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Impact of farmland characteristics on grain costs and benefits in the North China Plain

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ABSTRACT

Land characteristics in general and socio-economic characteristics in particular are assumed to play important roles in the determination of grain costs and benefits. This study explores the effects of farmland characteristics on grain costs and benefits using a multilevel linear model. The data refer to 1282 grain plots of 566 grain producers in the provinces of Henan, Shandong, and Anhui in the North China Plain. The results show that the coefficients of the variables used to measure plot size and tenure insecurity have different values and signs for households with different grain planted areas. It can be concluded that the effects of plot size and ratio of rented land are closely related to farmers' total grain planted area, and only farmers with grain areas below 1.33 ha can achieve economies of scale. The effects of tenure insecurity of rented land on grain costs and benefits were negative, but the values became smaller and insignificant when farmers' total grain area was sufficiently large. Regarding farmland bio-physical characteristics, farmers obtain more profit from plots with water conservancy facilities and have to invest more in poor land, with no output increments.

1. Introduction

As food security is closely related to the sustainable development of a country's economy and national security (Li et al., 2017), no country can afford to ignore this problem, regardless whether it is a developing country such as South Africa (Holden and Otsuka, 2014) or a developed one such as Japan (Ito et al., 2016). The United Nations puts food security at the front and center of the global agenda (United Nations, 2015). High dependence on imports exposes a country to international market shocks, which may pose serious risks for food security as well (Koirala et al., 2016). As such, the food self-sufficiency rate is highly emphasized in numerous countries.

Considering farmers' land performance in grain production as the micro-foundation of food self-sufficiency rate, policies regarding the determinants of land performance could be emphasized to achieve food security. Farmlands are becoming increasingly important for humankind within the production function (Liu et al., 2017) and farmland characteristics, including bio-physical and socio-economic factors, influence the land performance of grain production significantly. Farmers make investment decisions based on both natural conditions and the socio-economic factors of their farmland, within a complex influencing mechanism (Tan, 2014). The bio-physical conditions of farmland include terrain, slope length, soil structure, water facilities, and other natural characteristics, while the socio-economic factors are rather related to human activities such as land tenure, poverty, labor availability, and economic incentives. Therefore, it is of great importance to explore the impact of land characteristics on grain production comprehensively.

During the past decades, the role of farmland bio-physical characteristics has been endorsed by most scholars in this field. For example, land degradation reduces crop yields (den Biggelaar et al., 2004) and factors such as labor quality and road density pose less constraints for poorly endowed countries than for those with better soil and climate (Wiebe, 2003a). However, the main reason shaping these relationships lies on farmers' decision (Wiebe, 2003b). Recently, research on socio-economic factors has drawn increasing attention, and studies started to explore the relationship between farmland characteristics and land performance from perspectives of farm size, tenure security, among others.

Scholars have focused on the reverse relationship between farm size and land productivity ever since it was first identified by Sen (1966). A common empirical finding is that smaller farms achieve higher productivity than larger ones in low-income or developing countries (Rada and Fuglie, 2018). Additionally, small farms appear to have lower inefficiencies than large ones due to small farmers' more efficient use of inputs (Ma et al., 2015). However, a low machinery level of smallholder

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farms can inhibit the application of precise fertilization technologies and scientific management (Wang et al., 2015; Ju et al., 2016). If so, a higher efficiency would be expected when farm size increases. With economic and market growth, the inverse relationship between farm size and land productivity disappeared in many countries such as Vietnam (Liu et al., 2016), India (Manjunatha et al., 2013), Indonesia (Yamauchi, 2016), and China (Rada et al., 2015). However, different perspectives at both farm and plot levels may yield different conclusions.

Although land is privately owned in many countries, collectively owned or managed lands remain widespread in the developing world, including China, Mexico, and several parts of sub-Saharan Africa (Leight, 2016). In the context of such a land ownership system, tenure security is an important factor influencing farmers' grain production behavior. Secure land rights enable farmers to invest, with the expectation they will reap benefits without fear of their lands being confiscated arbitrarily (Lawry et al., 2014). Generally, a decrease in the probability of losing current plots yields an increase in agricultural inputs and productivity (Leight, 2016). The positive impacts of more secure land tenure on both investment and land values in rural areas have already been demonstrated for China (Jacoby et al., 2002), Thailand (Feder et al., 1991), Latin America (Deininger and Chamorro, 2002; Field and Torero, 2006; Bandiera, 2007), Eastern Europe (Rozelle, 2004), Africa (Deininger and Jin, 2006), among others. In most cases, extending the original land contract enhances farmers' sense of security and motivates them to invest more in farmland (Deininger and Jin, 2003; Gao et al., 2012). Banerjee et al. (2002) also found a positive impact of tenure reform on land productivity, partly attributed to high investments due to improved tenure security.

