Extended Abstract
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Paper/Poster Title	Adoption of farm management practices and its impact on crop productivity in Central Asia: an analysis accounting for unobserved heterogeneity and self-selection bias.

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Abstract	***200 words max***

One of the key barriers to increasing agricultural productivity and boosting farm incomes in developing countries is a low rate of adoption of efficient Farm Management Practices (FMPs) and poor diffusion of the latest agricultural innovations. Farmers` crop production technology relies on the simultaneous adoption of several farm management practices that improve the welfare of farmers. Examining the agricultural technology adoption in Central Asia through the lens of a combination of several FMPs, we analyse the impact of the bundle of production technologies on farmers' welfare and investigate the factors that determine the adoption of different levels of FMPs. Using household-level cross-sectional data from Central Asia, this is one of the few empirical analyses to account for crop technology heterogeneity (based on farmers` adoption behaviours) in explaining technology adoption decisions in a developing economy context and understanding farmers` behaviour in choosing different intensities of FMPs that drive their crop production technologies. We found two classes of farmers with distinct preferences for using FMPs and explain their selection decision accounting for self-selection bias. The classes were significantly different in terms of household socio-economic and farm characteristics. The analysis further shows that intensive technology class achieve higher productivity rates using production recourses more efficiently.

Keywords	e.g. farm management practices, production technology heterogeneity, self-selection bias, crop productivity
JEL Code	O3 Innovation; Research and Development; Technological Change; Intellectual Property Rights; O33 Technological Change: Choices and Consequences; Diffusion Processes see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The world has entered a new phase of the agricultural transition age that has evolved from being very homogeneous to one with dramatic differences in terms of farm scale, crop production technology and market orientation. The notion of an “average-sized” farm can no longer be applied to represent farming entities that capture their

economies of size. Smaller farms have continuously been growing in its relative share of all farm operations in developing countries. Most notably, farm structure is particularly being differentiated due to level of exposure to modern agricultural technological innovations and technical advances, which make it possible to supply foods with the desired quality attributes for the domestic and international markets. Therefore, significantly growing heterogeneity in farming practices is complicating understanding farmers` decision-making behaviours during the assessment of farmers` well-being. The evidence suggests that improved agricultural technologies should be used in multiple combinations and the maximum potential can only be realized when these technologies are adopted with other complementary inputs (Asfaw et al., 2012; Biru et al., 2020; Kassie et al., 2015; Marenya et al., 2020; Spielman et al., 2010). Unlike the standard technology adoption models applied for exploring the probability of adopting an improved technology or not, our mission goes beyond that and attempts to understand the intensity of crop production technology. The objectives of this study are twofold: (i) to explore the heterogeneity in preferences for integrated farm management practices (IFMP) and identify the factors that contribute to those preferences; (ii) to estimate the adoption decisions of a farmer for adopting an intensive IFMP by controlling for observable (e.g., farmer and farm characteristics) and unobservable (e.g., motivation, managerial skills, and land quality) factors. We aim to identify the patterns of the best performing practices that can bring about farmers` well-being in terms of farm productivity and income level, and through this, suggest policy incentives to adopt the best management practices for weaker farmer segments.

Methodology	***100 – 250 words***

To capture FMPs, we construct mutually exclusive groups of homogenous production technologies based on the package of management and agronomic practices using Latent Class Analysis (LCA) model. The LCA, which is a relatively novel cluster analysis approach, is used to identify distinct homogenous subsets of farmers, which have a varying choice of technology preferences as well as diverse household and institutional characteristics affecting the choice of a particular pattern of IFMPs. Few studies (Jaeck and Lifran, 2014; Maligalig et al., 2021; Schlecht and Spiller, 2012) acknowledged the significance of accounting for heterogeneity in farmer preferences to find holistic approaches to improve the well-being of farmers and introduce targeting tailored agricultural policies.

Based on a two-stage procedure, our study is the first to suggest applying the combination of Latent Class Analysis (LCA) for addressing technology heterogeneity in the first stage, and estimating the Endogenous Switching Regression (ESR) model in explaining farmers` technology preferences for the second-stage analysis. In exploring the adoption decisions of a farmer for a particular IFMP class of farmers, we

account for self-selection bias due to both observable and unobservable factors using an Endogenous Switching Regression (ESR) model (Lokshin and Sajaia, 2004) for the continuous and ordered outcomes of farm productivity and net income, respectively. The ESR further allows the calculation of different treatment effects parameters such as average treatment effects (ATE), average treatment effects on the treated (ATT), and average treatment effects on the untreated (ATUT).

Results	***100 – 250 words***

We used the LCM framework to evoke farmers` preferences for the attributes of the crop-based intensification systems and the trade-offs between the attributes to better examine the determinants of adoption decisions. Having rationed on several facts, we concluded that a two-class model (labelled as intensive and less-intensive FMPs classes) performs better than a three-class model using LCA. The tests show that the differences between the classes were statistically significant, evidencing that Central Asian agriculture, as been expected, is exceedingly heterogeneous in applied crop production and farm management technologies. Even though farm size is a key differentiator, the differences between the examined classes did not solely arise from these disparities; this means the homogenous technology groups could not be established along the lines of the conventional classification of small and large-scale farms. The farmers also differ in their use of external factors and production intensity. In this paper, intensive crop technology use refers to the use of intercropping (diversification), farm size scale, fertilizing rate, capital intensity, soil fertility scores as well as integrated agronomic practices such as intensity of receiving extension advice and application of irrigation techniques.

The adoption decisions are likely to be endogenous to outcomes. The full information maximum likelihood estimator is used to estimate the selection and outcome equations jointly. The selection and outcome equations are correlated according to the results of the likelihood ratio test evidencing that it is appropriate to estimate selection and outcome equations jointly. The selection of instruments in this study, namely *distance to a district`s administrative centre* and *market distance*, is guided by economic theory and empirical studies.

Discussion and Conclusion	***100 – 250 words***

Identifying and describing the predominant farming styles within a group of farmers has been effective to target subsets of farmers who can encourage the widespread adoption of the best management practices. Characterizing farming styles or subcultures based on the diversity of farm management practices as well as understanding the heterogeneity in farmers' preferences for technology adoption are still key issues in the literature. Therefore, it is important to investigate and assess the extent to which farmers in developing countries have adopted improved agricultural technologies under farm heterogeneity and information asymmetry. We believe that understanding farmers` management strategies towards the adoption of

new technologies can have a positive impact on initiating and effectively implementing relevant group-oriented development programs in the future, which better reflect farmers' needs. The patterns of crop management intensification are first examined through a combination of different crop production technologies, and the microeconomic model of adoption of integrated farm management practices (IFMPs) is introduced. To capture IFMPs, we construct mutually exclusive groups of homogenous production technologies based on the package of management and agronomic practices using Latent Class Analysis (LCA) model. To further reduce the endogeneity arising from self-selection process, we used the ESR model to calculate the treatment effect of intensive farm management practices on crop productivity.