Technical Efficiency on Flue-cured Tobacco Production and Its Hierarchical Influencing Factors: an Empirical Study in China

Yan-ling Peng, Rong Kong

Northwest A&F University

Abstract

This is one of the first empirical studies to estimate the technical efficiency of farmers' flue-cured tobacco production, and explore the influencing factor of technical inefficiency on the perspective of within effects and between effects, aiming to provide a basic evaluation of farmers' flue-cured tobacco production, and promote producers optimize their production. Results showed that the average technical efficiency level of flue-cured tobacco farmers was 0.7685; the scale elasticity was 2.67. Our study also revealed that the variation of farm household factors contributed 80.07% to technical inefficiency, and the other could be attributed to the variation of regional factors. Technical inefficiency of flue-cured tobacco production was significantly relative to producers' education, planting scales, and planting years. In addition, regional disaster increased the possibility of technical inefficiency, while subsidies from flue-cured tobacco companies and government were to benefit reducing the technical inefficiency.

1 Introduction

China is a large flue-cured tobacco production country in which the planting area and output are on the top of world. Chinese flue-cured tobacco output represented about 30 % of the global total yields. Tobacco production is a heavy concentration in China. There are five main producing areas of flue-cured tobacco which distributed in Yunnan, Guizhou, Henan, Hunan, Fujian et al. provinces, these yields accounted for over 70% of total production in China, and it is a important approach for farm households to increase their income[1]. Moreover, flue-cured tobacco industry contributes much to the economic development since it is a vital source of government revenue. According to the national finance statistics report of 2013, nearly 13.6 percent of national finance income was imposed from tobacco industry which supports the budget for the country. The flue-cured tobacco sector has been widely acknowledged as the outstanding contribution to national finance revenue and one of the greatest agro-business success stories in China. Due to the above facts and increased tobacco industry concerns, the production and its technical efficiency of flue-cured tobacco have attracted the attention of the scholars and governments.

Previous research has shown that the trend of flue-cured tobacco production indicates dynamically in recent years. For instance, based on the statistical data in China from 1989 to 2007, Yuan and Jiang (2010) analyzed the flue-cured tobacco production. It was found that the production of five major flue-cured tobacco producing areas displayed significant fluctuation. Specifically, the flue-cured tobacco production in south area is increasing, while the flue-cured tobacco production in Huanghuai area is decreasing as well as the flue-cured tobacco production in the north area keep robust. Meanwhile, the concentration ratio of flue-cured tobacco industry increases markedly, the technical efficiency in major flue-cured tobacco producing areas is low generally, and the differences of regional technical efficiency are observably. Tian and He (2010) conducted a research on the growth rate of total factor productivity (TFP) in flue-cured tobacco production and its fluctuation using the statistical data in China from 1997 to 2008. Their results indicated that the trend of TFP in flue-cured tobacco production can be divided into stationary

[1]Note: Zunquan Zhu, status and prospect of tobacco production in China [J], Journal of China Tobacco, 2008(12):70-72. “There are five main producing areas of flue-cured tobacco in China including southeast area, southeast, Yangtze River area, Huaihe zone and north area, and Fujian is the main production area in southeast area.”

phase and non-stationary phase, and 2003 is the kick point. Moreover, the differences of the trend on flue-cured tobacco TFP among southwest zone, southeast area, and Yangtze River area were similar, while both Huaihe zone and north area reflected on distinctions markedly. Meanwhile, if on the view of the whole country, the flue-cured tobacco producing efficiency difference of every province shrinks as the time changes and they have the same trend.

Existing literatures demonstrate that flue-cured tobacco producing efficiency received widespread attention on the perspective of the whole country from Chinese scholars. However, there is little knowledge about the farm households' producing efficiency of flue-cured tobacco on the basis of regional attributes, especially in respect of influencing factors on farmers' technical inefficiency from the within effects and between effects. Moreover, a research conducted on the producing technical efficiency of farm household that was the managers of producing decision, can be more veritably and effectively. This study refers to Longyan city in Fujian province. In the southeast producing area, the production of Fujian province accounted for 57.83% of the flue-cured tobacco total yields, among which Longyan city contributed 26.17% [2]to the production of Fujian province, locates in the southeast area which is one of five main tobacco producing areas. We assumed that, the sample could be more representatively and respectively. Simply stated, Longyan city provides a good case for empirically investigating and estimating the technical efficiency.

