Extended Abstract
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Paper/Poster Title	Adoption of multiple soil fertility management practices and its impact on farm performance in Rural China

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Abstract	*200 words max*

The adoption of soil fertility management practices (SFMPs) has become an important issue in the development economies, especially as a way to tackle land degradation, erosion and low agricultural productivity. This study analyses the factors that facilitate or impede the probability and extent of adoption of multiple SFMPs as well as the performance effects, using a farm survey data of 773 vegetable producers in rural China. Multivariate and ordered probit models are applied to the modelling of adoption decisions by farm households facing multiple SFMPs, which can be adopted in various combinations. Multinominal endogenous switching regression model is used to investigate the impact of SFMPs adoption on farm productivity. The results show that: (1) the adoption of straw returning and advanced irrigation have substitution effect, and subsoiling practice is significant correlated to straw returning and soil testing; (2) both the probability and the extent of adoption of SFMPs are influenced by many factors: household's education, cadre membership, cooperative and training participation, social capital and individual awareness; (3) farms' productivity is increasing with the intensive adoption of SFMPs. These results imply that policy-makers should seek to promote local institutions and training providers, increase household education and awareness, and strengthen social networks in order to improve the adoption of SFMPs.

Keywords	soil fertility management; multivariate probit; multinominal endogenous switching regression, simultaneous adoption
JEL Code	Q1, Q16, Q18

Introduction	*100 – 250 words*

The pressure on land resources in the world is currently enormous, and developing countries in particular are facing serious challenges. China, with high population pressure and small landholding per capita, has paid much attention in recent years on the adoption of soil fertility management practices (SFMPs) to tackle land degradation, erosion and low agricultural productivity. This study analyses the factors that facilitate or impede the probability and extent of adoption of multiple SFMPs as well as the performance effects, using a farm survey data of 773 vegetable producers in rural China. We include four practices including advanced irrigation, subsoiling, strawing retuning and soli testing. It is crucial to know what the adoption pattern of SFMPs in rural China and if the current SFMPs enhance or threaten the productivity of land use.

The contributions of our article to the empirical literature are as follows. First, the adoption of multiple SFMPs in the farming context, ranging from livestock to food, are well studied, but research on vegetable production is, in general, scarce. This study attempts to close this gap. Second, instead of roughly classifying SFMP-adopters, we consider the nature of interrelationships among the set of practices, and jointly analyze farmers' decision to adopt multiple SFMPs and help policy-makers and development practitioners to define their strategies for promoting agricultural practices. Third, a more specific comparison of technical efficiencies between SFMPs adopters of different extent and non-adopters provides new evidence for our understanding of the impact of SFMPs on farm performance.

Methodology $\qquad$ *100 – 250 words*

Farmers face multiple SFMPs which can be adopted in various combinations, and their adoption decision is not randomly assigned, which may be influenced by both observed and unobserved factors (for example, motivation, self-control, and preference). Inclusion of observed variables in the analysis and model specification are primarily based on theoretical frameworks and past empirical adoption literature. To allow for the potential endogeneity associated with unobserved heterogeneity and simultaneous adoption decisions, our empirical framework includes three parts: first, farmers' choice of interrelated SFMPs is modelled using a multivariate probit model and the determinants of the extent of combinations of SFMPs adopted are investigated in an ordered probit model. Second, to explore the impact of SFMPs adoption on farm productivity, we apply multinominal endogenous switching regression model following Dubin and McFadden (1984) and Bourguignon et al. (2007) to correct selection bias, which holds the explanatory variables and the error term uncorrelated and lead to unbiased results. In the third stage, we estimate the average treatment effect (ATT) of SFMPs adoption on farms' productivity by comparing the actually observed outcomes and their respective counterfactual expected outcomes between non-adopters and adopters.

Results $\qquad$ *100 – 250 words*

Of the 773 farms considered in the analysis, about 77.1% benefited from one or more SFMPs although all four SFMPs were applied in only 11 farms. Advanced irrigation is the most common SFMP used by the sample households and its adoption has substitution effect with straw returning. Subsoiling practice is significant correlated to straw returning and soil testing, suggesting that adoptions of SFMPs are interrelated.

Probability and extent of adoption of SFMPs are influenced by several factors: householder educational level, and cadre membership in the village are the important household characteristics variables that have high impacts on adoption of SFMPs; The significant role of cooperative participation, and training assistance in practice adoption suggests more accessible information enhance the adoption of SFMPs; farmers with higher social capital are more likely to adopt most practices; individual awareness and attitude to practice adoption play important roles in a household's decision to adopt SFMPs.

Compared with the mean difference of technical efficiency between the SFMPs adopters and non-adopters, the positive and significant statistics of ATT reveal that farms with SFMPs are

more efficient than traditional farms in vegetable production and productivity is increasing with the intensive adoption of SFMPs. Specifically, one-practice adopters would reduce efficiency in vegetable production by 0.03 if they had not adopted. Efficiency would shrink by 0.1 when switching from two-practice adoption to traditional production. The three-practice and four-practice adopters would have a score of 0.15 and 0.14 lower respectively if without any practice adoption. Overall, the findings emphasize the importance of the adoption of SFMPs among farmers as a means of improving the soil fertility and farm productivity.

Discussion and Conclusion	*100 – 250 words*

This study uses vegetable growers' data to analyze the adoption of SFMPs and its impact on farms' efficiency in China. We adapt multivariate probit model and endogenous switching regression framework to correct for selection bias and endogeneity originating from both observed and unobserved heterogeneity in the comparison of different combinations of SFMPs and traditional farms in vegetable production. The results reveal that there are strong complementarities and substitutabilities between different SFMPs adoption. Meanwhile, we find that, on average, vegetable farms with SFMPs adoption are better than traditional farms in terms of economic performance. Moreover, householder educational level, cadre membership, cooperative participation, training assistance, social capital, and individual awareness and attitude to practice adoption are tested to promote SEMPs adoption.

These results imply that policy-makers should seek to promote local institutions and training providers. Services such as cooperative organizations or agricultural experts could be established to provide farming guidance. The relevant agricultural policies could be more strongly oriented toward education provided for farmers, by means of training, consulting, and problems solving. ICT and other social media could be vigorously carried out into publicity and education activities on soil fertility management to enhance the enthusiasm of farmers to participate in SFMPs adoption. it is also suggested to provide aid or subsidies of soil fertility management practices by government and international organizations to vegetable farmers.

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