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# Farmers' seed choice behaviors under asymmetrical information: Evidence from maize farming in China

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**Abstract**
Using a household survey data collected from four leading maize producing provinces in China, this paper studies the decisions of maize farmers on seed choices and variety portfolios when asymmetrical information exists in the market. Our findings indicate, while farmers generally tend to adopt new varieties with the expectation of potential higher yield, the primary driver to do so for those who have less information on seed varieties is to reduce production risk. Improving seed market management and providing more seed information to farmers would be beneficial in choosing seed varieties and maize production.

**Keywords**: new technology adoption, seed portfolio, asymmetrical information, maize

## 1. Introduction

Managing seed portfolios is a common strategy for farmers to seek for better output and cope with potential production risks. Heisey and Brennan (1991) and Traxler *et al.* (1995) found that farmers' decisions on the choice between own saved wheat seeds and higher-yield new seeds were mainly determined by the yield stability of the varieties. Barkley and Porter (1996) indicated that variety choice was endogenous with the production characteristics of each variety, such as disease resistance and yield. In addition, their decisions were significantly correlated with the farming experience and learning capacity of farmers, as well as farm characteristics and resource endowment (Smale *et al.* 1994). Bowden *et al.* (2001) and Garrett and Cox (2008) showed that farmers plant a combination of crop varieties in order to reduce production risks from unpredictable climate disasters and crop diseases. The recent study by Shi *et al.* (2013) suggested the existence of selection bias of farmers' seed choice between hybrid corn and genetically modified (GM) corn, which was influenced by the market concentration of biotech firms in US. A better understanding of farmers' decisions on seed choices is critical for promoting agricultural research and development and the extension of new seed varieties.

Understanding maize farmers' seed portfolio strategies and decisions on new seed variety adoption is essential to China. First, the average annual maize yield increase in

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China was 81 kg ha$^{-1}$ between 2001 and 2015, which was substantially low compared with the yield increase of 143 kg ha$^{-1}$ in the US and 182 kg ha$^{-1}$ in Argentina (FAO 2015; NSBC 2015). One reason for this low productivity growth is the ineffective management of China's seed market, such as the weak protection of intellectual property right (Hu *et al.* 2009). Second, maize has become China's largest stable crop in both output and sown area since 2011 due to the rising demand for forage. Whether China is able to maintain a high self-sufficiency in maize and to what extent China has to depend on the global market are both domestic and international concerns. Third, China issued its first *Seed Law* in 2000, and the tightly centralized (maize) seed markets started opening to private sectors since then, resulting in a dramatic expansion of seed industry in the country.

The booming seed industry in China coexists with serious problems of infringement of intellectual property rights on the seed. The associated authorities have been heavily criticized for being incapable of preventing fake, unexamined, uncertified, and mislabeled seeds from entering into the market (Huang *et al.* 2010). Since the implementation of China's *Seed Law* in 2000, the number of seed companies has increased to more than 5 000 in 2015, with more than a quarter specialized in maize seed production and retails (MOA 2015). However, only about one percent of those seed enterprises have the R&D capacity for breeding. A significant number of these seed companies profited only through buying validated seed brands and packing unbranded seeds for sale. This poorly regulated seed market creates many difficulties for farmers to choose varieties because of the nature of asymmetrical information between buyers and farmers.

Meanwhile, China's seed labeling system and regulations of seed market lack necessary enforcement in disclosing precise seed information on seed package. The information on seed package often fails to reflect the traits of the seeds and other required information, causing huge uncertainties and risks for seed buyers and significantly higher searching cost in seed market. Given the difficulty for farmers to figure out whether the traits of the seeds in the package are consistent with its descriptions, maize variety adoption behaviors of the farmers under the disordered seed market differ significantly from the optimal decision under the information symmetry on seed market under which they can buy the most suitable seed varieties.

In 2012, China's Ministry of Agriculture (MOA) had to start another round of reform in seed market. Significant efforts in the new reform include: to invest more on agricultural R&D, especially in biotechnology (Hu *et al.* 2012), to encourage more private sectors to participate in seed breeding, and to open the seed market to international giant seed companies (Qiu *et al.* 2013). However, to what degree the policy reform will succeed remains unclear. Studying farmers' seed choices behaviors will help better understand this and provide new insights for further reforms of seed markets.

