【論文】

Effects of Household Heads' Wage Work on Farm Technology Level and Technical Efficiency in China*

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1. Introduction

As China's economy develops, farm households have more opportunities in the wage employment sector. More farmers will choose to reallocate their time from the agricultural sector to the non-agricultural sector if the latter offers higher wages than the reward from farming. For example, the Chinese Household Income Project survey of 2002 (hereinafter CHIP2002; Li, 2002) verifies that wage work has recently gained economic importance in rural China: nearly 60% of household heads participate in wage work and the share of wage income in total income exceeds 30%.

Such increased participation of rural households in wage work has been shown to have important effects on farm productivity. A farm household's participation in wage work could raise its farm productivity for several reasons. Wage income can be used to facilitate farm management through a more flexible purchase of inputs. Participation in wage work can also increase information about farm inputs and technology through better access to urban areas (Herdt and Mandac, 1981). However, on the other hand, farm productivity could decline if households increase wage work. According to Goodwin and Mishra (2004), wage work participation decreases farm households' attention to the optimal use of variable inputs and farm technology. It also changes the quality of inputs. More specifically, Mu and van de Walle (2011) and Chang, Dong, and Macphail (2011) explain that the migration of males increases farm work hours of females and the elderly left behind in rural areas. If increased participation of rural households in wage work deteriorates farm productivity, further economic development will threaten stable domestic supply of farm commodities in China.

Nonetheless, only a few studies have investigated the effects of more wage work on farm productivity and especially on technical efficiency. Mochebelele and Winter-Nelson (2000) estimate Cobb-Douglas stochastic production frontiers (SPF) separately for households with and without migrants in Lesotho. They find that the technical efficiency

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of households with migrants is 12% higher. Chang and Wen (2011) estimate a similar SPF for rice farmers in Taiwan. They find that the technical efficiency of households without off-farm workers is slightly higher than that of households with off-farm workers. Pfeiffer, Lopez-Feldman, and Taylor (2009) specify technical inefficiency as a function of off-farm incomes. They find for Mexican households that more off-farm incomes have a positive effect on farm technical efficiency. For Chinese households, many studies, including Chen, Huffman, and Rozelle (2009), have estimated farm technical efficiency, but no studies have estimated the effects of more wage work on technical efficiency.

Furthermore, it is important to decompose productivity into technology level and technical efficiency when estimating the effects of more wage work on farm productivity. Technology level represents the best production technology that is potentially available for all households. On the other hand, technical efficiency represents how efficiently each household actually produces its outputs in comparison with those that could be produced using the best technology. The distinction between technology level and technical efficiency is important because some policies might have different implications. For example, improved education of farmers will raise the technology level through their use of new inputs and crop varieties. However, it may not always raise technical efficiency. While education improves farmers' managerial ability, it also induces them to participate in off-farm activities, thereby reducing their attention toward farm production. Few studies have estimated the effects of more wage work on technology level and technical efficiency separately.

Using data from CHIP2002, this study estimates Cobb-Douglas SPF for farm households with and without a wage worker separately to compare the technology level and technical efficiency of the two groups of households.[1] After estimating the two frontiers, we follow the method of Kumbharkar, Tsionas, and Sipiläinen (2009) to compare them. We focus on wage work participation of household heads because they are most likely to participate in wage work, as we will see in the next section, and because their decisions on wage work are likely to have the greatest effect on farm technology and technical efficiency.[2] We adopt a similar approach to that of Mochebelele and Winter-Nelson (2000), rather than following Pfeiffer, Lopez-Feldman, and Taylor (2009), because there are no plausible ways to split the sample if we use wage incomes or hours to explain technical efficiency.[3] Finally, we examine factors affecting technical efficiency as most other studies estimating technical efficiency do.

The second section describes wage work

1 This study prefers SPF to DEA method partly because the stochastic disturbance plays an important role in agricultural production due to weather shocks and partly because heteroskedasticity of technical inefficiency term is assumed to test its homoskedasticity.

2 Some studies are interested in the effect of migration (mostly by young family members rather than the household head) on farm outputs for Chinese farm households (e.g., Yang, 2003). However, their results show that this effect is not significant.

3 This method might suffer from sample selection bias. However, a standard way to correct this bias (i.e., adding the inverse Mills ratio as a regressor) does not solve the problem, as Kumbharkar, Tsionas, and Sipiläinen (2009) explain. For this reason, we just follow Mochebelele and Winter-Nelson (2000) and Chang and Wen (2011), although we need to carefully interpret our empirical results.

participation of Chinese rural households and makes some inferences on the effect of this participation on farm productivity. The third section introduces SPF with a heteroskedastic error term and its estimation method. It also briefly explains procedures to compute technical efficiency and production frontiers. The fourth section examines estimated parameters of SPF, technical efficiency, production frontiers, and factors to determine technical efficiency. The final section summarizes the analysis and concludes the paper.

2. Wage Work Participation and Farm Production in Rural China

This empirical analysis uses data of 9,200 rural households in CHIP2002. Gustafsson, Li, and Sicular (2008) and Knight, Deng, and Li (2011) provide a detailed description of the survey. We specifically examine 4,391 households for which data on relevant variables are not missing and the following conditions are satisfied: 1) total production value from grains, economic crops, and livestock production is positive, 2) both crop production costs and cultivated land areas are positive, 3) the household head is a married male and he, as well as his wife, works on his own farm, and 4) each village includes at least two sample households.[4] The empirical analysis also uses data on village-level variables from the Administrative Village Questionnaire annexed to CHIP2002. To allow for regional differences in farm production and labor markets, we classify 22 provinces, autonomous regions, and directly administered municipalities into eastern, central, and western regions.[5]

2.1 Wage work participation of rural households

We first examine wage work participation of 4,391 rural households in CHIP2002. Table 1 presents the participation rate of wage work by the household head, his wife, other adult males (excluding the head) and other adult females (excluding the head's wife). Wage work includes migration (working out of his or her home county at least 90 days in the survey year), the rate of which is shown in parentheses. Over 50% of the household heads participate in wage work in all regions, but only 6–8% of them migrate. The participation rate of the wife is the lowest, and it is only 17% in the most developed region. Other adult males (most of them are the household head's sons) work for wages at a relatively high rate in all regions, and their migration rate (14–25%) is much higher than the household head. The participation rate of other adult females (most of them are the household head's daughters) is lower than other adult males, but it is much higher than the head's wife. These results are consistent with those found by Mu and van de Walle (2011) who use the China Health and Nutrition Survey over the period 1997–2006.

In summary, migrants are mainly composed of young adults, while most of the household heads and wives do not migrate but engage in farm work and/or local wage work —

4 We need at least two households in each village to estimate the coefficient of village dummy variables (or to control for village fixed effects) in estimating SPF.

5 The eastern region includes Beijing, Hebei, Liaoning, Jiangsu, Zhejiang, Shandong, and Guangdong. The central region includes Shanxi, Jilin, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region includes Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, and Xinjiang.

Table 1. Rate of Wage Work Participation by Rural Households (%)

	Head	Wife	Other males	Other females
East	65.1 (6.2)	17.4 (0.7)	50.5 (13.5)	31.3 (10.2)
Center	62.9 (7.0)	10.1 (1.1)	44.2 (24.8)	26.7 (17.8)
West	55.4 (8.0)	11.0 (0.9)	36.3 (19.2)	20.1 (11.7)

Note: Rate of migration is shown in parentheses.

CHIP2002 shows that the average farm work hours are 1,021, 1,140, 655, and 636 for the head, his wife, other adult males, and other adult females, respectively. Also, the household head is most likely to participate in local wage work, while his wife is least likely to do so. Consequently, it seems plausible to focus on the household head when we examine the relationship between farm production and the wage work participation of rural households. For this reason, the subsequent analysis separates households with and without a wage worker depending on wage work participation of the head.

