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Determinants of Factor Misallocation in Agricultural Production and Implications for Agricultural Supply-side Reform in China

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Abstract

Allocative inefficiency in agriculture is an issue puzzling researchers and policy-makers in China. Based on household data from the China Family Panel Studies of 2012, the present paper quantifies the potential distortions in China's agricultural production and examines their underlying determinants across regions. The results reveal that there are different levels of distortions across regions. The Middle region is facing the greatest distortion. Increases in machinery input, the proportion of non-farm income and effective labor input will reduce distortions. Household saving, farmland rent and farmland size are significantly positively related to distortions. There is a complementary effect between labor and farmland in alleviating production inefficiency, but substitution effects exist between capital and farmland and also capital and labor. The increase in farmland size will aggravate the impact of capital on distortions. Given the constraint of super small-scale farmland, facilitating land transfer is a necessary precondition for improving allocative efficiency.

Key words: allocative efficiency, factor misallocation, total factor productivity
JEL codes: D13, D24, Q12

I. Introduction

Under assumptions of constant supply of available production factors and accessible management know-how, traditional small farmers are believed to be reasonably efficient at allocating their available resources as a response to price incentives, even when they are trapped in a low equilibrium in a given institutional framework and have limited

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resources at their disposal (Schultz, 1964). Schultz's "poor-but-efficient" hypothesis has been one of the enduring themes in rural development economics over the past three decades. One strand of criticism against Schultz's perspective relates to the applicability of modern economics tools in understanding the situation in poor countries; a second line of criticism focuses on the existence of surplus labor (Abler and Sukhatme, 2006). The sources of total factor productivity have emerged as the core issue of development economics research (Hayami and Ruttan, 1970), and allocative inefficiency arising from factor misallocation is becoming an issue of much concern among development economists. A full account of the allocative efficiency of all factors is too ambitious due to the lack of data in agricultural economic research (Caselli and Feyrer, 2007). "Many empirical contributions to this discussion treat efficiency as a black-box concept and lack the explicit consideration of the scale of agricultural production" (Sauer and Mendozaescalante, 2007, p. 114). The sources of distortions have been poorly explained, and the effects of other institutional factors, industry characteristics and demographic factors on distortions have been neglected (Aoki, 2008). These issues inevitably hinder the process of improving allocative efficiency in agricultural production.

Although the increase in total factor productivity (TFP) has made a major contribution to agricultural growth as a result of technical progress and institutional improvement (Lin, 1992), the misallocation of resources (Zhu et al., 2011) and the barriers to factor mobility have retarded the economic growth in China (Yuan and Xie, 2011). Factor misallocation is common in agricultural production in China, yet little attention has been given to the determinants of misallocation in China (Guo and Jia, 2005). How is agricultural allocative efficiency impacted by distortions of production factors? What are the determinants of factor misallocation? All of these questions have remained unanswered. With specific attention to agriculture in China, the present study aims to answer the abovementioned questions by evaluating the extent of agricultural distortions and investigating the determinants of these distortions.

This study has two primary goals. First, it measures the level of distortions in agricultural production to show how distortions drive wedges between the marginal products of capital and labor across regions. Following Hsieh and Klenow's framework and the extended application for Chinese agriculture by Zhu et al., the allocative distortions of capital and labor and a factor distortion index are calculated based on farm-level data (Hsieh and Klenow, 2009; Zhu et al., 2011). Second, the sources of agricultural distortions, including the effect of capital structure, farm size, labor migration and the interactive effects of input factors, will be examined. Finally, policy recommendations are made. The rest of this paper proceeds as follows. Section II elaborates on the determinants of distortions, and the methodology and data used in this study. The measurement of distortions is also reported in this section. Regressive analyses on determinants underlying distortions based on micro-level survey data and empirical results are reported in Section III. Finally, Section IV concludes, presenting key findings and policy implications.

II. Determinants of Distortions

1. Sources of Distortions

Following Hsieh and Klenow (2009), a typical farmer is supposed to produce a single final agricultural product (Y) by employing the inputs of capital (K), labor (L) and farmland (M) in a perfectly competitive market. For the purpose of simplicity, as indicated by Luo (2000), it is assumed that there is constant returns to scale, and the production function of farmer i is given as a modified Cobb–Douglas production function "mainly because of its ease in manipulation and interpretation" (Hayami and Ruttan, 1970, p. 898):

$$Y_i = A_i K_i^{\alpha} L_i^{\beta} \overline{M}_i^{\gamma}, \tag{1}$$

where Y_i denotes the real output value of household i; K_i, L_i and M_i are the real capital, labor and farmland inputs of household i, respectively; and $\alpha + \beta + \gamma = 1$. TFP is measured by A_i. Farmland input is given as fixed in the model. Consistent with previous research (Zhu et al., 2011), the restrictions of the farmland property rights system and the transaction costs associated with farmland transfer make it difficult for farmers to adjust their scale of operation to create an ideal situation in the short term.