Literature on maize farmers' seed choices in China is limited. Yuan and Yan (2009) found that farmers' maize seed choosing behavior was heavily motivated by reducing production risk. Meng *et al.* (2005) indicated that yield potential was one of the top concerns when farmers selected new seed varieties. However, none of these studies paid attention to the impacts of asymmetrical information in seed markets on farmers' seed choice behavior. Moreover, the existing studies are either largely descriptive in nature or based on small-scale samples (Fok and Xu 2011; Qiu *et al.* 2013).

Based on a recent large-scale rural household survey, this study aims to empirically investigate the effect of farmers' information and knowledge of seed on their seed choices and variety portfolios. Several important implications on China's seed market reforms and extension of seed varieties are provided. The reminder of the paper is organized as follows: Section 2 introduces the data sources and provides a brief description of the variables. Section 3 presents the model framework and model specifications, followed by section 4 reporting the empirical results, and the final two sections discusses and concludes with major findings.

## 2. Data

The data used in this study were collected by authors from four major maize production provinces (Heilongjiang, Jilin, Henan, and Shandong) in 2010. The total maize production in these four provinces alone accounts for more than half of the total maize production in China (NSBC 2011). We jointly applied a multi-stage and random cluster sampling methods for sample selection. In each province, five counties were randomly selected using a probabilistic proportion to sampling size; then two townships in each county and two villages in each township were randomly selected using the systematic sampling method based on local maize yield. In each village, we relied on the household rosters provided by village leaders to randomly choose eight households. The data used in this study contain 621 farmers from 80 villages.

The survey consists of two questionnaires, one for village leaders, and the other for selected households. In household survey, in addition to household's demographics and farming information, a special module was also designed to capture farmers' adoption of maize varieties, seed portfolios, and farmers' knowledge of seeds and seed market. The information on farmers' maize variety adoption collected covers the period from 2007 to 2010. This facilitates us to set up a four-year panel dataset on farmers' use of maize varieties by plot in the sampled households. In each sampled village, we interviewed the village leader to obtain the basic social and economic information of the village. Furthermore, the information of seed markets at the township- and county-levels were obtained by interviewing people from local seed administrative authorities, seed producing enterprises and retailers in the selected.

### 2.1. Farmers' seed variety choice

Following the studies by Bowden *et al.* (2001) and Garrett and Cox (2008), we used four measurements to represent maize farmer's decisions on variety choice behavior: (1) the proportion of land area planted with new maize varieties out of the total maize area in 2010, (2) the number of new maize varieties adopted in the year, (3) the total number of maize varieties planted by farmers in the year, and (4) the variety diversification index. This index (D) is calculated as

$$D=1-\sum_{i=1}^{n}(\frac{a_i}{A})^2,$$

Where, $n$ is the total number of varieties planted by a farmer, $a_i$ is the sown area of variety $i$ by the farmer, $A$ is the total sown area of maize by the farmer. This index ranges from zero to one. $D$ equals to zero if the farmer only plants one variety, and approaches to one when the number of varieties increases, which means that the more diversified the variety portfolio is, the larger the magnitude of the index ($D$) becomes.

Fig. 1 describes the numbers of new and old seed varieties adopted in each year from 2007 to 2010 in our sampling provinces. Both the number of new varieties and the total number of varieties being planted in each year are increasing. The average number of new maize varieties adopted by a farmer in Jilin Province was only 0.83 in 2007, and it increased to 1.66 in 2010. The rising trend of new seed varieties being adopted occurred in all of the four provinces. This is consistent with Hu *et al.* (2009)'s result that even though the Chinese technology extension system does not function well, farmers are still willing to rely on new technologies in agricultural production, including trying new seed varieties. From a regional perspective, farmers in Shandong adopted the fewest new maize varieties (less than one in every year), while those in Jilin and Heilongjiang were more willing to apply new varieties.

The total number of maize varieties planted by each household increased across all of the four provinces from 2007 to 2010. The average number increased from 1.47 in 2007 to 2.17 in 2010. In 2007, on average, farmers planted around 1.5 varieties without significant difference across regions. In the following three years, farmers in Heilongjiang, Jilin and Henan all increased the number of varieties rapidly, except in Shandong where the number just slightly increased. In 2010, there were on average 2.48 and 2.23 maize varieties being planted in each household in Jilin and Heilongjiang, which were mainly driven by the adoption of new varieties.