Moreover, prior research has shown that the empirical data with hierarchically structure is inevitable and veritably. Yet, in the procedure of analysis on impact factors, there was little research took hierarchically structured data into account, especially in term of analyzing the effect of factors. Additionally, previous research are tend to mix up the within effects in the same group and between effects among the different groups, consequently the result was biased generally (Zeng, et al., 2008). Hierarchical liner model provides a good approach exploring and analyzing the determinants of technical inefficiency on the basis of distinguishing between within effects and between effects, especially to reveal the relationship between individuals and groups (Yang, 2006). In this study, the data contain two levels: the level-one units are farm households represent individual attributes (the farmer level); the level-two units are towns which reflect on the regional

[2] Data refers to the <China rural statistical yearbook in 2012> and <Longyan Statistical bulletin for national economic and social development in 2012 >.

characteristics (the town level). Through the analysis of farmer level and town level, the study can distinguish the impact of within effects and between effects on technical inefficiency. The main purpose of this article is to empirically estimate the technical efficiency and analyze the determinants of farm households technical inefficiency from the within effects in the same group and between effects among the different groups. The study provides empirical insight into the main household operating decision and regional environment characteristics that contribute to the technical inefficiency of farmers. Clear findings will be instrumental in flue-cured tobacco industry recommendations. The remainder of this paper is organized in three sections. First, we describe the survey design and data collection; discuss our research method on Data and Methods. Besides, on Empirical Results section we present results refers to the estimation of technical efficiency on the base of stochastic frontier production function, and the hierarchical analysis of factors affecting technical inefficiency by using two-level hierarchical liner model; then we demonstrate our key findings on farmers' technical efficiency and an average technical efficiency, scale elasticity, output elasticity, factors impact on technical inefficiency. Finally, we will discuss our results and conclude with conclusions of the findings in light of their implications for practical producers and theory development on Discussions and Conclusions.

2 Data and Methods

In this paper, a combine methodology was applied to analyze farmers' technical efficiency and factors affecting technical inefficiency of flue-cured tobacco production. In the field of technical efficiency study, it was found that the prior research neglect attributes of the hierarchically structured data, scholars mixed up the within effects and between effects in the procedure of analysis on influencing factors when ANOVA (analysis of variance) and regression methods were conducted to estimate the technical efficiency and its factors impact on technical inefficiency universally. Although the ANOVA models commonly well for balanced designs having discrete independent variables, they are not widely applicable when the data are unbalanced and some predictors are continuous (Raudenbush, 2002). He also pointed out that balanced designs with discrete independent variables arise primarily in carefully designed, small-scale experiments; yet in field experiments, quasi-experiments, and surveys, unbalanced data and a mix of discrete and continuous predictors will be the rule rather than the exception. Furthermore, unfortunately, the benefits of standard regression analysis are available only in fixed-effects models. Also, standard computing packages for regression, based on the ordinary least squares estimation, are inappropriate when some factors are viewed as random (Kang, 1991, Chapter IV). While the inappropriate use of multiple regressions for data yielded has a long and disreputable history in education, sociology, and psychology (Cronbach and Webb, 1975; Burstein, 1980). Of course, both ANOVA and regression are special cases of a "general linear model" (Kirk, 1982).

A hierarchical liner model is a class of models that combine the advantages of the mixed-model ANOVA with its flexible modeling of fixed and random effects as well as regression with its advantages in dealing with unbalanced data and predictors that are discrete and continuous(Raudenbush, 2002). To overcome the difficulties in extending general linear model analysis to designs having fixed and random effects and handling the unbalanced data, the hierarchical liner model is appropriate (Raudenbush, 2002). Results based on hierarchical liner models, duplicate the results of many classical ANOVA models (Winer, 1971). Consequently, in this study, two-level hierarchical liner model was applied to identify both of the within effects (the random effect from the farmer-level units) and between effects (fixed effects from the town-level units) factors contribute to the technical inefficiency of farm households.

2.1 Survey Design and Data Collection

Cross-section data are used in this study. In the procedure of survey, sampling of the respondents involved four stages. First, selection of the administrative province in the southeastern part of the China where tobacco production is concentrated, and the flue-cured tobacco income accounts for the main revenue of farm households; secondly, selecting counties in the selected province; third, selecting towns in the selected counties; finally, selection of the farm households from the selected towns.

There are five main tobacco production regions in China; Longyan city in Fujian province is the most import producing area in the southeast zone. There are five counties in Longyan city. Next, of the five counties, Changting and Liancheng were randomly selected. Eventually, farm households were randomly selected from the villages; 25%–30% of the total families in each village were surveyed. Investigators conducted one-on-one interviews and filled in the questionnaires for each farmer. The ultimate number of observations is 413, comprising Changting

(206 FHs) and Liancheng (207 FHs). After accounting for missing variables, we obtained 405 valid questionnaires. The structured questionnaire consisted of five separate surveys of tobacco farmers' demographic characteristics, input-output in tobacco planting, sale status, agricultural disaster, and risk measurements.