2.2 Comparison of relevant variables for households with and without a wage worker

We next compare farm inputs and outputs of households with and without a wage worker. Output Y is the sum of gross revenues from grains, economic crops, and livestock products and 10% of the livestock value.[6] When the gross revenues are not available, values consumed of those commodities produced by the household are used.[7] Labor L is the sum of work hours of the family and hired workers in the production of grains, economic crops, and livestock products.[8] Variable input VC for crop production is the sum of production costs of grains and economic crops (excluding costs of hired labor) and the value of grains used for seeds and seedlings. Variable input VL for livestock production is the sum of costs in livestock production (excluding costs of hired labor) and the value of grains used for feed. Farm capital K is the sum of the value of large- and medium-sized tools, machinery and equipment for farming, and livestock used for labor and food. Land T is the sum of cultivated own and rented land.[9] The share *irr_share* of irrigated land areas is used to control for the quality of land.

Table 2 presents means and standard deviations of these variables. In all regions, households without a wage worker produce a higher amount of output than those with a wage worker: the former produce 92%, 41%, and 47% more output in the eastern, central, and western regions, respectively. The much

6 Jacoby (1993) adds 20% of the livestock value in computing the value of outputs, although many other studies do not. The present study uses the intermediate value.

7 For households which miss the data on gross revenues, they are assumed to consume exactly what they produce on their farm. Of the 9,200 households originally included in the survey, the shares of households that miss the data for gross revenues from grains, economic crops, and livestock production are 6%, 8%, and 15%, respectively.

8 We focus on total work hours because hours of hired workers occupy only about 1% in the total hours of family and hired workers on average.

9 Most households in our sample do not rent land from other households. The average share of rented land in total land T is about 8%.

Table 2. Means and Standard Deviations of Variables for Households with and without a Wage Worker

Region	East		Center		West	
With or without a wage worker	With worker	Without worker	With worker	Without worker	With worker	Without worker
Sample size	852	456	1062	627	772	622
X [yuan]	6434 (7727)	12332 (22766)	6526 (5121)	9209 (7622)	6426 (5108)	9424 (8747)
L [hours]	2002 (1538)	3225 (2297)	2061 (1358)	2925 (1716)	2933 (1719)	3810 (2206)
VC [yuan]	1248 (1235)	2098 (3021)	1142 (1123)	1634 (1482)	1056 (1435)	1811 (2394)
VL [yuan]	1485 (5518)	3962 (19940)	1164 (3091)	1480 (4285)	2012 (3409)	2084 (5200)
K [yuan]	1970 (4444)	3317 (4943)	2068 (4190)	3212 (4923)	1601 (2584)	3126 (5467)
T [mu]	5.477 (5.000)	7.962 (9.531)	7.968 (8.005)	10.297 (9.639)	5.808 (4.841)	9.850 (10.10)
irr_share	0.679 (0.391)	0.609 (0.411)	0.573 (0.421)	0.452 (0.424)	0.497 (0.358)	0.511 (0.397)
large_scale	0.266 (0.442)	0.439 (0.497)	0.282 (0.450)	0.394 (0.489)	0.206 (0.405)	0.407 (0.492)
educ6	0.388 (0.488)	0.452 (0.498)	0.503 (0.500)	0.445 (0.497)	0.418 (0.494)	0.354 (0.479)
educ9	0.383 (0.486)	0.296 (0.457)	0.261 (0.439)	0.255 (0.436)	0.281 (0.450)	0.159 (0.366)
educ12	0.095 (0.293)	0.042 (0.200)	0.043 (0.204)	0.018 (0.131)	0.043 (0.202)	0.032 (0.177)
age	45.97 (9.452)	49.33 (9.646)	41.72 (8.756)	46.55 (9.911)	42.62 (9.287)	46.61 (10.90)
nonlabor_inc [yuan/1000]	0.510 (1.646)	0.493 (1.807)	0.437 (1.710)	0.494 (1.720)	0.283 (1.052)	0.303 (1.544)
num_hh	3.609 (1.050)	3.950 (1.195)	3.920 (0.994)	3.997 (1.194)	4.187 (1.260)	4.682 (1.531)
num_childlt6	0.092 (0.297)	0.138 (0.364)	0.179 (0.405)	0.169 (0.419)	0.210 (0.491)	0.259 (0.494)
collective_pest	0.174 (0.379)	0.149 (0.357)	0.116 (0.320)	0.150 (0.357)	0.108 (0.310)	0.272 (0.445)
collective_purchase	0.059 (0.235)	0.039 (0.195)	0.048 (0.214)	0.041 (0.200)	0.039 (0.193)	0.114 (0.318)

Note: Standard deviations are shown in parentheses and units are shown in brackets. One mu is approximately equal to 0.067 ha.

higher output of households without a wage worker is quite natural because their farm work hours should be much longer. In fact, their farm work hours are 61%, 42%, and 30% longer in the eastern, central, and western regions, respectively.

They also use much larger amounts of other inputs. In the eastern region, they use 45–68% more inputs (excluding *VL*) to produce 92% more output. They use 167% more of *VL* partly because they tend to produce more livestock products when the household head does not participate in wage work: the revenue share of livestock products is 22% and 25% for households with and without a wage worker in this region, respectively. In the western region, households without a wage worker use 70–95% more inputs (excluding *VL*) to produce 47% more output. They use only 4% more of *VL*, unlike those households in the eastern region, partly because they tend to produce more crops when the household head does not participate in wage work: the revenue share of livestock products is 41% and 34% for households with and without a wage worker in this region, respectively. Compared to the eastern and western regions, the input-output ratio seems similar between households with and without a wage worker in the central region: households without a wage worker use 27–55% more inputs to produce 41% more output.

These results allow us to make an inference about the productivity of households with and without a wage worker. The productivity of households without a wage worker is inferred to be higher in the eastern region, although they use much more amounts of inputs for livestock production. On the other hand, it is inferred to be lower in the western region, although they use much less amounts of inputs for livestock production. A similar inference for the central region is not so clear at this point. We estimate SPF to check these inferences and decompose the differences in productivity into differences in technology level and technical efficiency.

For the subsequent analysis, we introduce 10 variables to explain technical efficiency *TE* based on other studies (e.g., Chen, Huffman, and Rozelle, 2009; Sherlund, Barrett, and Adesina, 2002), which are shown in Table 3. The last column shows the sign of the effect of each variable on *TE*, which is explained in the following way. A household with larger farm land (*large_scale* = 1) tends to have higher *TE* because it can introduce more effective machinery or inputs in farm production. An increase in the number of household members (*num_hh*) improves *TE* partly because larger households can more easily mobilize labor to meet peak demands at the time of planting and harvesting. An increase in the number of young children (*num_childlt6*) tends to reduce *TE* because family members have to devote more time and attention to rearing young children. Furthermore, collective pest control (*collective_pest* = 1) and collective purchase of inputs (*collective_purchase* = 1) are likely to facilitate farm management to raise *TE*.

Other variables are expected to have positive or negative effects on technical efficiency. More education (*educ6* = 1 or *educ9* = 1 or *educ12* = 1)[10] basically tends to raise *TE* because they increase the head's ability in farm management. On the other hand, higher education of the household head can cause lower *TE* partly because it raises the

10 For households with *educ6* = *educ9* = *educ12* = 0, years of education of the household head are shorter than six.

Table 3. Variables to Explain Technical Efficiency (TE) and Their Expected Effects on TE

Variables	Description of the variables	Effect on TE
large_scale	Dummy variable taking value 1 if the household has larger land than the regional average.	+
educ6	Dummy variable taking value 1 if schooling years of the household head are between 6 and 8.	?
educ9	Dummy variable taking value 1 if schooling years of the household head are between 9 and 11.	?
educ12	Dummy variable taking value 1 if schooling years of the household head are more than 12.	?
age	Age of the household head	?
nonlabor_inc	Household non-labor incomes [yuan]	?
num_hh	Number of household members	+
num_childlt6	Number of children younger than six years old	−
collective_pest	Dummy variable taking value 1 if the village collectively prevents and cures plant diseases and insect pests	+
collective_purchase	Dummy variable taking value 1 if the village provides the service of purchasing farm inputs unified	+

Note: In the column "Effect on TE", the signs show expected effects of the corresponding variables on technical efficiency.

possibility for him to participate in wage work or work longer for wages, which reduces his attention to farm management. Higher age of the household head (*age*) may raise *TE* due to his longer farm experience, while it may lower *TE* due to his weaker physical strength. An increase in non-labor incomes (*nonlabor_inc*)[11] can raise *TE* through more flexible purchase of production inputs, while it might reduce household members' attention to farm production because those incomes in this study might include incomes from non-agricultural family operation.