The average proportion of new maize variety sown area to the total maize sown area in the four provinces was 47 and 49% in 2009 and 2010, respectively (Table 1). However, it differs substantially across regions. The share of sown area of new varieties in Jilin and Heilongjiang were higher than 50% in 2009, and the number for Jilin Province even increased

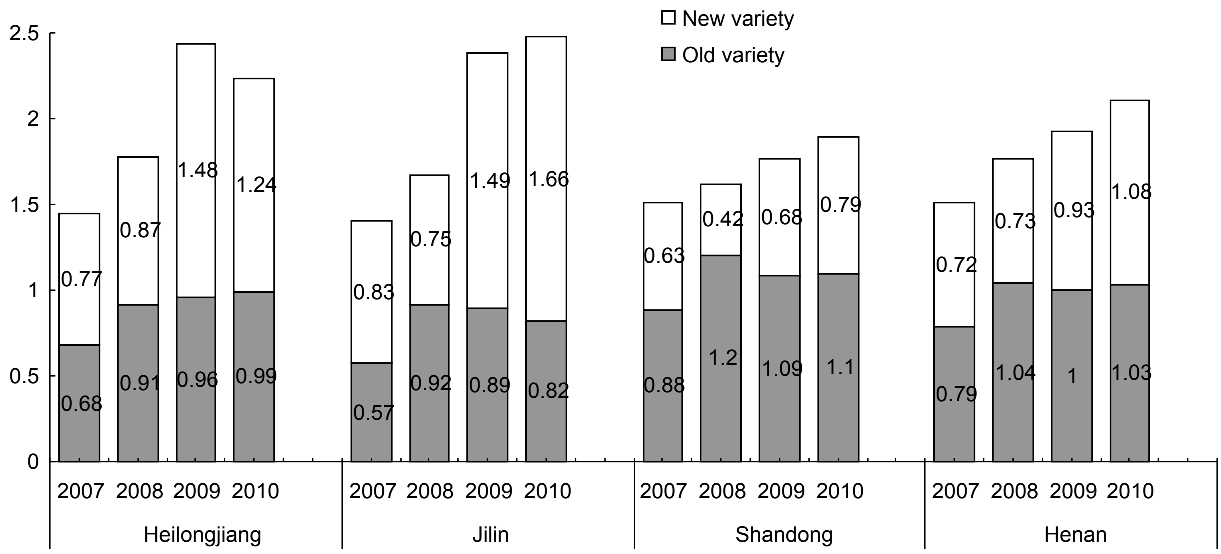


**Fig. 1** The numbers of new and old seed varieties planted by farmers in the sampled provinces, 2007–2010. Source: Authors' calculation based on survey data.

**Table 1** Proportion of new varieties area to total sown area of maize and the index of varieties diversitfication in the sampled provinces, 2009–2010

| | 2009 | 2010 |
|---|---|---|
| Proportion of new variety area to total sown area (%) | | |
| All Samples | 47 | 49 |
| Heilongjiang | 54 | 49 |
| Jilin | 58 | 62 |
| Shandong | 33 | 37 |
| Henan | 44 | 47 |
| Index of varieties diversification (0–1) | | |
| All Samples | 0.34 | 0.36 |
| Heilongjiang | 0.37 | 0.35 |
| Jilin | 0.40 | 0.40 |
| Shandong | 0.27 | 0.33 |
| Henan | 0.31 | 0.36 |

Source: Authors' calculation based on survey data. The same as below.

to 62% in 2010. While the number for Shandong was much lower, only 33 and 37% maize production area planted new seed varieties for the year of 2009 and 2010, respectively.

The indices of variety diversification are consistent with the results from the number of varieties. Table 1 indicates that on average the index increased from 0.34 in 2009 to 0.36 in 2010, mainly driven by the increases in Shandong and Henan. Even though the varieties turned to be more diversified in Jilin Province, the magnitude of the index kept constant at 0.40 during the two years.

## 2.2. Cross tabulation

The key variable of interest in this study is the degree to which the asymmetrical information exists in seed market. The labeling system of seed package in China is implemented and monitored poorly (Qiu *et al.* 2013). For example, many seed varieties have much lower germination rate than those described on the package. Other traits such as adaptation to the agricultural ecological zone differ significantly with those on the tag. The information on the tag is exaggerated. From the viewpoints of farmers, information of seed is imperfect and costly to obtain, suggesting that asymmetries of information plays an important role in determining farmers' seed choice behavior. In this disordered seed market, it is reasonable to assume that the more seed varieties in the market, the more difficulty the farmers faced to identify the accurate information about each seed variety. Thus, we measure information asymmetry in the following two ways: The first is the number of maize seed varieties in a county, which is used to measure the degree of market information asymmetry faced by farmers. China's seed market is usually based at county level, so this variable hereby can represent the macro-level domain of seed varieties for all maize farmers in the county. We hypothesize that the more seed varieties in the market, the higher degree of information asymmetry exists in the county's seed market. The second measurement is the number of selectable varieties that had ever been heard by each farmer. This variable reflects the seed domain on the farmer's radar screen. We hypothesize a significant effect of this variable on farmers' variety decisions because majority of the farmers acknowledged that the more the number of varieties that they could access to, the harder for them to distinguish the variety information from its true traits.