2.2 Statistics Description of Independent Variables

2.2.1 Input and Output Variables

Inputs in the data set include seven categories: land rent, seed, pesticide, fertilizer, irrigation, labor, fuel and power, and all of them are measured in RMB/Mu. Land rent refers to the cost of rented cultivated land. Seed refers to the cost of purchasing flue-cured tobacco seeds. Pesticide refers to the cost of potion to treat the aphid and carpenter worm, trichlorfon and others. Chemical fertilizers refer to the cost of nitrogenous, phosphate, and potash fertilizers that consumed in one Mu cultivated land. Labor refers to the cost of the number of workers in the process of flue-cured tobacco production. Fuel and power include cost of fuel from tractor and other machines. The output and input series are summarized in Table 1.

Summary of the variables used in the stochastic frontier production function is presented in Table 1. The output of farmers is pretty unbalanced, farmer has the minimum yield of RMB130.43 per MU, and maximum amount is up to 23076.92 RMB/Mu. Among inputs, about 90% of total cost is from land rent, fertilizer, labor, fuel and power. The highest cost is labor input, the mean value up to RMB 820.26 per Mu. The mean of fertilizer represents RMB 479.81 per Mu which takes up the second input cost in the production. Yet the mean values of land rent, and fuel and power are RMB 375.10 and 343.65 per Mu.

2.2.2 Hierarchical Independent Variables

This section describes the determinants of technical efficiency loss using in the hierarchical liner mode. The statement of the determinants presented in Table 2 is based on an extensive review of the theoretical and empirical literature on technical efficiency and related topics. It is well known from the literature that the production technical efficiency is influenced by both characteristics of the farmer and factors related to the location, such as education of farmers and planting scale of regional industrialization (Liu, 2013). However, in the prior research, scholars do not take into account the mixed up characteristics of the farmer and factors leads to biased estimation, especially in term of analyzing the effect of factors. As it was all know that, different categories variables are likely to have distinguished impact on technical efficiency. Moreover, in a cross-sectional study like the present, it is difficult or impossible to neglect that the data are unbalanced. In other words, the data with hierarchically structure is inevitable. Thus, in this study, the explanatory variables influencing the technical efficiency loss are broadly divided into two levels (farmer-level and town-level).Specifically, farmer-level characteristics represents the random effect of within effects in the same group and town-level characteristics shows the fixed effects of between effects among various groups. Below we briefly discuss the determinants in the two levels. First, we pay attention to level one; the farmer-level characteristics including producers' education, planting years, planting scales, and agricultural insurance. Next, we focus on level two; the town level characteristics comprising frequency of disaster, quantity of company's subsidies, and government subsidies. And Table 2 shows the definitions, measurement and descriptive statistics for the variables.

Farmer-Level Characteristics

Education tends to lead to more knowledge and skills (Schultz, 1979). Specifically, the more the farmer is educated, the better his farming skills and the greater the number of crops a year (Schultz, 1979). And that are important prerequisites to make decisions for individuals (Folmer, 2010). Hence, we expect education to positively impact on the enhancing technical efficiency. In other words, the lower education of producer, the higher probability leads to loss of tobacco production.

Planting years representing a farmer's professional capacity which is assumed to be a determinant in affect the technical efficiency. It is also an indicator for having skills and interest in the adoption of new production techniques. We hypothesize that the shorter of planting year, the higher probability tends to lead to more loss of technical efficiency in production. This point is based on the assumption that a farmer with a relatively high professional capacity in agriculture will strive for an even higher production performance.

Planting scale is measured as arable land. It is expected to have an impact on technical efficiency, since it facilitates acquisition of inputs such as labor, equipment, and capital. Specifically, moderate scale planting is an effective approach to optimize production. Yet it is an indicator for farmer has professional status, and interest in production technique innovativeness. Meanwhile, planting scale reflects on individuals' attitude toward risk. The risk-taking farmer is tend to plant a larger scale of arable land than a risk-averse or risk-neutral farmer, because large scale means more production risk, market risk, technical risk, weather risk they have to deal with. Base on the assumption that a farmer with risk-taking in planting tobacco will strive for an optimal production performance, we hypothesize that the larger of planting scale, the lower probability results in the loss of technical efficiency in production.

Agricultural insurance is an attitude towards risk for farm households. It is well known that risk refers to production risk, market risk, technical risk, credit risk, weather risk and so on. In this paper, we mainly inspect the crop risk and weather risk that results in the loss of technical efficiency, hence the study adopt the variable whether or not farmers purchase the agricultural insurance to reflect farmer's risk awareness. Farmers are usually rational economic persons (Schultz, 1979), who prefer to risk aversion (Popkin, 1979). In other words, in the face of risks, they will show risk aversion tendency. Whether or not to participate in agricultural insurance depends on their' expectations of risks and benefits and their demand degrees for performance. We hypothesize that if a farmer had agricultural insurance, it implies that the more intensiveness of risk awareness, the lower probability bring about production loss. That is to say, farmer's risk consciousness has played a positive role in reducing technical inefficiency.