Table 2 shows that the proportion of households whose head has more than 12 education years is 56%, 58%, and 26% smaller for households without a wage worker in the eastern, central, and western regions, respectively. It also shows that the proportion of households whose head has 9-11 years of education is 23%, 2%, and 43% smaller for households without a wage worker in the same regions. This result is consistent with the result of Jolliffe (2004): farm household members with higher education tend to engage in non-agricultural activities. Households without a wage worker also tend to have more children younger than six years old in the eastern and western regions. Finally, those households tend to receive a much larger amount of collective services of pest control and input purchases in the western region, showing that households can receive those

11 *nonlabor_inc* is the sum of non-wage incomes, subsidies received by joining the survey, net transfers received from the village and town (excluding taxes paid for production activities and wage work), and other incomes. This variable is deflated by the provincial price index estimated by Brandt and Holtz (2006).

services if the head mainly engages in farm production.

3. Empirical Method

A farm household uses labor L, input VC for crop production, input VL for livestock production, farm capital K, and land T to produce output Y. We specify its SPF as [12]

$$\ln Y = \beta_0 + \beta_1 \ln L + \beta_2 \ln VC + \beta_3 \ln VL + \beta_4 \ln K + \beta_5 \ln T + \beta_6 irr\_share + v - u, \quad (1)$$

where irr_share denotes the share of irrigated land areas. We assume that v is a normal random variable with mean 0 and constant variance σ_v^2 and $u \geq 0$ follows a half normal distribution with variance σ_u^2.

Caudill, Ford, and Gropper (1995) emphasize that the heteroskedasticity of inefficiency variable u can have a serious effect on the estimated technical efficiency index. We apply this reason to specify the variance σ_u^2 as [13]

$$\ln \sigma_u^2 = \delta_0 + \sum_{k=1}^{10} \delta_k W_k \quad (2)$$

For variable W_k, we use the 10 variables introduced in the second section.

Equation (2) not only gives a specification of heteroskedasticity of u but also represents the effects of variable W_k on an index of technical efficiency, $TE = E[\exp(-u) \mid W]$, where W includes all variables W_k, and explanatory variables in equation (1) are omitted from conditional variables for simplicity. If $\delta_k > 0$, an increase in W_k raises the variance σ_u^2, which means that non-negative inefficiency u can appear more rightward (non-positive efficiency $-u$ can appear more leftward), which in turn means $TE = E[\exp(-u) \mid W]$ decreases. Hence, variable W_k with positive coefficient δ_k is interpreted as a negative factor of TE. Conversely, if $\delta_k < 0$, an increase in W_k reduces the variance σ_u^2, which means that inefficiency u (and efficiency $-u$) is more likely to appear near 0, which means $TE = E[\exp(-u) \mid W]$ increases. Therefore, variable W_k with the negative coefficient δ_k is interpreted as a positive factor of TE.

We estimate the SPF (1) and the heteroskedasticity function (2) jointly using the maximum likelihood method for each group of households. Specifically, the density function of the error term $\varepsilon = v - u$ under the present assumptions is written as

$$f(\varepsilon) = \{1 - \Phi(\lambda\varepsilon / \sigma)\}(2/\sigma)\phi(\varepsilon/\sigma), \quad (3)$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\lambda = \sigma_u / \sigma_v$. ϕ and Φ respectively denote the density and cumulative distribution functions of the standard normal variable. After substituting equation (2) into $\sigma_u^2 = \exp(\ln \sigma_u^2)$ of equation (3), this density function is used to construct the likelihood function and to estimate parameters in equations (1) and (2) simultaneously. After this estimation, we follow Battese and Coelli (1988) to compute technical efficiency TE as

$$TE = E[\exp(-u) \mid Y] = \{\Phi[(u^*/\sigma_*) - \sigma_*] \big/ \Phi(u^*/\sigma_*)\} \exp[(\sigma_*^2/2) - u^*] \quad (4)$$

where $u^* = -(v-u)\sigma_u^2 / \sigma^2$ and $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$.

To compare the (deterministic) production frontiers for households with and without a

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12 Livestock inputs VL and farm capital K take the value of 0 for some households. In this case, we follow Sherlund, Barrett, and Adesina (2002) to replace the values of these variables with $\zeta/10$ (ζ: the smallest positive value of the relevant variable in the sample).

13 A more popular way might be to assume a truncated normal distribution of technical inefficiency u and specify its mean as a function of W_k. We did adopt this method but could not obtain convergence in the parameters of SPF for our data.

wage worker, we use two approaches. The first is to compare the two sets of coefficients $\beta_1,\cdots,\beta_5$, in equation (1) using the Wald test. The second is to compute an index of predicted output in a manner similar to that of Kumbhakar, Tsionas, and Sipiläinen (2009). Let $\hat{Y}_1$ and $\hat{Y}_0$ denote outputs that can be predicted using deterministic frontiers (the right hand side of equation (1) excluding the terms u and v) of households with and without a wage worker. We compute both these predicted outputs for each household by substituting the actual amount of the five inputs and the actual share of irrigated land into the two deterministic frontiers.

To explain the second method in more detail, we simply express the production frontier of households with a wage worker as $Y = f_1(X)$ and that of households without a wage worker as $Y = f_0(X)$, where X denotes vector of inputs. Suppose household i has a wage worker and uses the amount X_i of inputs. Then, we can compute two predicted outputs $\hat{Y}_{1,i} = f_1(X_i)$ and $\hat{Y}_{0,i} = f_0(X_i)$ for household i. Whereas $\hat{Y}_{1,i}$ represents the largest amount of output when this household uses its own technology $Y = f_1(X)$, $\hat{Y}_{0,i}$ represents the largest amount of output if it could use the other technology $Y = f_0(X)$. Comparison of $\hat{Y}_{1,i}$ and $\hat{Y}_{0,i}$ for the same household allows us to control the amount of inputs and therefore to compare the distributions of $\hat{Y}_1$ and $\hat{Y}_0$.

4. Empirical Results

The SPF specified by equations (1) and (2) is estimated for each region and each type of household after adding village dummy variables.[14 15] Table 4 presents the estimation results. Production elasticities of *L, VC, VL, K,* and *T* are estimated to be significantly positive at the 5% level for all groups of households. Although the coefficient of *irr_share* is not statistically significant for most cases, we keep this variable to achieve convergence in the parameter estimation and obtain plausible results for technical efficiency.[16]

Our production elasticities for the eastern and western regions can be compared with those for the eastern and southwestern regions estimated by Chen, Huffman, and Rozelle (2009) (hereinafter CHR) and those for Jiangsu (eastern) and Sichuan (western) provinces estimated by Liu and Zhuang (2000) (hereinafter LZ). Although our production

14 The numbers of villages in our sample are 204, 242, and 189 for households with a wage worker in the eastern, central, and western regions, respectively. The corresponding numbers for households without a wage worker are 133, 171, and 175.