The average number of varieties in a county was 233 with the maximum at 353 in a county of Jilin Province and the minimum at 136 in a county of Henan Province. This suggests that the degree of market information asymmetry varies across counties. Since there was no official statistics of the actual number of varieties within a county, we obtained these data by interviewing the seed administrative officials and three seed companies in each county during the survey. The numbers used in this study are the average number of the available varieties faced by a farmer we collected from the above channels. The average number of the available varieties faced by a farmer was 34.6, that is, averagely each farmer ever heard 34.6 maize varieties.

To better understand the different decision-making behaviors of farmers in the adoption of new varieties and use of variety portfolios, we further classified the farmers into five quintiles according to their rank of the information asymmetry degree (Table 2). Apparently, the adoption of new variety and variety portfolio are positively correlated with information asymmetry degree. The more asymmetrical the market is, the more new and total varieties farmers adopt and the more variety diversification exists.

To isolate the effects of asymmetrical information in seed market on farmers' seed choices, we also control a series of farm characteristics, household characteristics as well as village features in the regressions. Variables reflecting farm characteristics in model include operating land area, number of land plots owned by the household, and a dummy variable representing the irrigation condition. Household's characteristics include family size, the proportion of off-farm labors out of total in the family, household head's education, gender, age, risk preference, household social capital, number of people attending agricultural technical training, and farming experience (years that have participated in agricultural production). Variables at village level representing village features include the proportion of non-agricultural income in total per capita net income and main soil types. The potential regional heterogeneity is captured by introducing province or township dummies. The summary statistics of other control variables are presented in Table 3.

**Table 2** Variety choices by farmers with different information asymmetry in 2010

| | New variety area proportion (%) | Number of new varieties adopted (No.) | Number of varieties adopted (No.) | Index of variety diversification (0, 1) |
|---|---|---|---|---|
| Number of county-level seed varieties | | | | |
| Quintile I | 31 | 0.72 | 1.91 | 0.31 |
| Quintile II | 48 | 1.00 | 2.02 | 0.34 |
| Quintile III | 55 | 1.18 | 1.97 | 0.31 |
| Quintile IV | 39 | 1.02 | 2.10 | 0.35 |
| Quintile V | 73 | 1.95 | 2.75 | 0.47 |
| Number of selectable varieties that farmers face (No.) | | | | |
| Quintile I | 35 | 0.70 | 1.77 | 0.28 |
| Quintile II | 46 | 1.07 | 2.11 | 0.35 |
| Quintile III | 47 | 1.13 | 2.16 | 0.36 |
| Quintile IV | 53 | 1.34 | 2.33 | 0.39 |
| Quintile V | 64 | 1.62 | 2.35 | 0.42 |

**Table 3** Variable description and summary statistics

| | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| Dependent variables | | | | |
| The proportion of new variety area to total areas (0–1) | 0.49 | 0.42 | 0 | 1 |
| Number of new varieties adopted in 2010 (No.) | 1.17 | 1.13 | 0 | 8 |
| Number of varieties adopted in 2010 (No.) | 2.15 | 1.16 | 1 | 9 |
| Index of variety diversification (0–1) | 0.36 | 0.27 | 0 | 0.88 |
| Independent variables | | | | |
| Key variables | | | | |
| Number of county-level seed varieties (No.) | 233 | 118 | 50 | 500 |
| Number of selectable varieties that farmers face (No.) | 34.57 | 30.84 | 5 | 250 |
| Land features | | | | |
| 2009 operating land area (mu) | 26.43 | 32.43 | 1 | 244.5 |
| Number of land parcels (No.) | 4.54 | 3.53 | 1 | 30 |
| Whether irrigation can be realized or not (1=Yes, 0=No) | 0.65 | 0.48 | 0 | 1 |
| Household characteristics | | | | |
| Population scale (person) | 4.26 | 1.47 | 1 | 9 |
| Proportion of non-agricultural labors (%) | 35.1 | 32.02 | 0 | 100 |
| Length of education (year) | 7.03 | 2.62 | 0 | 13 |
| Gender (1=Male, 0=Female) | 0.84 | 0.37 | 0 | 1 |
| Age (year) | 49.09 | 9.9 | 20 | 76 |
| Farmers' social capital and experience | | | | |
| Social capital (1=Yes, 0=No) | 0.09 | 0.29 | 0 | 1 |
| Number of agricultural technical training participants (No.) | 0.36 | 0.58 | 0 | 4 |
| Planting experience (year) | 28.17 | 11.17 | 0 | 57 |
| Village characteristics | | | | |
| Proportion of non-agricultural income in net income per capita (%) | 43.30 | 20.45 | 5 | 80 |
| Main soil types of the village (1=Sand soil, 0=Others) | 0.30 | 0.46 | 0 | 1 |