Town-Level Characteristics

Frequency of disaster is supposed to be a crucial factor affecting the production technical inefficiency. That is to say, the higher frequency of disaster like pests, diseases, drought, water-logging et al. that happened, the more restriction of time and energy a farmer have to pay attention to the agricultural activities. Simple stated, the disaster that occurred have positive impact on the production technical inefficiency because of the increasing input and limited time and energy of farmers. It is well known that the towns were not assigned at random to the occurrence of disaster and its frequencies and severity. In other words, the occurrence of disaster is regional fact, which cannot be determined by households themselves. While because of the distance attribute, the phenomenon that difference of disaster exists in various towns is inevitable. Hence, it will be import to control for potentially confounding effects, so that between effects can be identified separately (Raudenbush, 2002). Thus, we assumed that the higher frequency of disasters will directly affect the efficiency of production technology and lead to production loss.

Quantity of company's subsidies denotes the time was taken to obtain tobacco company's subsidies after disaster happened for farm households. After disaster, technicians from tobacco companies will estimate the disaster severity immediately and calculate the loss for all of the victims. Then the subsidies can be provided to them via several procedures. In the same town, the availability/accessibility of subsidies from the tobacco company is simultaneous. We assumed that the lower quantity of obtaining tobacco company's subsidies, the higher the higher probability results in technical inefficiency in production. Subsidy is a kind of guarantee for capital input; it promotes the investing confidence of farmers in production. The larger quantity of subsidies, the more confidence and investments will be input into the production. For instance, farmers can purchase the seeds and pesticide, also increasing the fertilizer to enhance the production.

Government subsidies is expected to have a positive impact on optimizing technical efficiency, since it refers to a member of the government provide farm households who suffer from disaster some financial donations as well as to the price or income support. In other words, the effective and seasonable subsidies can help farms get rid of loss to some certain. Specifically, they can re-grow tobacco seedlings or switch to crops to facilitate the income.

Table 2 summarizes each of the variables from the data that have been used in the two levels hierarchical analysis. Each household has an average planting year of 23.14, which denotes most of the respondents in possession of professional skill. Also, each farmer has planting scale in possession of 16.20 Mu, while the difference of planting scale is significantly; it varies from 2 Mu to 100 Mu. In addition, the data presented only 35.6% of surveyed farmers had bought the agricultural insurance. In other words, most of respondents' risk awareness is expected to improve. Besides, farmer has a high expectation in suffering from disaster. About 59.5% of surveyed farmers thought about that the disaster happened were "strongly frequent" and "relatively frequent", only 23.5% of farmers have the expectation that the disasters would occur moderately frequent. Only 2.2% of surveyed farmers were "yes" to the subsidies, it represented that minority of farmers got access to the subsidies; another 6.9% respondents thought that the subsidies from the tobacco company can cover the half cost. That is to say, the subsidies from the tobacco company were low in general, since over 90% of farmers agreed with that the subsidies was too low to cover the half cost. Eventually, after the occurrence of disasters, the percent of farmers actual has access to the government subsidies was only 15.1%.

2.3 Stochastic Frontier Production Function

In this study, stochastic frontier analysis approach is applied to measures the production technical efficiency of flue-cured tobacco. And maximum likelihood estimation is used to estimate the parameters. We followed the dominant functional specification as it appears in the current literature based on the works of Battese and Coelli (1992, 1995). A production frontier function can be shown as follows:

$$Y_i = f(x_i;\beta)TE_i \quad (1)$$

where y_i represents the output of farmer i ($i = 1,..., N$), x_i is a vector of N input used by the farmer i, $f(x_i;\beta)$ is the production frontier, and β are parameters to be estimated. Then technical efficiency of farmer i can be described as:

$$TE_i = \frac{y_i}{f(x_i;\beta)'} \quad (2)$$

where TE denotes technical efficiency defined as the ratio of observed output to maximum feasible output. If $TE_i = 1$, it implies that the production of farmer i reach the maximum possible output, otherwise there exists technical inefficiency.

Considering that output can be affected by random shocks, a stochastic component is added. This stochastic element shows the effects of random shock impact on producing process. Thus, stochastic production frontier will be as follows:

$$y_i = f(x_i;\beta)\cdot TE_i \cdot \exp(v_i) \quad (3)$$

where $f(x_i;\beta)\cdot\exp(v_i)$ is the stochastic frontier, which contains the deterministic part $f(x_i;\beta)$ common to all farmers and a farmer-specific part $\exp(v_i)$ that captures the effect of the random shock to each procedure.