15 Output *Y* includes both crops and livestock products in our empirical study. If we estimate equations (1) and (2) using this output, the difference in production frontiers or technical efficiency between different groups can arise from the difference in the revenue share of livestock products between them. To examine this possibility, equations (1) and (2) were reestimated by adding the revenue share of livestock products as a regressor in the two equations. The result showed that our essential conclusion was not affected by this consideration. In addition, when this share was computed for households with and without a wage worker, it was 22% and 25% for the eastern region, 24% and 23% for the central region, and 41% and 34% for the western region. The result shows that the difference in composition of farm products is negligible between the two groups for the eastern and central regions, although it might not for the western region.

16 When *irr_share* is excluded, convergence in parameter estimation is not achieved for one group of households and estimated technical efficiency *TE* extremely concentrates near 1 for two groups of households.

Table 4. Estimated Parameters of Stochastic Production Frontiers and Variance Functions for Households with and without a Wage Worker

Region	East		Center		West	
With or without a wage worker	With worker	Without worker	With worker	Without worker	With worker	Without worker
Sample size	852	456	1062	627	772	622
ln$L$	0.2857 (9.15)	0.2268 (4.66)	0.1619 (6.28)	0.1199 (3.00)	0.0732 (2.65)	0.1306 (3.44)
lnVC	0.2486 (10.45)	0.2438 (6.23)	0.2149 (10.97)	0.2578 (8.09)	0.2612 (11.81)	0.1542 (6.33)
lnVL	0.0723 (11.44)	0.0768 (8.32)	0.0831 (15.23)	0.0851 (10.27)	0.0943 (11.63)	0.0903 (9.72)
ln$K$	0.0306 (3.51)	0.0268 (2.04)	0.0274 (4.72)	0.0185 (2.15)	0.0536 (5.91)	0.0181 (2.44)
ln$T$	0.2368 (5.60)	0.2523 (4.36)	0.3202 (10.20)	0.2998 (6.62)	0.2283 (7.12)	0.2572 (6.14)
irr_share	0.1286 (1.24)	0.2041 (1.47)	0.0767 (0.77)	−0.0655 (0.52)	0.0024 (0.03)	0.5213 (4.54)
Variables in σ_u^2 *large_scale*	−2.6660 (1.56)	1.2399 (1.90)	−0.5028 (0.83)	-0.0532 (0.07)	0.2481 (0.55)	−0.9241 (2.57)
educ6	0.0589 (0.12)	−1.2710 (0.84)	−1.1264 (2.77)	−1.1913 (1.13)	0.5948 (1.32)	−0.3349 (1.30)
educ9	−0.2438 (0.46)	1.8546 (1.84)	−1.1666 (2.74)	−1.6632 (1.18)	0.3884 (0.79)	0.3105 (1.00)
educ12	−1.7068 (1.46)	2.5133 (2.01)	−2.3071 (1.58)	0.2469 (0.18)	−0.7545 (1.01)	−1.7696 (1.74)
age	−0.0054 (0.30)	0.0010 (0.02)	−0.0164 (0.77)	−0.0145 (0.34)	−0.0639 (2.70)	0.0092 (0.83)
nonlabor_inc	−0.0896 (0.57)	0.4776 (2.43)	−0.7884 (1.60)	0.2446 (1.87)	0.2017 (2.07)	0.2859 (3.28)
num_hh	−0.5781 (1.96)	−0.3531 (0.95)	−0.1058 (0.60)	−0.2104 (0.53)	−0.8946 (3.44)	−0.0202 (0.25)
num_childlt6	1.1339 (2.07)	−4.2839 (1.28)	0.5063 (1.53)	0.6688 (1.21)	0.4211 (1.39)	0.1387 (0.62)
collective_pest	−1.7716 (0.78)	5.3993 (3.78)	1.4708 (2.12)	2.5197 (1.45)	3.0937 (5.05)	−0.6131 (1.24)
collective_purchase	1.0109 (1.05)	1.8216 (0.65)	−0.1508 (0.16)	−5.1524 (1.14)	−0.5240 (0.79)	−27.6097 (0.02)
constant	−0.2193 (0.15)	−6.2973 (2.11)	−1.5029 (1.40)	−2.7877 (1.11)	1.5701 (1.12)	−2.1557 (2.99)
σ_v	0.3633 (24.25)	0.3858 (27.64)	0.2779 (22.85)	0.2793 (19.96)	0.2426 (25.31)	0.2157 (14.94)
log-likelihood	−405.34	−241.67	−227.68	−114.00	−89.30	−104.35
LR test of homoskedasticity	26.08 [0.00]	36.44 [0.00]	26.90 [0.00]	16.71 [0.08]	Not available	44.22 [0.00]

Note: Absolute values of the t statistics are shown in parentheses and the upper tail area for $\chi^2(10)$ is in brackets. To save space, the estimated coefficients of the village dummy variables and the constant term of SPF are not shown.

elasticity of labor (0.29 or 0.23 for east and 0.07 or 0.13 for west) tends to be higher than that of CHR and LZ, it is similar to CHR (0.12 for east and 0.07 for southwest) because the elasticity is higher in the eastern region. On the other hand, our production elasticity of land (0.24 or 0.25 for east and 0.23 or 0.26 for west) is much lower than that of CHR and LZ, which is higher than 0.40. Our production elasticity of farm capital (0.03 for east and 0.05 or 0.02 for west) also tends to be lower than that of CHR and LZ, which is between 0.01 and 0.20. The differences in these results arise probably because outputs and inputs in this study cover livestock production, whereas those in CHR and LZ do not.

4.1 Comparison of production frontiers

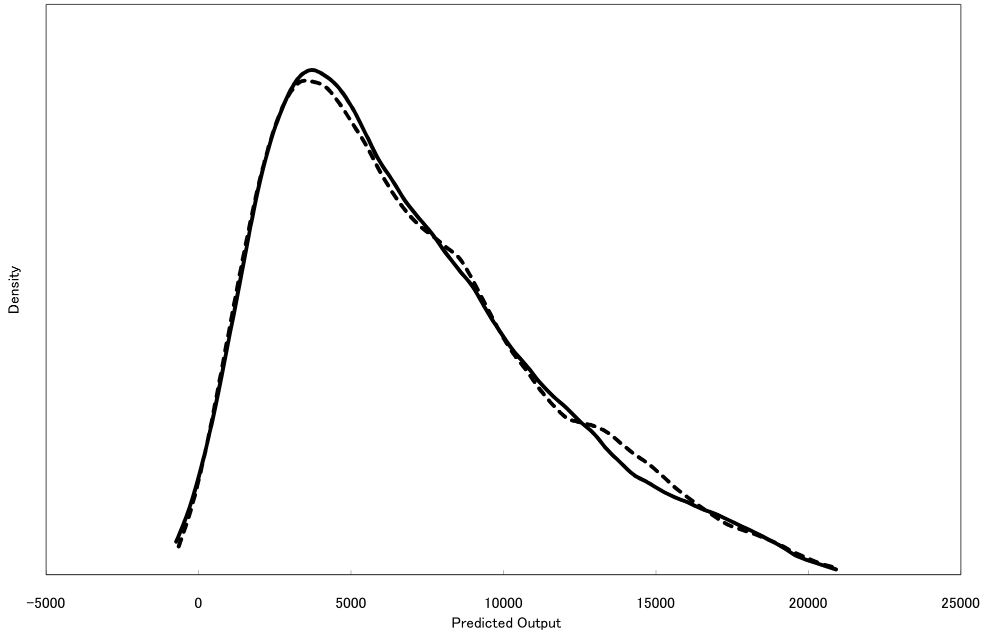
First, we briefly compare the production elasticities between households with and without a wage worker. Although production elasticities of *VL* and *T* are similar between the two groups for any region, those of *L*, *VC*, and *K* differ for most cases. We use the Wald test to check equivalence across the five production elasticities between the two groups. The test statistics are computed as 1.29 [0.94], 2.53 [0.77], and 24.89 [0.00] for the eastern, central, and western regions, respectively, which can be compared with critical values of χ^2 distribution with five degrees of freedom (p-values are shown in brackets). The result shows that equivalence of the deterministic production frontiers of the two groups is not rejected for the eastern and central regions, whereas it is rejected for the western region.