## 3. Model framework

### 3.1. Theoretical model

The farmers' decision on whether to adopt new seed variety and change variety portfolio are determined by the utility of farmers expected to achieve by that decision. The decision rule of seed selection and variety portfolio can be expressed as:

$$y_i=f(I_i, X_i, \xi_i) \tag{1}$$

Where, $y_i$ denotes the $i$th farmer's decisions on seed choices; $I_i$ is an indicator to measure market information asymmetry the farmer faces; $X_i$ is a vector of exogenous variables that describe the household characteristics, as well as village features; $\xi_i$ is the error term.

### 3.2. Model Specification

In this study, four measurements are used to represent maize farmer's decisions on variety choice behaviors: (1) the proportion of land area planted with new maize varieties out of the total maize area in 2010 (heretofore refer to as Model 1), (2) the number of new maize varieties adopted in the year (Model 2), (3) the total number of maize varieties planted by farmers in the year (Model 3), and (4) the variety diversification index (Model 4). Model 1 and model 4 are specified as Tobit model because of censored samples. For model 1, about one third of the surveyed farmers did not plant any new varieties in the survey year, resulting in a corner optimization. For model 4, the domain for the diversification index ranges from 0 to 1, suggesting a two-side censoring problem. In empirical studies, statistical estimation procedures that do not account for the censoring problem could lead to biased and inconsistent parameter estimates (Wooldridge 2002). Tobit model is developed for this problem (Tobin 1958), and the model can be expressed as:

$$y_i=\begin{Bmatrix} y_i^*=\mathbf{x}_i\boldsymbol{\beta}+\varepsilon_i^* \\ 0 \end{Bmatrix} \text{if} \begin{cases} y_i^*>0 \\ y_i^*\leq 0 \end{cases} \quad (2)$$

Where, $y_i^*$ is a latent variable, $x_i$ denotes a vector of explanatory variables, which include $I$ and $X$ listed in equation (1).

Following Greene (2008), we specify model 2 and model 3 as Negative Binomial Model (NBM) because both the number of new varieties and total varieties adopted by farmers are typically count data. Compared with the traditionally used Poisson regression model for count data, NBM does not need the strong assumption of equidispersion. The explanatory variables are the same as models 1 and 4. Given the control variables are only collected for year 2010, we only use the 2010 data to estimate the above four models.

## 4. Empirical results

The estimated results are presented in Tables 4 and 5. Maximum likelihood techniques are used for these estimations. The likelihood ratio test and $\chi^2$ statistics indicate that the models are fitted well. Most coefficients are statistically significant with expected signs.

The estimated parameters of variables reflecting the degree of information asymmetry are positive and statistically significant in model 1 and model 2. The results of model 1 show that the market information asymmetry has a significantly positive impact on the adoption of new seed varieties. The more asymmetrical the market is, the larger share of total maize producing area that new varieties is allocated, and the more new varieties are adopted. The results from model 2 may indicate that in seed market with asymmetrical information farmers expand the share of cultivated area for new variety and adopt more new varieties to increase the expected profit. This is not surprising that given new varieties are commonly expected or at least advertised to have higher yield potential than old varieties.

Moreover, the estimated results from model 3 and model 4 indicate that the information asymmetry also has significant and positive impacts on the total number of varieties planted and variety diversification. These results indicate that maize farmers are not only planting significantly more number of varieties as the degree of information asymmetry increases, but also are more likely to diversify their seed varieties which can be seen as a reasonable choice to reduce their production risks. These results based on econometric analysis are consistent with the above descriptive analysis.