If we combine Equations (1) and (3), assuming a trans-log (TL) specification, the stochastic frontier production function for this study can be written as follows:

$$LnY_i = \beta_0 + \sum_{a=1}^{7}\beta_a Lnx_{ni} + \frac{1}{2}\sum_{b=8}^{14}\beta_b (Lnx_{ni})^2 + \sum_{c=15}^{35}\beta_c (Lnx_{ni} * Lnx_{mi}) + V_i - U_i \qquad (4)$$

where y_i represents the output of farmer i ($i = 1,..., N$), x_{ni} is a vector of $n(n = 1,..., 7)$ input used by the farmer i, x_{mi} is a vector of $m(m = 1,..., 7)$ input used by the farmer i, and $n \neq m$; $a = 1,..., 7$, $b = 8,...,14$, $c = 15,..., 35$; β_o represents the intercept, $\beta_a, \beta_b, \beta_c$ denotes the parameters which should be estimated; V_i represents the random error of farmer i and it is typically assumed independently of U_i, normally distributed; U_i is a non-negative random variable on technical inefficiency of farmer i obeying the truncation of the $N^+(m_i, \sigma_U^2)$ distribution (Battese & Coelli, 1995), and m_i denotes the function of technical efficiency loss. $\sigma^2 = \sigma_V^2 + \sigma_U^2$, $\rho = \sigma_U^2 / (\sigma_V^2 + \sigma_U^2)$, σ^2 represents the composite variance item, ρ denotes the variance of technical inefficiency variables from σ^2, its value in the interval [0, 1], and when the value of ρ closer to 0, it means that the systematic effects accounted for by the production frontier function are the dominant source of the stochastic random error. Otherwise, the value of ρ closer to 1, it indicates that technical inefficiency mainly leads to the gap between the actual production and maximum. In this study, the output y_i of farmer i is the income of tobacco production, measured in RMB; the inputs x_i of farm households i are investment of land rent, seed, pesticide, fertilizer, irrigation, labor, fuel and power.

2.4 Two-level Hierarchical Liner Model

In this paper, the effects from both of the within effects and between effects' factors contribute to the technical inefficiency of farm households were identified. Two-level hierarchical liner model is applied to distinguish the random effect (Within Effects) from the farmer-level units and the fixed effects (Between Effects) from the town-level units in this study. Through the analysis of farmer level and town level, the impact of within effects and between effects on technical inefficiency can be separated independently. On the basis of the survey, there are 413 farmers live in 11 towns separately. As discussed above, the data in this study contain two levels: the level-one units are farm households represent individual attributes (the farmer level); the level-two units are towns denote the regional characteristics (the town level).

At level one, the farmer-level, the outcome u_{ij} for farmer i in town j $(i=1,...,n_i; j=1,...,J)$, varies as a function of farmer characteristics, $W_{qij}, q=1,...,Q,$ and a random error e_{ij}, which is assumed normally distributed and homoscedastic. The level-one model can be written as:

$$U_{ij} = \delta_{0j} + \sum \delta_{qj} W_{qij} + e_{ij} \tag{5}$$

where U_{ij} represents technical efficiency loss, δ_{0j} is the intercept denoting the random factors that cannot be observed or unobservable, and each $\delta_{qj}, q=1,...,Q$,is the regression coefficient indicating the strength of association between each W_{qij} and the technical efficiency loss within town j. Note that the intercept and the regression slopes are each subscripted by j, allowing them with variation from town to town.

At level two, the town level, each regression coefficient $\delta_{qj}, q=1,...,Q$, defined by the level-one model, becomes an outcome variable to be predicted by town-level characteristics $Z_{sj}, s=1,...,S$. Thus, according to the regression model, the level-two model can be described as:

$$\delta_{qj} = \gamma_{q0} + \sum \gamma_{qs} Z_{sj} + \mu_{qj} \tag{6}$$

where γ_{q0} is an intercept; each $\gamma_{qs}, s=1,...,S$, is the regression slopes specifying the strength of association between each Z_{sj} and the outcome δ_{qj}; $\mu_{qj}, q=1,...,Q$ is a random error denoting the random effects. Meanwhile, in this study, our goal is to identify the effect from both of the farmer-level and town-level factors contribute to the technical inefficiency, without considering the interaction effect from crossed levels. Simply stated we need to constrain a regression to be homogeneous. Thus, it assumed that each Z_{sj} has no effect, the regression coefficient $\gamma_{qs}, s=1,...,S$ are set to zero, and the random effects μ_{qj} is also constrained to zero, then $\delta_{qj} = \gamma_{q0}$, for instance ; δ_{qj} is fixed across all towns. Eventually, the If we combine Equations (5) and (6), the two-level hierarchical liner models to examine the factors contribute to the technical inefficiency for this study can be written as follow:

$$U_{ij} = \gamma_{00} + \gamma_{01} Z_{1j} + ... + \gamma_{0s} Z_{sj} + \gamma_{10} W_{1ij} + \gamma_{20} W_{2ij} + ... + \gamma_{q0} W_{qij} + \mu_{qj} + e_{ij} \qquad (7)$$

where the technical efficiency loss is the dependent variable, the explanatory variables includes farmer-level characteristics (producers' education, planting years, planting scales, and agricultural insurance) and town-level characteristics (frequency of disaster, quantity of company's subsidies, and government subsidies).