Next, we compare the deterministic frontiers between the two groups of households by following the method of Kumbharkar, Tsionas, and Sipiläinen (2009).[17] The averages of the predicted outputs $\hat{Y}_1$ and $\hat{Y}_0$ (maximum outputs that can be produced using technologies of households with and without a wage worker) are 7,792 (6,557) and 9,560 (18,347) for the eastern region, 7,942 (4,795) and 8,493 (8,409) for the central region, and 8,116 (5632) and 9,641 (6,801) for the western region, where standard deviations are shown in parentheses. Therefore, on average, the deterministic frontier is higher for households without a wage worker in all regions after controlling for input amounts.

Because the average of $\hat{Y}_1$ and $\hat{Y}_0$ can be sensitive if their distributions are skewed, we compare their kernel density (a smoother version of the histogram) for each region in Figure 1 (a)–(c). In these figures, the horizontal axis measures the amount of predicted output ($\hat{Y}_0$ or $\hat{Y}_1$) and the vertical axis measures its density, with the dotted and solid lines respectively drawn for $\hat{Y}_0$ and $\hat{Y}_1$. For the eastern and central regions, $\hat{Y}_0$ and $\hat{Y}_1$ seem to have a similar distribution, although $\hat{Y}_1$ has a little higher density at smaller output and $\hat{Y}_0$ tends to have a little higher density at larger output. For the western region, the distribution of $\hat{Y}_0$ is located more rightward for any output

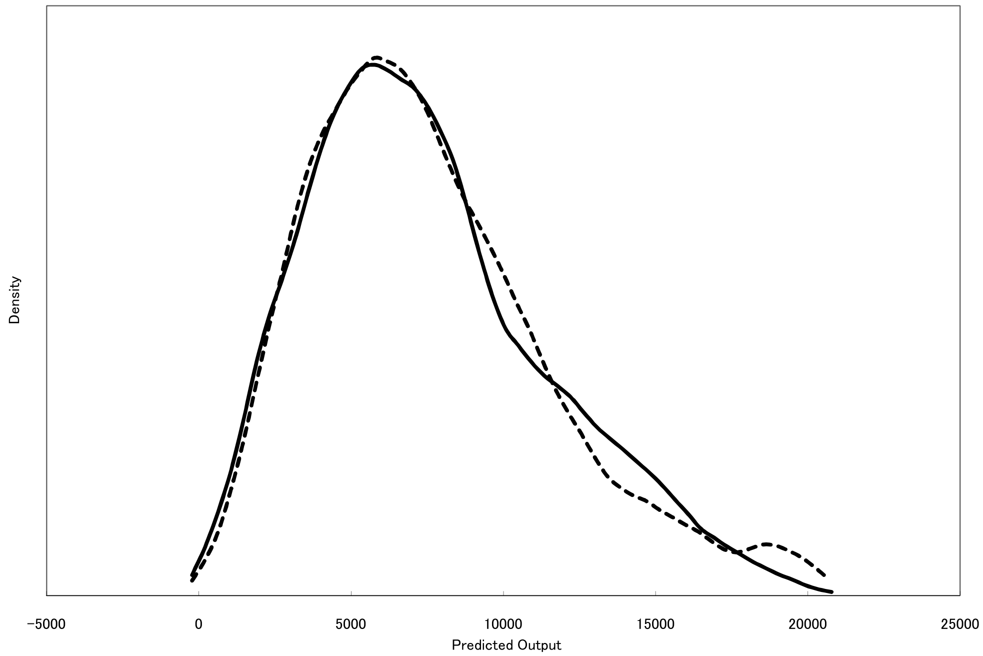
17 Because villages in the sample differ for the two groups of households, we evaluate the intercept of the SPF in the following way. For a village that includes both groups of households, we evaluate its intercept using the constant term and the coefficient of the corresponding village dummy. For a village that includes only households with a wage worker in the sample, we evaluate its intercept to compute $\hat{Y}_1$ in the same way as above. For this village, however, we evaluate its intercept to compute $\hat{Y}_0$ using the constant term and the average of available coefficients of village dummies. A similar procedure is applied to the evaluation of the intercept for a village that includes only households without a wage worker in the sample.

Figure 1 (a). Distributions of Predicted Outputs under Production Technologies of Households with and without a Wage Worker (Eastern Region)



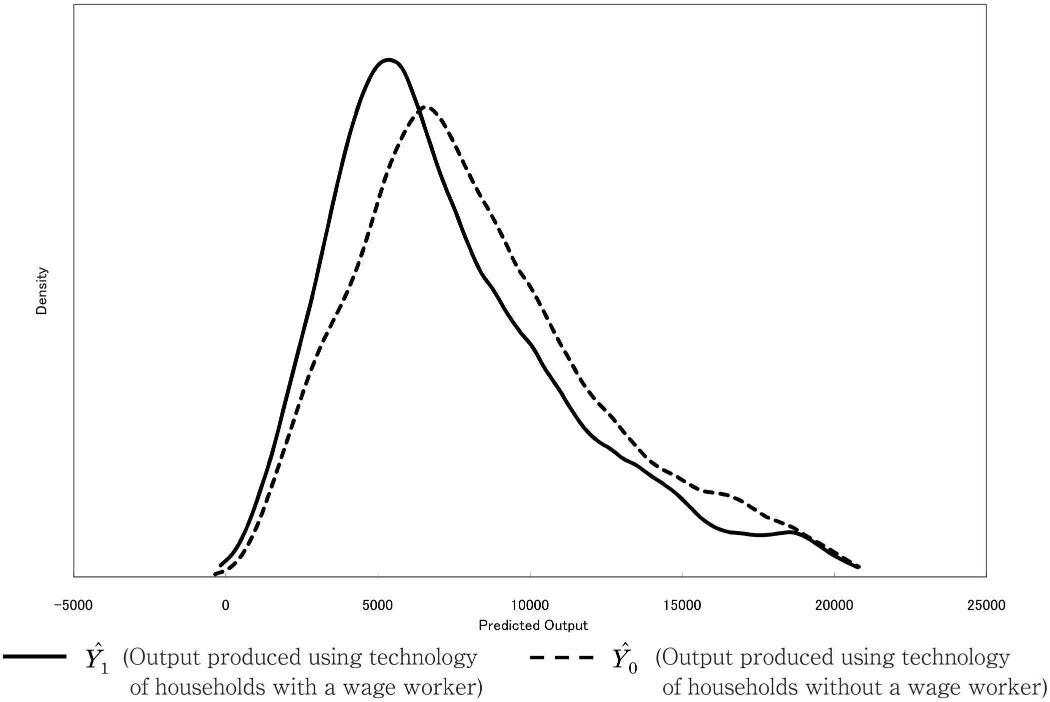
—— $\hat{Y}_1$ (Output produced using technology of households with a wage worker)　　- - - $\hat{Y}_0$ (Output produced using technology of households without a wage worker)

Figure 1 (b). Distributions of Predicted Outputs under Production Technologies of Households with and without a Wage Worker (Central Region)



—— $\hat{Y}_1$ (Output produced using technology of households with a wage worker)　　- - - $\hat{Y}_0$ (Output produced using technology of households without a wage worker)

Figure 1 (c). Distributions of Predicted Outputs under Production Technologies of Households with and without a Wage Worker (Western Region)



level. Consequently, the deterministic frontier of households without a wage worker is higher only for households with relatively large output in the eastern and central regions, whereas it is always higher in the western region. This finding is consistent with the result of the Wald test above.

The higher production frontier of households without a wage worker can be attributed to their higher production elasticities, their higher coefficient on irrigation share, or the higher intercept of their production frontier. For the eastern region, the production elasticities are similar between the two types of households and the production elasticity of labor is lower for households without a wage worker.[18] Therefore, their higher production frontier is inferred to come from their higher intercept or their higher managerial ability and land quality which cannot be observed by researchers. A similar explanation seems to apply to the result for the central region, although households without a wage worker have a slightly higher production elasticity of crop inputs.

For the western region, households without a wage worker have a higher production elasticity of labor and a higher coefficient of irrigation share. Their higher coefficient of irrigation share suggests that it is difficult to effectively manage water use without the

18 The lower production elasticity of labor for households without a wage worker in the eastern region suggests the increasing number of farm households which are managed by the elderly. In fact, Table 2 shows that the average age of the household head is the highest for households without a wage worker in this region.

household head working on farm actively because the western region is more likely to suffer from natural disasters.[19] Regarding the higher production elasticity of labor, the household head tends to have lower farm productivity due to lower quality (or effort) of his labor when he engages in full-time wage employment and works on farm only at peak seasons.

4.2 Comparison of technical efficiency and its determinants

Table 4 also presents the estimated coefficients of the heteroskedasticity function (2). Many of the individual coefficients are statistically insignificant at the 5% level, suggesting some difficulty in estimating effects of those factors on technical inefficiency using the variance σ_u^2. Nonetheless, the likelihood ratio test for homoskedasticity of technical inefficiency u reveals joint significance of coefficients δ_k ($k=1,\cdots,10$) in equation (2), as shown at the bottom of Table 4.[20] For this reason, we use the results under heteroskedasticity for the subsequent discussion.[21]

Before interpreting the significant coefficients in Table 4, we compare technical efficiency (TE) between households with and without a wage worker, which is estimated using equation (4). The average TE for households with and without a wage worker are 0.86 (0.09) and 0.92 (0.13) for the eastern region, 0.88 (0.07) and 0.92 (0.07) for the central region, and 0.88 (0.10) and 0.81 (0.13) for the western region, where standard deviations are shown in parentheses. The average TE is higher for households without a wage worker in the eastern and central regions, while it is higher for those with a wage worker in the western region. The two studies CHR and LZ cited above estimate TE at 0.73–0.77 for the eastern region and 0.55–0.69 for the (south) western regions using the data on crop production in China. Our estimates are higher than theirs but are similar in that the average TE is lower in the western region. Our higher estimates seem plausible partly because our inputs and outputs cover livestock production, for which Latruffe et al. (2004) find a 15% higher TE than for crop production in Poland.

Figure 2 (a)–(c) depict the kernel density of TE for the two groups of households in each region. The horizontal axis measures TE and the vertical axis measures its density, with the solid and dotted lines respectively drawn for households with and without a wage worker. Unlike Figure 1, Figure 2 exhibits distinct distributions for the two groups in all regions. For the eastern and central regions, TE for households without a wage worker concentrates around 0.95–0.99, whereas TE for households with a wage worker has a wider distribution with its mode locating

19 The Administrative Village Questionnaire annexed to CHIP2002 shows that 45%, 49%, and 66% of villages in the eastern, central, and western regions had natural disasters in 2002.

20 For households with a wage worker in the western region, we cannot compute the test statistic because parameter convergence is not achieved under homoskedasticity of u. However, the individual coefficients of *age, nonlabor_inc, num_hh,* and *collective_pest* are significant, suggesting rejection of homoskedasticity for this case.

21 Another reason to use all those factors is to achieve parameter convergence and obtain plausible results for technical efficiency. When we assume homoskedasticity of *u,* parameter convergence is not achieved for one case and technical efficiency extremely concentrates near 1 for four cases.

Figure 2 (a). Distributions of Technical Efficiency Index for Households with and without a Wage Worker (Eastern Region)

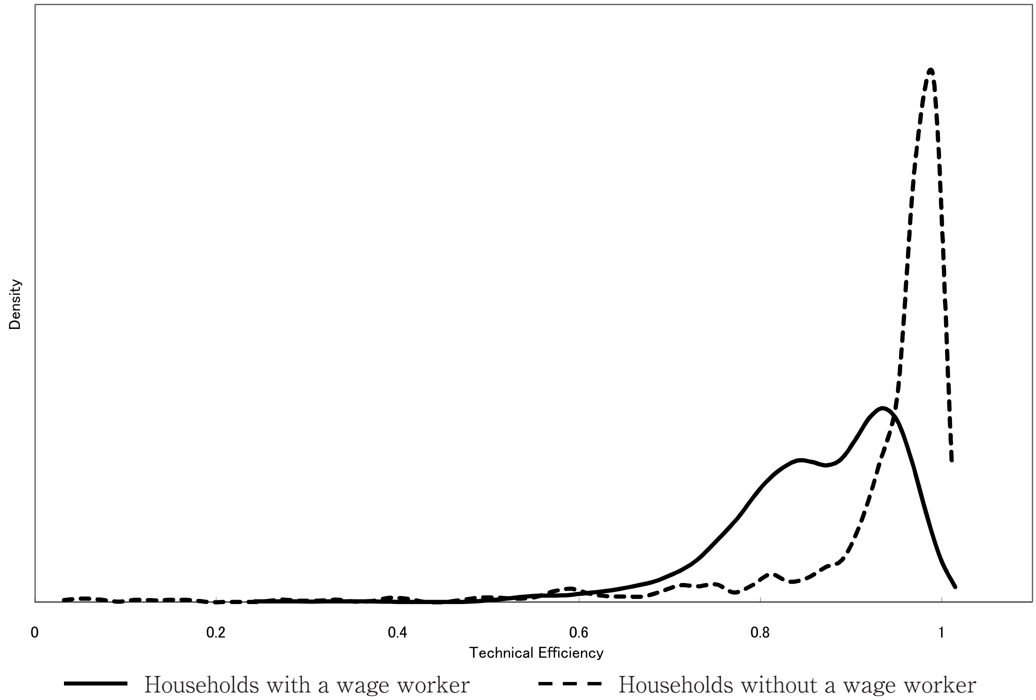


Figure 2 (b). Distributions of Technical Efficiency Index for Households with and without a Wage Worker (Central Region)

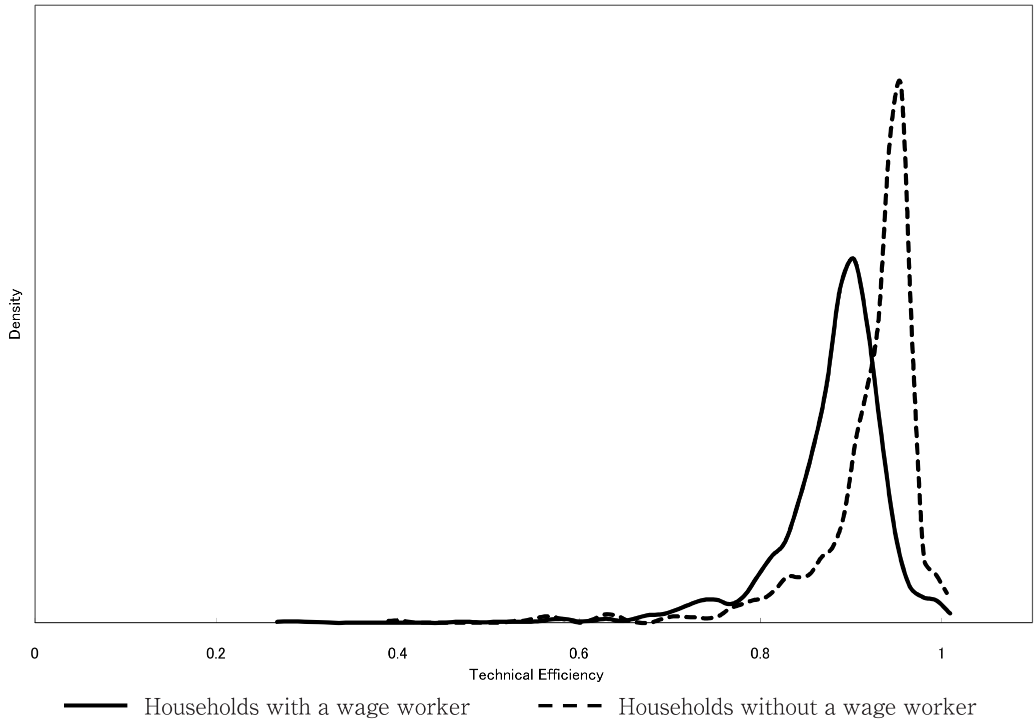
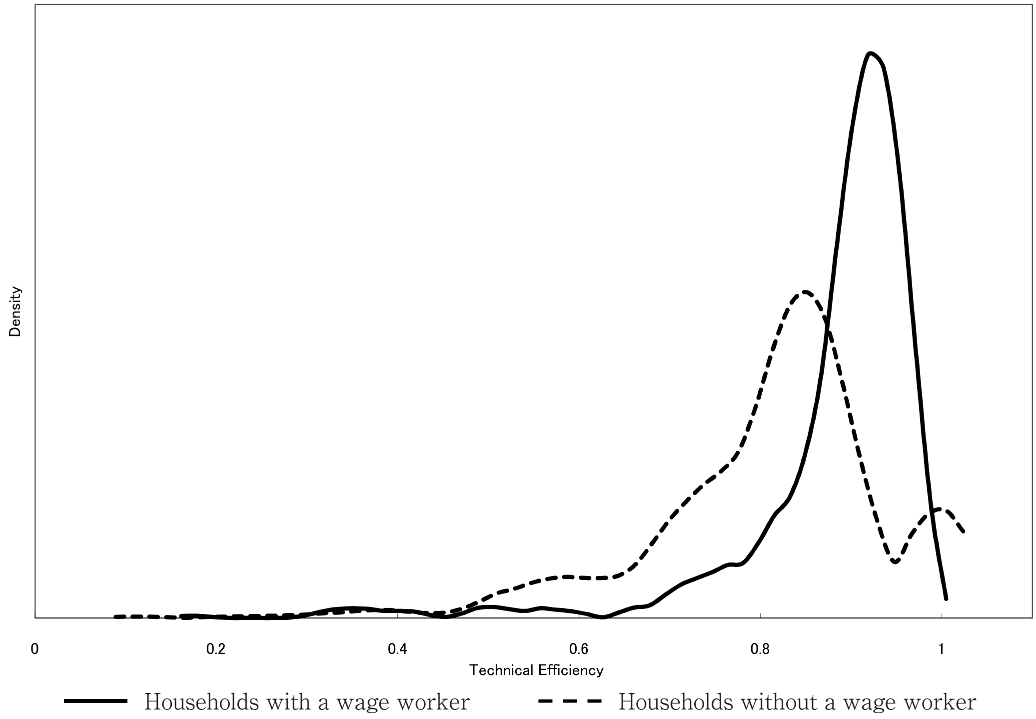


Figure 2 (c). Distributions of Technical Efficiency Index for Households with and without a Wage Worker (Western Region)



around 0.90–0.94. For the western region, on the contrary, the former has a wider distribution with its mode locating around 0.85, whereas the latter concentrates around 0.92.

In summary, households without a wage worker are more technically efficient in the eastern and central regions, whereas those with a wage worker are more technically efficient in the western region. To investigate reasons for this result, we first examine effects of the variables W_k in equation (2) on technical efficiency *TE*. Table 5 presents the result of regression of estimated *TE* on these variables. Although this method might cause biased estimates of the parameters, as pointed out by Wang and Schmidt (2002), we find the result in Table 5 to be plausible because we obtain a similar result by applying the interpretation of the coefficient δ_k (variable W_k with $\delta_k > 0$ has a negative effect on *TE*) to their estimates in Table 4. Therefore, we use the result in Table 5 to examine statistically significant effects of W_k on *TE*.

Variables *large_scale, num_hh, num_childlt6, collective_pest,* and *collective_purchase* have expected effects on *TE* in most cases. As we examined in Table 3, larger cultivated land, more household members, fewer children, and more collective pest control and input purchase raise technical efficiency. The three education dummies have positive coefficients for most cases, implying that households with higher education (than those with schooling years shorter than six years) have higher *TE*. The negative coefficient for households without a wage worker in the eastern region suggests that the household head tries harder to search for wage work if he has relatively high education (*educ9*=1) but he does not participate in the labor market, which can

Table 5. Results of Ordinary Least Squares Regression of Technical Efficiency

Region	East		Center		West	
With or without a wage worker	With worker	Without worker	With worker	Without worker	With worker	Without worker
Sample size	852	456	1062	627	772	622
large_scale	0.1101 (14.07)	−0.0351 (1.80)	0.0248 (4.16)	−0.0068 (0.93)	−0.0170 (1.62)	0.0713 (3.69)
educ6	−0.0081 (1.08)	0.0149 (1.11)	0.0653 (10.32)	0.0494 (8.45)	−0.0265 (3.34)	0.0266 (2.38)
educ9	0.0119 (1.49)	−0.0556 (3.82)	0.0671 (10.55)	0.0621 (11.67)	−0.0212 (2.35)	0.0097 (0.53)
educ12	0.0777 (8.50)	−0.0471 (0.90)	0.1039 (11.32)	−0.0167 (1.11)	0.0382 (1.94)	0.1035 (2.75)
age	0.0001 (0.32)	0.0004 (1.01)	0.0008 (4.13)	0.0004 (2.15)	0.0024 (7.81)	−0.0013 (2.17)
nonlabor_inc	0.0039 (3.15)	−0.0204 (6.42)	0.0106 (5.08)	−0.0122 (7.37)	−0.0112 (3.06)	−0.0065 (0.57)
num_hh	0.0306 (10.99)	0.0068 (1.83)	0.0046 (2.63)	0.0078 (4.67)	0.0339 (13.12)	0.0094 (2.21)
num_childlt6	−0.0593 (7.15)	0.0372 (3.04)	−0.0295 (5.20)	−0.0276 (3.59)	−0.0286 (4.51)	−0.0292 (2.79)
collective_pest	0.1451 (2.34)	−0.0698 (1.23)	−0.0367 (1.59)	0.0466 (1.51)	−0.1912 (3.69)	0.1967 (0.79)
collective_purchase	−0.1087 (1.68)	0.0162 (0.30)	−0.0061 (0.33)	0.0482 (4.29)	0.0727 (1.38)	0.1244 (3.73)
$\overline{R}^2$	0.5995	0.7071	0.4892	0.7072	0.5920	0.2964

Note: Absolute values of the t statistics (based on robust standard errors) are shown in parentheses. To save space, the estimated coefficients of the village dummy variables and the constant term are not shown. $\overline{R}^2$ denotes the adjusted coefficient of determination.

lower *TE*. The negative coefficient for households with a wage worker in the western region suggests that the household head tends to have a relatively stable job (rather than a seasonal or temporary job) as wage work, which can reduce attention to farm production to lower *TE*.

Furthermore, age of the household head (*age*) has a positive effect on *TE* for most cases, implying that longer farm experience tends to raise technical efficiency. Non-labor incomes (*nonlabor_inc*) have a negative effect on *TE* for households without a wage worker partly because their family members might engage in non-agricultural family operation and they might lose their attention to farm production. On the other hand, non-labor incomes tend to have a positive effect on *TE* for those with a wage worker partly because non-labor incomes in addition to wage incomes further facilitate flexible purchase of production inputs.

Finally, we find some reasons for the different *TE* between households with and without a wage worker by comparing the regression coefficients in Table 5 and the sample means of W_k in Table 2.[22] If we focus

22 The idea is similar to the Oaxaca-Blinder decomposition.

only on statistically significant coefficients and marked difference in sample means of W_k, we find the following factors important to explain higher *TE* for the relevant households. For the eastern region, households without a wage worker are more technically efficient because the higher coefficient of *num_childlt6* and the higher mean of *large_scale* contribute to the higher *TE* for these households.[23] For the central region, households without a wage worker are more technically efficient because the higher coefficient of *collective_purchase* and the higher mean of *large_scale* contribute to the higher *TE* for these households. Therefore, households without a wage worker in both the eastern and central regions are more technically efficient partly because of their larger farm land. For the western region, households with a wage worker are more technically efficient because the higher coefficient of *age* and *num_hh* and the higher mean of *educ12* contribute to the higher *TE* for these households.[24] Therefore, they have higher *TE* because they have more members with higher education and because they are better at raising technical efficiency from longer experience on farm and more family members.

5. Concluding Remarks

This study uses a Chinese household income survey from 2002 to estimate stochastic production frontiers for farm households with and without a wage worker to determine effects of the head's participation in wage work on farm productivity in China. Using the estimated frontiers, it compares deterministic production frontiers (technology levels) and technical efficiency of the two groups of households and examines determinants of technical efficiency.

In the eastern and central regions, typical households with a wage worker tend to have lower farm productivity because of their lower technical efficiency. We can attribute this lower technical efficiency to their smaller farm land. One implication of this result is that domestic food supply in these regions will stagnate or deteriorate as rural household heads participate more in wage work as economic development provides more opportunities to increase nonfarm income. To improve the lower technical efficiency in these regions, an important policy is to make the land market more active and allow farm households to expand their cultivated land.

In the western region, typical households with a wage worker may have higher farm productivity because of their higher technical efficiency. We can attribute this higher technical efficiency to better education of the household head and better utilization of farming knowledge and family members. One implication of this result is an increase in domestic food supply in this region along with further economic development. This improvement, however, might be limited because it depends on more farm work by women and the elderly. To make the domestic food supply sustainable, it is important to encourage farmers in this region to use more farm machinery and a newer variety of crops, which not only helps women and the elderly improve farm production but also boosts the

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23 Note that *num_childlt6* has a positive effect on *TE* for these households.

24 Note that *age* has a negative effect on *TE* for households without a wage worker probably because weaker physical strength of older members can decrease *TE* in the western region where the value share of livestock production is much higher.

production frontier to increase the domestic food supply in this region.

References

Battese, G. E. and T. J. Coelli (1988). "Prediction of Firm-Level Technical Efficiencies with a Generalised Frontier Production Function and Panel Data." *Journal of Econometrics* 38, pp. 387–399.

Brandt, L. and C. Holtz (2006). "Spatial Price Differences in China: Estimates and Implications." *Economic Development and Cultural Change* 55, pp. 43–86.

Caudill, S. B., J. M. Ford and D. M. Gropper (1995). "Frontier Estimation and Firm-Specific Inefficiency Measures in the Presence of Heteroscedasticity." *Journal of Business & Economic Statistics* 13, pp. 105–111.

Chang, H., X. Dong, and F. Macphail (2011). "Labor Migration and Time Use Patterns of the Left-behind Children and Elderly in Rural China." *World Development* 39, pp. 2199–2210.

Chang, H. and F. Wen (2011). "Off-Farm Work, Technical Efficiency, and Rice Production Risk in Taiwan." *Agricultural Economics* 42, pp. 269–278.

Chen, Z., W. E. Huffman, and S. Rozelle (2009). "Farm Technology and Technical Efficiency: Evidence from Four Regions in China." *China Economic Review* 20, pp. 153–161.

Goodwin, B. K. and A. K. Mishra (2004). "Farming Efficiency and the Determinants of Multiple Job Holding by Farm Operators." *American Journal of Agricultural Economics* 86, pp. 722–729.

Gustafsson, B. A., S. Li, and T. Sicular (2008). *Inequality and Public Policy in China.* New York: Cambridge University Press.

Herdt, R. W. and A. M. Mandac (1981). "Modern Technology and Economic Efficiency of Philippine Rice Farmers." *Economic Development and Cultural Change* 29, pp. 375–399.

Jacoby, H. G. (1993). "Shadow Wages and Peasant Family Labour Supply: An Econometric Application to the Peruvian Sierra." *Review of Economic Studies* 60, pp. 903–921.

Jolliffe, D. (2004). "The Impact of Education in Rural Ghana: Examining Household Labor Allocation and Returns on and off the Farm." *Journal of Development Economics* 73, pp. 287–314.

Knight, J., Q. Deng, and S. Li (2011). "The Puzzle of Migrant Labour Shortage and Rural Labour Surplus in China." *China Economic Review* 22, pp. 585–600.

Kumbharkar, S. C., E. G. Tsionas, and T. Sipiläinen (2009). "Joint Estimation of Technology Choice and Technical Efficiency: An Application to Organic and Conventional Dairy Farming." *Journal of Productivity Analysis* 31, pp. 151–161.

Latruffe, L., K. Balcombe, S. Davidova, and K. Zawalinska (2004). "Determinants of Technical Efficiency of Crop and Livestock Farms in Poland." *Applied Economics* 36, pp. 1255–1263.

Li, S. (2002). *Chinese Household Income Project, 2002* [Computer file]. ICPSR21741-v1. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2009-08-14. doi: 10.3886/ICPSR21741.

Liu, Z. and J. Zhuang (2000). "Determinants of Technical Efficiency in Post-Collective Chinese Agriculture: Evidence from Farm-Level Data." *Journal of Comparative Economics* 28, pp. 545–564.

Mochebelele, M. T. and A. Winter-Nelson (2000). "Migrant Labor and Farm Technical Efficiency in Lesotho." *World Development* 28, pp. 143–153.

Mu, R. and D. van de Walle (2011). "Left behind to Farm? Women's Labor Re-Allocation in Rural China." *Labour Economics* 18, pp. S83–S97.

Pfeiffer, L., A. Lopez-Feldman, and J. E. Taylor (2009). "Is Off-Farm Income Reforming the Farm? Evidence from Mexico." *Agricultural Economics* 40, pp. 125–138.

Sherlund, S. M., C. B. Barrett and A. A. Adesina (2002). "Smallholder Technical Efficiency Controlling for Environmental Production

Conditions." *Journal of Development Economics* 69, pp. 85–101.

Wang, H. and P. Schmidt (2002). "One-Step and Two-Step Estimation of the Effects of Exogenous Variables on Technical Efficiency Levels." *Journal of Productivity Analysis* 18, pp. 129–144.

Yang, L. (2003). "Rural Labor Migration Choice in China and Its Impacts on Rural Households." Chicago: Department of Economics, University of Chicago.

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Effects of Household Heads' Wage Work on Farm Technology Level and Technical Efficiency in China

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Keywords: Wage Work, Technology Level, Technical Efficiency, Chinese Farmers
JEL Classification: Q16, Q18

This study investigates the effects of a household head's participation in wage work on farm productivity in China. To this end, we use a Chinese household income survey from 2002, which includes 4,391 households in 22 provinces, autonomous regions, and directly administered municipalities. For this data set, we estimate stochastic production frontiers (SPF) separately for farm households whose head is a wage worker (households with a wage worker) and those whose head is not a wage worker (households without a wage worker). After estimating SPF for each group of households, we compare the deterministic production frontiers and technical efficiency.

The empirical results for the eastern and central regions show that typical households with a wage worker tend to have lower farm productivity because of their lower technical efficiency. This lower technical efficiency is due to their smaller farm land. To improve technical efficiency in these regions, the government should try to make the land market more active and allow farm households to expand their land.

The empirical results for the western region show that typical households with a wage worker may have higher farm productivity because of their higher technical efficiency. This higher technical efficiency is due to better education of the household head and better utilization of farming knowledge and family members. However, the higher technical efficiency depends on more farm work being carried out by women and the elderly, which might not be sustainable in the future. To address this concern, the government should encourage farmers to use more farm machinery and newer varieties of crops so that their production frontier can shift upward.