In addition, the operating land area has a significantly positive impact on the adoption of new seed varieties in the cultivated area. Male and older farmers are more conservative in using new seed varieties (Table 4). Variety portfolio is also positively influenced by land resource endowment measured by cultivated area and number of land plots (Table 5). Farmers with more agricultural land endowment and more land plots are more likely to diversify their variety portfolios. The negative and statistically significant coefficient on gender indicates that male head households are less likely to diversify variety in production.

## 5. Discussion

Understanding the impact of market information asymmetry on farmers' new agricultural technology adoption is of importance for agricultural technology extension. Using a survey data from four major maize producing provinces in China in 2010, we estimated the effects of asymmetrical market information on farmers' maize variety choosing behaviors and their willingness to adopt new technology. We found that market information asymmetry has significant impact on farmers' seed variety choices. When market information on the attributes of seeds is missing, farmers tend to use two strategies to maximize profit and minimize risk in production: increase new varieties and allocate more land to varieties for a higher output potential, and diversify seed varieties to reduce production risk.

Higher and sustainable yield could be achieved through technology improvement. New seed varieties normally represent new generation technologies, and thus the average yield of new varieties is expected to be higher than that of the old ones. Our study showed that in markets lacking seed variety information, farmers are likely to increase the number of new varieties and the share of planted area for new seed varieties to achieve a higher yield. However, this also implies that market information asymmetry makes farmers to have less incentive to centralize land allocation for high yielding new varieties, which in practice will have

**Table 4** Estimations of factors influencing the new variety choice of farmers

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | New variety area proportion (Tobit, d*y*/d*x*) | | Number of new varieties (NBM, d*y*/d*x*) | |
| Key variables | | | | |
| Number of county-level seed varieties (no.) | 0.001*** | | 0.002*** | |
| | (2.855) | | (3.845) | |
| Number of selectable varieties that farmers face (no.) | | 0.001** | | 0.003** |
| | | (2.370) | | (2.360) |
| Land features | | | | |
| 2009 operating land area (mu) | –0.002** | –0.000 | 0.001 | 0.004** |
| | (–1.954) | (–0.221) | (0.848) | (2.187) |
| Number of land plots (no.) | –0.008 | –0.007 | 0.011 | 0.009 |
| | (–1.259) | (–1.068) | (0.856) | (0.622) |
| Whether irrigation can be realized or not(1=yes, 0=no) | –0.019 | 0.042 | –0.021 | –0.027 |
| | (–0.382) | (0.695) | (–0.179) | (–0.190) |
| Household characteristics | | | | |
| Population (person) | 0.021* | 0.008 | 0.085*** | 0.058** |
| | (1.707) | (0.699) | (2.957) | (2.028) |
| Proportion of non-agricultural labors to total labors (%) | –0.001** | –0.001** | –0.002 | –0.002 |
| | (–2.097) | (–2.258) | (–1.177) | (–1.628) |
| Length of education (year) | –0.000 | 0.007 | 0.011 | 0.020 |
| | (–0.055) | (0.958) | (0.656) | (1.207) |
| Gender (1=male, 0=female) | –0.161*** | –0.162*** | –0.461*** | –0.292** |
| | (–3.221) | (–3.145) | (–3.184) | (–2.103) |
| Age (year) | –0.003 | –0.006* | –0.008 | –0.012 |
| | (–0.800) | (–1.923) | (–0.950) | (–1.479) |
| Social capital and experience | | | | |
| Social capital (1=yes, 0=no) | 0.019 | 0.003 | –0.074 | –0.096 |
| | (0.308) | (0.048) | (–0.535) | (–0.725) |
| Number of agri. technical training participants (no.) | 0.012 | –0.008 | 0.050 | 0.003 |
| | (0.399) | (–0.250) | (0.693) | (0.036) |
| Planting experience (year) | 0.003 | 0.007** | 0.011 | 0.013* |
| | (1.171) | (2.368) | (1.393) | (1.717) |
| Village-level features | | | | |
| Share of non-agri. income in net per capita income (%) | –0.001 | –0.003** | –0.001 | –0.010*** |
| | (–1.266) | (–2.018) | (–0.298) | (–2.616) |
| Man soil types of the village (1=sand soil, 0=otherwise) | 0.079* | 0.057 | 0.033 | 0.024 |
| | (1.924) | (0.977) | (0.330) | (0.172) |
| Regional dummy variables | Province | Town | Province | Town |
| Likelihood ratio test $\chi^2$ statistics | 71.9*** | 176.0*** | 100.9*** | 206.5*** |
| No. of observations | 621 | 621 | 621 | 621 |

*z*-statistics in the brackets. ***, **, * denote 1, 5 and 10% significance level, respectively. The same as below.

negative effect on yield increase.