3 Empirical Results

3.1 Estimation of Stochastic Frontier Production Analysis

The result of flue-cured tobacco production was obtained by using the maximum likelihood estimation which represented in Table 3. The sigma square of 6.7833 is highly statistically significant. This result indicated a good fit. Based on the above analysis, the value of ρ closer to 1, it indicates that technical inefficiency leads to the gap between the actual production and maximum. In this paper, the value of ρ is 0.9929, it implies that technical inefficiency dominantly affect the output level of tobacco production. Thus, further analysis of factors resulting in technical inefficiency is necessary.

3.1.1 Producing Technical Efficiency

Table 4 summarizes distribution of farmers' technical efficiency. Results show that the characteristic of farmers' technical efficiency is more like an inverted "U" Curve in Longyan region. Each household has an average technical efficiency of 0.7685. The lowest technical efficiency is of 0.2574, and the highest technical efficiency up to 0.9619; which implies that the technical efficiency of flue-cured tobacco production can be optimized a lot.

3.1.2 Output Elasticity

Results of output elasticity in flue-cured tobacco production were represented in Table 5. From the results, land rent appeared to be the most important production factor, with the elasticity of 0.84. This is in agreement with the concept of land rent in tobacco production. Irrigation appeared to be the second most important production factor, with an elasticity of 0.70. Seed, labor, and fuel and power cost seems to be the similar important production factor, with an elasticity of 0.43 approximately. Fertilizer costs were found to be least important production factor in the production process, with an elasticity of 0.13. Pesticide appeared to be the second least important production factor, with an elasticity of 0.29, but the sign was negative. Totally, the average scale elasticity was 2.67. It revealed that the flue-cured tobacco production as a whole is in a stage of scale increasing returns, which was beneficial to boost the scale management and the development of tobacco industry.

3.2 Results of Hierarchical Liner Model

This part null model was used to identify whether both of the within effects and between effects' factors contribute to the technical inefficiency of farm households. Results showed that, great gap of difference exits between the farm household factors and regional factors. Specifically, the coefficient of variation among town is 0.23, which denoted the regional factors affect the technical inefficiency significantly. In other words, there was a strong correlation between the various farm households' technical inefficiency that lived the same regional town. And the coefficient of region correlation is 0.1993, it represented that the variation of regional factors contributed 19.93% to technical inefficiency. That is to say, the between effect should take into account separately on the base of household contract responsibility system. In addition 80.07% influence of technical inefficiency could be attributed to the variation of farmers' factors. Obviously, few can deny the distinguishing between the within effects and between effects in this study. To estimate the different effect exactly, two-level hierarchical liner model is applied to find out the influencing factors of technical inefficiency from within effects and between effects.

Table 6 presents the results of hierarchical factors analysis. Additionally, to compare with the hierarchical/separate effects, ordinary least square was used to estimate the traditional liner model in which all factors were mixed-up.

As indicated in table 6, among the farmer-level characteristics, planting scales seemed to be the most important negative factor affecting the technical inefficiency and it was significant at the 1% level. It implied that the larger of planting scale, the lower probability results in the loss of technical efficiency in production, which supported the hypothesis discussed in the Data and Methods section. And it strongly confirmed the earlier result that scale elasticity was 2.67. In other words, there were economies of scale in farmers' flue-cured tobacco production. Moreover, variables of producers' education, planting years displayed negative influence on the technical inefficiency, but they were not significant. It indicated that the lower education of producer with a shorter of planting year, the higher probability leads to loss of tobacco production, and they also confirmed the previous assumptions discussed in the Data and Methods section. Eventually, the variable whether or not the farmer bought the agricultural insurance represented a positive impact on the technical inefficiency, but it was not significant. It revealed that the more intensiveness of risk awareness, the high probability brought about production loss. That is to say, farmer's risk consciousness has played a positive role in increasing technical inefficiency. It failed to respond to the previous assumption.

On the basis of town-level characteristics results, it indicated that the variable frequency of disaster appeared to be the most important positive factor affecting the technical inefficiency and it was significant at the 5% level. It implied that the higher frequency of disasters will directly affect the efficiency of production technology and lead to production loss. In addition variables like quantity of company's subsidies and government subsidies played a negative impact on the technical inefficiency, but they were not significant. It indicated that the higher quantity of subsidies, the lower probability results in technical inefficiency in production. That is to say, farmers benefited more from companies and government subsidies when they fall victim to the disaster, to some extent. Thus, all these results supported the assumptions discussed in the Data and Methods section.