Social security considerations, ambiguous law formulations, and village self-governance are the main causes for the insecurity of actual and perceived land tenure (Ma et al., 2015). On the land rental market, rented land often involves tenure insecurity because rentals can be informal and temporary. Therefore, the insecurity of rented plots may discourage long-term investment and reduce agricultural productivity (Feng, 2008; Feng et al., 2010). Further, organic manure applications and land productivity are significantly lower on rented plots (Gao et al., 2012; Muraoka et al., 2018), meaning that leaseholders are less likely to invest in land improvement activities for rented land (Abdulai et al., 2011). Land transfers thus influence investments, which in turn influence technical efficiency and land productivity (Koirala et al., 2016).

In China, grain production is confronted with many challenges due to farmland use and changing man-land interrelations (Enenkel et al., 2015), posing great threats to the national food security. First, the man-land relationship features a large population with relatively little arable land (Ge et al., 2018), although China's total agricultural available resources are large (Long et al., 2018). Data show that the per capita farmland area of China is 0.1 ha, which is below the world average (Xiao et al., 2017). Second, the urbanization and industrialization of China is in an acceleration stage, during which the migration of a large number of people from rural to urban areas decreases the use of farmland for agricultural purposes (Long et al., 2016). Third, there is a spatial mismatch between grain production and farmland resources, with the grain production barycenter in the North area (Li et al., 2017). At last, soil pollution, land degradation, and water pollution also intensify the food security problem (Liu et al., 2015).

Farmland is the core resource ensuring food security, while the farmland characteristics are more diversified, being attributed to land tenure and diverse landscape in China. Specifically, there is a hybrid legislative system of land ownership, in which land is held by the village collective and contractual management rights are held by households. On the land rental market, contracted farmers can lease out their management rights instead of the contract rights to others by land transfer at plot level. However, for each plot, the locations, crop rotation systems, and the condition of available water resources may be different.

Although numerous studies have focused on the impacts of soil quality, land size, and tenure security on farm costs (e.g., fertilizer, pesticide, irrigation, machinery, seeds, and labor) or benefits (e.g., yield, profit), few have considered these aspects simultaneously. Moreover, the inputs and outputs of different plots are not the same even if operated by the same producer. Considering that the North China Plain is typical of China's farming areas and is one of the fastest growing areas of urbanization in the world (Bren d'Amour et al., 2017), it is meaningful to use the North China Plain as an example to explore the effects of land characteristics on grain production. Thus, we applied an in-depth survey in the North China Plain to evaluate the effects of farmland characteristics on plot-level grain costs and benefits using a multilevel model. This research is expected to serve as reference for policy makers to understand the influencing mechanism of land characteristics on grain production and modify policies to safeguard national food security.

2. Estimation strategy

It is worth noting that individual households make investment decisions depending not only on their resource endowments but also on the aggregate level of the village to which they belong, and thus the failure to consider village characteristics could introduce significant bias (Dong, 2000). The existence of such "clustering" presents the particular problem of model specification due to lack of independence between measures. A multilevel linear model was developed to analyze this type of problem. Specifically, a two-level model was chosen to test whether village and household variances are the main reasons for the gap of grain costs and benefits in different plots.

2.1. Null model

The null model is used to test whether variables from different levels have a significant effect on the explained variable. In the model, we decomposed the variance of explained variables into two levels, according to the proportion of the total variance. If the variance from the high level is large enough, it will indicate that we have to use a multilevel linear model.

The null model can be expressed as follows:

Level 1:

$$y_{ij} = \beta_{0j} + \varepsilon_{ij} \quad (1)$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \mu_{0j} \quad (2)$$

Full equation:

$$y_{ij} = \gamma_{00} + \varepsilon_{ij} + \mu_{0j} \quad (3)$$

Level 1 denotes the household level and level 2 the village level. y_{ij} in Eq. (1) is the explained variable, which includes grain costs and benefits. β_{0j} in Eqs. (1) and (2) is the average value of the explained variable in village j. γ_{00} represents the total intercept, which is the average value of y_{ij}. ε_{ij} and μ_{0j} are random effects. By using $Var(\varepsilon_{ij}) = \sigma_1^2$ in level 1 and $Var(\mu_{0j}) = \sigma_2^2$ in level 2, we can calculate the between-group correlation coefficient with equation $\rho = \sigma_2^2/(\sigma_1^2 + \sigma_2^2)$. A high value of σ_2^2 means a large within-group correlation coefficient, that is, the multilevel model can be used.

2.2. Random intercept model

We assume that the average value of the explained variable varies by group and the slope of the regression model is fixed. In other words, variables from each level influence the explained variable. Therefore, we ran a random intercept model to evaluate the effects of farmland characteristics on grain costs and benefits at both the village and household levels. The specific models are set as follows: