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Assessing the impacts of land fragmentation and plot size on yields and costs: A translog production model and cost function approach

Hua Lu[a], Hualin Xie[a,b,*], Yafen He[a], Zhilong Wu[a], Xinmin Zhang[c]

[a] Institute of Ecological Civilization, Jiangxi University of Finance and Economics, Nanchang 330013, China
[b] Co-Innovation Center of Institutional Construction for Jiangxi Eco-Civilization, Jiangxi University of Finance and Economics, Nanchang 330013, China
[c] Graduate School of Life and Environmental Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan

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ABSTRACT

More attentions should be focused on the changes in plot size of each household rather than the size of farmland in the discussions of economic problem of land fragmentation in China. This study empirically analyzes the impact of land fragmentation and plot size on yields, along with average costs, using household survey data collected from the Jiangsu province in China. A detailed and careful translog production model and cost function are employed to understand and analyze these problems. The empirical results reveal that there are increasing returns to scale in agricultural production. Land fragmentation reduces yields through changes in marginal outputs of agricultural inputs. Especially in areas with high opportunity costs of labor, the negative impact is more obvious. A one-unit increase in the Simpson index leads to a 39% increase in the average cost, whereas a one-unit increase in plot size leads to an 8% decline in the average cost. Thus, moderate expansion of the size of the plot can reduce the average cost, implying that agriculture can achieve economies of scale within each plot. Economies of scale should be developed by keeping farm size constant, reducing the number of plots, and expanding the size of each plot. We suggest that economies of scale can be achieved in each plot by either land consolidation or land transfer as well as by joint farming and joint association.

1. Introduction

Research on agricultural development in China has increasingly focused on farm size. People generally think of the scale of agricultural operations in terms of the farms' size, especially in the context of land management. The Household Responsibility System (HRS) implemented in China contributed to the rapid development of agriculture by increasing farmers' incomes and narrowing the urban-rural divide. However, its implementation also led to each farmer separately possessing numerous small plots of lands. In 2013, the farm size in China was 0.66 ha, with an average plot size of 5.1 ha per household, each with an area of 0.129 ha.[1] For the increase in farm size, some policies do encourage the circulation of agricultural land management rights. Examples of these policies include the land circulation pilot in 1978; the legal promotion of the orderly circulation of land management rights in the central NO.1 document in 2016; and, actively encouraging farmers, through village organizations, to voluntarily exchange land in order to achieve contiguous land cultivation in the central NO.1 document in 2017. However, the results of these policies were not optimal. As of the end of June 2016, of the 0.087 billion ha of contracted land, only 30.682 million ha were circulated, which was approximately one-third of the total area of contracted land. Furthermore, of the 234 million Chinese farmers holding contracted land, nearly 170 million have not circulated their land; only around 66 million have partially or completely circulated their land (Xie and Lu, 2017).

Land fragmentation means that a household's land resources are divided among several spatially separated plots (Mcpherson, 1982). However, it does not refer to a lack of economies of plot size. Although farmers do have numerous dispersed plots, if the size of each plot accounts for, say, hundreds of hectares, the economic problem of land fragmentation would be harder to observe. With the development of agricultural outsourcing services and other forms of scale operations, economies of scale have moved from internal economies at the household level to external economies across households. The realization of economies of scale is no longer entirely dependent on expanding farm size; the importance of scale economy at the plot level has increased further. The economic problem of land fragmentation should be studied from the perspective of plot size rather than that of farm size.

In fact, the extant literature often focuses on the expansion of farm size, which neglects the size of each plot. More importantly, the

* Corresponding author at: Institute of Ecological Civilization, Jiangxi University of Finance and Economics, Nanchang 330013, China.
E-mail address: landuse2008@126.com (H. Xie).

[1] The data came from the fixed observation points of the Ministry of Agriculture of the People's Republic of China (MOA).

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measurement of changes in farm size should consider two aspects. First, the area of each plot may be constant, but the number of plots changes. Second, the number of plots may be constant, but the area of each plot changes. The average cost of some inputs is irrelevant to the number of plots but is related to the area of each plot. In addition, currently, land transfer is still inefficient—a long exchange chain results in a low probability of matching with adjacent areas and high transaction costs. Due to the high transaction costs and the difficulty of effective land transfer, farm size enlargement is likely to increase the number of plots rather than the area of each plot. Therefore, it is more reasonable to study economies of scale by focusing on the area of each plot.

In regions with large populations, relatively less arable land, and surplus labor, land fragmentation is a rational choice for farmers to maximize their income (Xu et al., 2008). Varied crop planting and harvesting seasons can effectively offset labor insufficiency during busy seasons and surplus labor during slack seasons, which allows a flexible allocation of agricultural inputs (Blarel et al., 1992). With problems like labor shortages and natural disasters or droughts, planting diversity can effectively decrease market risks, increase yields, or narrow the inequality of income (Falco et al., 2010; Foster and Rosenzweig, 2011; Li and Li, 2017; Niroula and Thapa, 2005; Paul and Githinji, 2017). Additionally, economic development or transition in many major agricultural regions worldwide, especially Asia, are experiencing drastic non-agricultural utilization (Long et al., 2009; Sreeja et al., 2015). You (2017) analyzed the impact of economic transition on agricultural landscape dynamics (ALD) and revealed that the magnitude of ALD is larger in non-urban planning zones. In particular, agricultural landscapes are changing into fragmented, irregular, decreased, and isolated patterns at a faster pace. The analysis also found that the efficiency of agricultural land protection in the non-urban planning zone was much lower than in the urban planning zone, and the absence of a land use master plan was a critical contributor to the low efficiency of agricultural land protection in the non-urban planning zone.

With the increase in non-agricultural labor supply, the negative effects of land fragmentation on agricultural production or on the ecology and environment have gradually become more evident (Cai, 2008). The rising labor cost led to the inevitability of mechanized alternative labor, and land use changed. Su et al. (2016) revealed that households with low agricultural labor intensities have a high probability of growing tea and mulberry plantations. Xiao et al. (2015) also found a consistently higher probability of cash crop expansion in places with abundant farmland, and the distance to a counter and to a provincial road were decisive determinants for farmers' choice of cash crop plantation. Furthermore, small plots that require extensive labor but are unsuitable for mechanical operations are abandoned or used inefficiently (Carter and Yao, 2002). Under these circumstances, land fragmentation could reduce both land and labor productivity, thus affecting agricultural production (Ali and Deininger, 2014; Barrett et al., 2010; Deininger et al., 2012; Jia and Martin, 2014; Kalantari and Abdollahzadeh, 2008; Schultz, 1953; Tan et al., 2010). Wan and Cheng (2001), in their study on corn, late rice, and wheat, noted drops in technical efficiency by 4%, 15%, and 17%, respectively, when the degree of land fragmentation increases by one unit. Small and dispersed plots waste more resources and time when transferred to different plots. Furthermore, small plots are an obstacle to the application of agricultural machinery and the construction of farmland infrastructure. They can also affect productivity, decrease overall grain production capability, and simultaneously increase input costs (Haji, 2007; Latruffe and Piet, 2014; Rahman and Rahman, 2008; Sklenicka et al., 2014; Tan et al., 2008). Latruffe and Piet (2014) found that land fragmentation increased cost but decreased income, profit, and efficiency. Wei (2015) further found that land fragmentation could influence the application of agricultural technology, forcing farmers to disburse more costs in terms of labor, time, and psychological costs.

To summarize, the effects of land fragmentation on agricultural production are different under varying assumed conditions. In cases of low costs, such as labor costs, land fragmentation is reasonable. However, an increase in agricultural costs decreases agricultural profit, forcing farmers with small plot sizes to desert their farmland. Besides, moderate farm size has become an inevitable trend in agriculture with rising costs and non-agricultural labor supply. However, here, moderate farm size refers to plot size enlargement, not an increase in the number of plots. Only a few studies measure economies of scale for each plot, but they lack empirical analysis. Therefore, we explore the relationships among land fragmentation, plot size, and economic benefit from the perspective of the average area of each plot.

2. Materials and method

2.1. Research hypothesis

Land fragmentation affects yields by influencing the allocation of other agricultural inputs. Small and dispersed plots not only increase the time cost but also evaporate agricultural inputs during plot transfers. Moreover, these plots reduce the efficiency of fixed assets, which are indivisible in agriculture. Due to increased boundaries and ridges between small and dispersed plots, irrigation efficiency falls and agricultural operation time is wasted, leading to poor field management. Small and dispersed plots also limit the use of machines and new technologies. Thus, we hypothesize:

H1. Land fragmentation reduces yields by affecting the efficiency of agricultural inputs.

The impact of land fragmentation on yields varies in different regions because the opportunity cost of farm labor varies. Based on maximizing benefits, farmers will choose to acquire more off-farm income in an area with higher opportunity costs of farm labor. Small and dispersed plots reduce farmers' enthusiasm for agriculture and increase the probability of extensive management. To meet basic family needs, farmers will not fully abandon their land, even with uneconomical scales in small plots. Furthermore, farmers will neglect increasing yields due to time and energy constraints. However, agricultural income may be a major source of income in an area with lower and less stable opportunity costs of farm labor. Land fragmentation also provides more opportunities to grow diversified crops. Thus, we hypothesize:

H2. The higher the opportunity cost of farm labor, the greater the negative impact on yields.

Land interchange or integration may hedge the negative effects of land fragmentation and reduce average cost. Even though the number of plots does not change, plot size enlargement will bring economies of scale. Before the analysis, we identify economies of and returns to scale. Samuelson and Nordhaus (1948) defined economies of scale as increased agricultural productivity or decreased average cost caused by the same proportional increase of all agricultural inputs. Mankiw (1998) concluded that economies of scale are defined by a long-term decrease in average cost along with increased output. Thus, there are similarities and differences between economies of and returns to scale. First, the conditions of the latter are stricter compared to those of the former. Returns to scale emphasize yield fluctuations with the same proportional increase of all agricultural inputs, whereas economies of scale also include non-proportional changes in inputs. Second, economies of scale that are measured from the perspective of average cost facilitate the analysis of monetary value. In contrast, returns to scale that are measured from the perspective of production function technology enable an analysis of physical value (Xu et al., 2011). Since the possibility of farmers changing agricultural inputs at the same proportion is low, they will rely more on economies of scale to lower cost and improve efficiency.

Fig. 1a illustrates economies of scale. With a yield increase, the average cost first increases and then decreases. If marginal cost (MC) < average cost (AC), the average cost will continue to decrease,