As proposed in table 6, apparently, the results of *HLM* and *Linear* were different. And evidently the results of *Linear* model were biased because of the mixed-up effect from both of the within effects and between effects. Specifically, comparing to the results of *HLM* and, the significant impact of planting scales had been weakened in the *Linear* model and it was significant at the 5% level. Besides, the variable frequency of disaster appeared to play a positive influence on the technical inefficiency; however, it was not significant. It demonstrated that in a cross-sectional study, the data with hierarchically structure is inevitable. Consequently, a hierarchical liner model was more appropriate to estimate parameters when some factors were view as random, thereby the within effects and between effects could be distinguished and measured exactly.

4 Summary and Conclusions

The objectives of this study are to evaluate the technical efficiency of farmers' flue-cured tobacco production and explore the factors of technical inefficiency in China. For that purpose, stochastic frontier production function is used to measure the production technical efficiency of flue-cured tobacco, and two-level hierarchical liner model is applied to find out the influencing factors of technical inefficiency based on a survey of 413 farm households. The main findings are as follows:

The characteristic of farmers' technical efficiency is more like an inverted "U" Curve in Longyan city. Each household has an average technical efficiency of 0.7685, which implies that the technical efficiency of flue-cured tobacco production can be optimized a lot.

The average scale elasticity was 2.67; the flue-cured tobacco production as a whole is in a stage of scale increasing returns, which is beneficial to boost the scale management and the development of tobacco industry. In addition, the differences of various inputs are significant, the rank elasticity of each inputs likes land rent＞ irrigation＞ seed＞ labor＞ fuel and power ＞ pesticide＞ fertilizer.

The variation of regional factors contributed 19.93% to technical inefficiency, and 80.07% influence of technical inefficiency could be attributed to the variation of farmers' factors. Planting scales has the most important negative impact on the technical inefficiency which suggested that the larger of planting scale, the lower probability results in the loss of technical efficiency in production, and there are economies of scale in farmers' flue-cured tobacco production. The variable frequency of disaster is the second most important factor in this study with a positive influence on the technical inefficiency and it was significant at the 5% level. Besides, variables of producers' education, planting years, quantity of company's subsidies, and quantity of government subsidies displayed negative influence on the technical inefficiency, but all of them were not significant. Additionally, the variable whether or not the farmer bought the agricultural insurance represented a positive impact on the technical inefficiency, but it was not significant. Eventually, in a cross-sectional study, the data with hierarchically structure is inevitable, the within effects and between effects should be attached great importance. Also, a hierarchical liner model was more appropriate to estimate parameters when some factors were view as random, thereby the within effects and between effects could be distinguished and measured exactly.

Findings of our study have several recommendations for the tobacco company and government management. First, the positive impact of education suggests that providing more purposive and effective skills training for farmers is necessary. Second, the significant negative effect of planting scale indicates that the highly centralized planting tobacco is a vital way to optimize the production. Furthermore, the positive impact of quantities of subsidies from Tobacco Company and government implies that a reasonable and scientific sort of compensation mechanism on disaster should be set up to reduce the production loss. Finally, in a cross-sectional study like the present, inevitably, the neglect of the phenomenon that data are unbalanced will lead to bias.

Tables:

Table 1 Summary statistics of input and output variables (Unit: Yuan/ Mu)

Variable	Mean	St. Dev.	Minimum	Maximum
Output	2309.30	1565.17	130.43	23076.92
Land Rent	375.100	185.10	40.00	1000.00
Seed	53.61	51.86	10.00	825.00
Pesticide	74.12	60.76	58.00	500.00
Fertilizer	479.81	180.03	160.00	1800.00
Irrigation	51.60	51.92	14.00	600.00
Labor	820.26	594.09	100.00	2100.00
Fuel and Power	343.65	116.29	36.00	1750.00

Note- Sample size: 413.

Source: Author calculation

Table 2 Definitions, Measurements and Statistics of Hierarchical Independent Variables

Category	Variable	Definition and Measurement	Mean	Std. Dev.
Farmer-level characteristics	Education	Farmer's education level：Illiterate = 1 , primary school = 2, junior school=3, senior school=4, vocational school=5,college graduates = 6	3.14	0.81
	Planting year	Years	23.14	8.95
	Planting scale	Total arable land of input (Mu)	16.20	9.31
	Agricultural insurance	Whether or not the farmer bought the agricultural insurance (No/yes: 0/1)	0.36	0.48
Town-level characteristics	Frequency of disaster	Strongly frequent=1, relatively frequent=2, moderately frequent=3, low frequency=4, rare=5	2.52	0.97
	Quantity of company's subsidies	Whether or not the subsidies from tobacco company can cover the cost: yes=1, no, but over half cost=2, no, but lower than the half cost=3	2.89	0.38
	Government subsidies	Whether or not the farmer has access to government subsidies (No/yes: 0/1)	0.15	0.36

Table3 Maximum Likelihood Estimation of SFA

Variables	Parameter	Coefficients	t-value	Variables	Parameter	Coefficients	t-value
Constant	β_0	1.6012	0.6589	$Lnx_1\, Lnx_5$	β_{18}	0.0043	0.1119
Lnx_1	β_1	0.8394	1.5053*	$Lnx_1\, Lnx_6$	β_{19}	0.0051	0.3171
Lnx_2	β_2	0.4367	0.6823	$Lnx_1\, Lnx_7$	β_{20}	-0.0047	-0.0675
Lnx_3	β_3	-0.2903	-0.8182	$Lnx_2\, Lnx_3$	β_{21}	-0.0012	-0.0605
Lnx_4	β_4	0.1315	0.2153	$Lnx_2\, Lnx_4$	β_{22}	-0.0172	-0.4032
Lnx_5	β_5	0.7012	1.5776*	$Lnx_2\, Lnx_5$	β_{23}	0.0032	0.1545
Lnx_6	β_6	0.4293	1.3768*	$Lnx_2\, Lnx_6$	β_{24}	-0.0134	-1.2724
Lnx_7	β_7	0.4185	0.7954	$Lnx_2\, Lnx_7$	β_{25}	-0.0406	-0.3598
$(Lnx_1)^2$	β_8	-0.0545	-0.6871	$Lnx_3\, Lnx_4$	β_{26}	0.1078	2.4564***
$(Lnx_2)^2$	β_9	-0.0009	-0.0377	$Lnx_3\, Lnx_5$	β_{27}	0.0058	0.3207
$(Lnx_3)^2$	β_{10}	-0.0189	-1.1429	$Lnx_3\, Lnx_6$	β_{28}	0.0233	1.7036**
$(Lnx_4)^2$	β_{11}	-0.1104	-3.0858***	$Lnx_3\, Lnx_7$	β_{29}	-0.0267	-1.3017*
$(Lnx_5)^2$	β_{12}	0.0220	0.8626	$Lnx_4\, Lnx_5$	β_{30}	-0.0291	-0.6729
$(Lnx_6)^2$	β_{13}	-0.0173	-1.7933**	$Lnx_4\, Lnx_6$	β_{31}	0.0018	0.0718
$(Lnx_7)^2$	β_{14}	-0.0041	-0.1818	$Lnx_4\, Lnx_7$	β_{32}	0.0904	1.1567
$Lnx_1\, Lnx_2$	β_{15}	0.0038	0.0877	$Lnx_5\, Lnx_6$	β_{33}	-0.0147	-1.1483
$Lnx_1\, Lnx_3$	β_{16}	-0.0528	-1.2930*	$Lnx_5\, Lnx_7$	β_{34}	-0.1001	-1.6104*
$Lnx_1\, Lnx_4$	β_{17}	-0.5820	-0.9488	$Lnx_6\, Lnx_7$	β_{35}	-0.6171	-1.1689

σ^2 =6.7833***(t=3.0295) ρ =0.9929***(t=357.4300)

Log likelihood = -161.0581   LR test of the one-side error = 134.9027

Note: ***Significant at 1 %level, and **significant at 5 %level and * significant at 10 % level; taking the coefficients into consideration, in this table four decimals were kept.

Table 4 Distribution of Farmers' Technical Efficiency in Flue-cured Tobacco Production

Value of technical efficiency	Sample (FHs)	Percentage (%)
≤0.6	46	11.36
0.6～0.7	36	8.89
0.7～0.8	102	25.18
0.8～0.9	180	44.45
＞0.9	41	10.12

Table 5 Sorting of an Average Output Elasticity in Flue-cured Tobacco Production

Inputs	Output Elasticity	Values	Order
Land rent（x_1）	e_{x_1}	0.84	1
Seed（x_2）	e_{x_2}	0.44	3
Pesticide（x_3）	e_{x_3}	-0.29	6
Fertilizer（x_4）	e_{x_4}	0.13	7
Irrigation（x_5）	e_{x_5}	0.70	2
Labor（x_6）	e_{x_6}	0.43	4
Fuel and power（x_7）	e_{x_7}	0.42	5

Table 6 Results of *HLM* and *Linear*

Category	variables	*HLM* Results		variables	*Linear* Results	
		coefficient	t-value		coefficient	t-value
Farmer-level characteristics (within effects)	w_1	-0.0056	-0.5830	w_1	0.0390	0.7860
	w_2	-0.0003	-0.3180	w_2	0.0180	0.3540
	w_3	-0.0036***	-4.2560	w_3	-0.2320**	-4.7100
	w_4	0.0017	0.0990	w_4	0.0610	1.2450
Town-level characteristics (between effects)	z_1	0.0251**	2.5510	z_1	-0.0750	-1.5220
	z_2	-0.0149	-0.5300	z_2	-0.0090	-0.1880
	z_3	-0.0165	-0.3960	z_3	-0.0670	-1.3710

Note: ***Significant at 1 %level, and **significant at 5 %level and * significant at 10 % level; taking the coefficients into consideration, in this table four decimals were kept.

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