.
- 786 2. B9 Labor cost: If the household hires workers at any part of the cost link (B5 – B8), count the cost as labor
- 787 cost and fill it in B9, and leave the corresponding blank (B5 – B8) empty.

C. Characteristics of Farmer Household and Members

Risk Awareness	D1 Have you bought fake fertilizers, fake seeds or fake pesticides () 0=No; 1=Yes
	D2 Do you care about new agricultural techniques or products () 0=No; 1=Yes
	D3 If there is a newly developed pesticide or fertilizer, but no one has ever used it. Will you be willing to try it () 1=Absolutely not; 2=Try in some fields; 3=Use it in all fields
	D4 Do you get relevant information of straw return through the following media? 0=No; 1=Yes a. neighbor/villager () e. radio/television media () b. relatives/friends () f. internet () c. village committee () g. other (please note _____) d. experts in agriculture ()
Household Information	D5 Total # of family members _____
	D6 Total # of family laborers _____
	D7 # of family migrant members working outside the village in 2015 _____
	D8 Average # of working (outside) months in 2015 _____
	D9 Average wages for migrant members in 2015 _____ ¥/month
	D10 Total income of migrant members in 2015 _____
	D11 Does your family have a village cadre () 0=No; 1=Yes
	D12 Does your family have a party member () 0=No; 1=Yes
	D13 Whether a basic-living-allowance family () 0=No; 1=Yes
	D14 Does your family participate in agricultural economic organization () 0=No; 1=Yes
	D15 Does your family purchase agricultural insurance () 0=No; 1=Yes
	D16 Does your family participate in land trusteeship () 0=No; 1=Yes
	D17 Is there a family member who participated in technical training () 0=No; 1=Yes
	D18 # of households with which your family often contact _____
D19 Are there any relatives who have settled down or worked in city () 0=No; 1=Yes	
D20 In 2015, the annual household income was _____ ¥, among which the crop profit was _____ ¥	
Household Head Information	D21 Gender () 0=Female; 1=Male
	D22 Age _____
	D23 Health condition () 1=Great; 2=good; 3=medium; 4=bad; 5=disabled
	D24 Years of education _____
	D25 The highest # of years of education of all your family members is _____
	D26 Farming experience _____ years

790 **Appendix 2: Additional Regression Results**

791 Table A.1 Probit Regression Results for Renters Only (Dependent: adoption=1)

Variable	(1) Base	(2)	(3)	(4)
Age	0.0297	0.0289	0.0280	0.0276
Farming experience	-0.0155	-0.0150	-0.0126	-0.0124
Risk preference	0.3962	0.4074	0.4172	0.4215
Education	0.1200**	0.1215**	0.1156**	0.1165**
Number of laborers	0.4566***	0.4500***	0.4702***	0.4654***
Income	-0.0058	-0.0039	-0.0294	-0.0269
Organization	0.8375	0.8453	0.8886	0.8883
Insurance	0.3692	0.3212	0.3770	0.3508
Plot size	0.0118	0.0093	0.0071	0.0054
July temperature	0.7747	0.7950	0.7542	0.7644
July precipitation	0.0049**	0.0050**	0.0044**	0.0045**
Winter season	0.0772	0.0609	0.0886	0.0784
Contract type		0.3711		0.2126
Term of lease			0.1109	0.1058
Intercept	-25.6801**	-26.2282**	-24.9656*	-25.2419**
Crop dummies	Yes	Yes	Yes	Yes
Observations	155	155	155	155

Note: ***, **, and * represent significance at 1%, 5%, and 10% level, respectively. Standard errors are clustered at the household level. “Contract type” is a dummy equal to unity if the lease is written (oral otherwise). “Term of lease” is a variable indicating how many years the lease covers.