## 6. Conclusion

This paper shows that seed information asymmetry has significant impact on farmers' selection of new seed varieties. Farmers often cannot obtain complete information of the seeds they are screening. As a result, they have little chance to get the most suitable seeds. So, making farmers easily get more accurate seed information is important for farmers to choose the appropriate seed varieties.

The results show that farmers adopt more new varieties under market information asymmetry than their best choice under information symmetry. It should be noted that farmers' profit in agricultural production is not necessarily increased with the more varieties they adopt or the larger area of the new varieties they cultivated. Theoretically the decision-making of farmers is optimal under the fully adequate information. However, it does not mean the more profit made, the more varieties the farmers adopted or the larger area of the new varieties the farmers cultivated. The adoption of more new varieties also suggests that farmers cannot better use land endowment to achieve profit maximum under the certain risk. Actually, under asymmetrical information condition, farmers' choice of varieties deviates from the choice of their optimal decision and hence making

**Table 5** Estimations of factors influencing farmers' variety portfolio

| | Model 3 | | Model 4 | |
|---|---|---|---|---|
| | Number of varieties (NBM, dy/dx) | | Index of variety diversification (Tobit, dy/dx) | |
| Key variables | | | | |
| Number of county-level seed varieties (no.) | 0.003*** | | 0.001*** | |
| | (3.474) | | (4.063) | |
| Number of selectable varieties that farmers face (no.) | | 0.002 | | 0.001* |
| | | (1.034) | | (1.913) |
| Land features | | | | |
| 2009 operating land area (mu) | 0.006*** | 0.008*** | 0.001 | 0.001** |
| | (2.717) | (3.087) | (1.561) | (2.025) |
| Number of land parcel (no.) | 0.040** | 0.025 | 0.012*** | 0.012*** |
| | (2.199) | (1.141) | (3.167) | (2.615) |
| Whether irrigation can be realized or not (1=yes, 0=no) | –0.122 | –0.183 | –0.005 | –0.023 |
| | (–0.708) | (–0.814) | (–0.153) | (–0.569) |
| Household characteristics | | | | |
| Population (person) | 0.080** | 0.067 | 0.012 | 0.009 |
| | (1.967) | (1.572) | (1.516) | (1.191) |
| Proportion of non-agricultural labors to total labor (%) | –0.000 | –0.002 | –0.000 | –0.000 |
| | (–0.168) | (–0.768) | (–0.332) | (–1.078) |
| Length of education (year) | 0.021 | 0.023 | 0.008 | 0.007 |
| | (0.864) | (0.918) | (1.590) | (1.445) |
| Gender (1=male, 0=female) | –0.429** | –0.210 | –0.127*** | –0.104*** |
| | (–2.268) | (–1.068) | (–3.843) | (–3.062) |
| Age (year) | –0.008 | –0.010 | –0.001 | –0.001 |
| | (–0.711) | (–0.797) | (–0.282) | (–0.385) |
| Social capital and experience | | | | |
| Social capital (1=Yes, 0=No) | –0.061 | –0.081 | 0.007 | –0.006 |
| | (–0.302) | (–0.389) | (0.169) | (–0.153) |
| Number of agri. technical training participants (no.) | 0.099 | 0.050 | 0.006 | 0.000 |
| | (0.951) | (0.446) | (0.285) | (0.018) |
| Planting experience (year) | 0.012 | 0.011 | 0.002 | 0.002 |
| | (1.167) | (1.023) | (1.222) | (1.159) |
| Village-level features | | | | |
| Share of non-agri. income in net per capita income (%) | –0.001 | –0.016*** | 0.000 | –0.003*** |
| | (–0.167) | (–2.883) | (0.726) | (–3.504) |
| Main soil types of the village (1=sand soil, 0=otherwise) | –0.129 | –0.068 | 0.007 | 0.021 |
| | (–0.943) | (–0.337) | (0.244) | (0.558) |
| Regional dummy variable | Province | Town | Province | Town |
| Likelihood ratio test $\chi^2$ value | 63.9*** | 116.0*** | 68.8*** | 173.2*** |
| No. of observation | 621 | 621 | 621 | 621 |

them a net loss. Given the uncertainty of the new varieties within China's disordered seed market, the expanded area of the new varieties leads to the higher risk in production as the yield of old varieties were expected.

Two suggestions are recommended to address this issue. First, improve seed market supervision and regulation. Specifically, a standardized labeling on seed packages which requires accurate information on variety characteristics, more information, such as the specified region suitable for plantation and the potential drawbacks of the variety, should be established and enforced to be added on the package. The government should strictly forbid seed companies of false propaganda. Second, a more efficient and effective agricultural extension system is under call to make farmers access to the information of new varieties more easily and less costly. The public sectors should provide more information on new varieties and extend the technology to farmers to improve the disadvantageous status of farmers under the information asymmetry and facilitate them to make the optimal decision in choosing the new varieties.

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## References

Barkley A P, Porter L L. 1996. The determinants of wheat variety selection in Kansas, 1974 to 1993. *American Journal of Agricultural Economics*, **78**, 202–211.

Bowden R, Shroyer J, Roozeboom K, Claassen M, Evans P, Gordon B, Heer B, Janssen K, Long J, Martin J, Schlegel A, Sears R, Witt M. 2001. Performance of wheat variety blends in Kansas. In: *Keeping up with Research No.128*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, Kansas.

FAO (Food and Agriculture Organization of UN). 2015. FAOSTAT. [2015-2-10]. http://faostat3.fao.org

Fok M, Xu N. 2011. Variety market development: A Bt cotton cropping factor and constraint in China. *AgBioForum*, **14**, 47–60.

Garrett K A, Cox C M. 2008. Applied biodiversity science: Managing emerging diseases in agriculture and linked natural systems using ecological principles. In: Ostfeld R, Keesing F, Eviner V, eds., *Cary Conference XI*: *Infectious Disease Ecology: The Effects of Ecosystems on Disease and of Disease on Ecosystems*. Princeton University Press, Princeton, New Jersey. pp. 368–386.

Greene W. 2008. Functional forms for the negative binominal model for the count data. *Economics Letters*, **99**, 585–590.

Heisey P, Brennan J P. 1991. An analytical model of farmers' demand for replacement seed. *American Journal of Agricultural Economics*, **73**, 1044–1052.

Huang J, Xu Z, Hu R, Zhang S. 2010. China's seed industry: achievement, challenges, and future development strategy. *Agricultural Economics and Management*, **3**, 21–25. (in Chinese)

Hu R, Cai J, Huang J, Wang X. 2012. Silos hamstring Chinese plant biotech sector. *Natute Biotechnology*, **30**, 749–750.

Hu R, Yang Z, Kelly P, Huang J. 2009. Agricultural extension system reform and agent time allocation in China. *China Economic Review*, **20**, 303–315.

Meng X, Rai J, Ye J. 2005. Factors in determine farmers adoption of new seed varieties. *Journal of Agrotechnical Economics*, **1**, 20–26. (in Chinese).

MOA (Ministry of Agriculture of China). 2015. *Crop Seed Industry Development Report in China*. China Agriculture Press, Beijing.

NSBC (National Statistical Bureau of China). 2011. *China Statistical Yearbook*. China Statistic Press, Beijing, China. (in Chinese)

NSBC (National Statistical Bureau of China). 2015. *China Statistical Yearbook*. China Statistic Press, Beijing, China. (in Chinese)

Qiu H, Xu Z, Cai Y. 2013. *China's Seed Market*, *Policy and International Comparison Analysis*. China Science Press, Beijing, China. (in Chinese)

Shi G, Chavas J, Lauer J, Nolan E. 2013. An analysis of selectivity in the productivity evaluation of biotechnology: An application to corn. *American Journal of Agricultural Economics*, **95**, 739–754.

Smale M, Just R E, Leathers H D. 1994. Land allocation in HYV adoption models: An investigation of alternative explanations. *American Journal of Agricultural Economics*, **76**, 535–546.

Tobin J. 1958. Estimation of relationships for limited dependent variables. *Econometrica*, **26**, 24–36.

Traxler G, Falck-Zepeda J, Sayre K. 1995. Production risk and the evolution of varietal technology. *American Journal of Agricultural Economics*, **77**, 1–7.

Wooldridge J. 2002. Econometric *Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, Massachusetts. p. 752.

Yuan J, Yan L. 2009. Factors in affecting farmers' acceptance of new bi-breed maize varieties. *Anhui Agricultural Scinece*, **14**, 6651–6652. (in Chinese)

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