Economic efficiency can be grouped into technical efficiency and allocative efficiency (Farrell, 1957), where technical efficiency aims to minimize inputs and allocative efficiency can be achieved at a point where the marginal products of input factors equal their marginal costs (Farrell, 1957). Allocative inefficiency refers to the failure in meeting these marginal conditions as a result of inadequate information, risk aversion, capital constraints, institutional constraints and failure of factor markets (Ali and Byerlee, 2002). Distortions of factor prices, which are identified as "taxes" or "wedges," are believed to be the main cause of allocative inefficiency (Restuccia and Rogerson, 2004). Taxes on factor prices may be derived from paying for access to intermediation or a banking system, underinvestment caused by risk of expropriation, discriminatory policy, shocks to assets market (Banerjee and Moll, 2010), limited access to cheap credit (Hsieh and Klenow, 2009), or financial credit market imperfections (Jeong and Townsend, 2007). All of these circumstances could distort factor allocation by adding tax on prices (Aoki, 2008).

It is assumed that farmers potentially face capital distortion τK_i and labor distortion τL_i, given the prices of capital as r and wage as ω. Under the assumption of linear taxes on input factors, the actual costs of capital and labor of household i are given as $(1 + \tau K_i)\ r$ and $(1 + \tau L_i)\ \omega$, respectively. Taking into account distortions, the profit maximization of household i is given by:

$$\pi_i = PA_iK_i^{\alpha}L_i^{\beta}\overline{M}_i^{\gamma} - (1 + \tau_{K_i})\, r\, K_i - (1 - \tau_{L_i})\,\omega L_i. \tag{2}$$

First-order conditions of profit maximization are as follows:

$$\frac{\partial \pi_i}{\partial K_i} = \alpha PA_iK_i^{\alpha-1}L_i^{\beta}\overline{M}_i^{\gamma} - (1 + \tau_{K_i})\, r = 0, \tag{3}$$

$$\frac{\partial \pi_i}{\partial L_i} = \beta PA_iK_i^{\alpha}L_i^{\beta-1}\overline{M}_i^{\gamma} - (1 - \tau_{L_i})\,\omega = 0. \tag{4}$$

The factor distortion equates to the disparity in factors' marginal products (Banerjee and Moll, 2010). The marginal revenue product of labor is proportional to revenue per farmer and the marginal revenue product of capital is proportional to the revenue per unit of capital:

$$MRPL_i \equiv \frac{\beta PY_i}{L_i} = \omega(1 - \tau_{L_i}), \tag{5}$$

$$MRPK_i \equiv \frac{\alpha PY_i}{K_i} = r(1 + \tau_{K_i}). \tag{6}$$

As the capital–labor ratio K/L can be expressed by capital and labor distortion $(1 + \tau K_i)$ and $(1 - \tau L_i)$, the real output Y_i can be expressed as:

$$Y_i = A_i^{*\frac{1}{1-(\alpha+\beta)}} P^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\alpha}{\gamma}\right)^{\frac{1}{1-(\alpha+\beta)}} \left(\frac{\beta}{\omega}\right)^{\frac{1}{1-(\alpha+\beta)}} \frac{1}{(1 + \tau_{K_i})^{\frac{\alpha}{1-(\alpha+\beta)}}(1 - \tau_{L_i})^{\frac{\beta}{1-(\alpha+\beta)}}}$$

$$\propto \left[A_i^{*} \frac{1}{(1 + \tau_{K_i})^{\alpha}(1 - \tau_{L_i})^{1-\alpha}}\right]^{\frac{1}{1-(\alpha+\beta)}}. \tag{7}$$

Therefore, the distortion index of household i can be expressed as follows:

$$DI_i = (1 + \tau_{K_i})^{\alpha}(1 - \tau_{L_i})^{1-\alpha}. \tag{8}$$

Moreover, the aggregate distortion of a given region could be measured as a weighted average of household capital distortion and labor distortion, represented by the household distortion index and its variance:

$$\overline{DI} = (1 + \overline{\mu_{KL}})^{\alpha}(1 - \overline{\mu_L}), \tag{9}$$

where $\overline{\mu_{KL}} \equiv \frac{1}{\sum_{i=1}^{N} \frac{(1-\tau_{L_i})}{(1+\tau_{K_i})} \frac{L_i}{L}} - 1$ and $\overline{\mu_L} = 1 - \sum_{i=1}^{N} (1-\tau_{L_i}) \frac{L_i}{L}$. $(1 + \overline{\mu_{KL}})$ is the weighted average of capital distortions of farms in a given region and $(1 - \overline{\mu_L})$ is the weighted average of labor distortions. When A_i and $\overline{DI}$ are jointly log-normally distributed, regional aggregate TFP, A, can be expressed as:

$$\ln A = (1-(\alpha+\beta)) \ln\left(\sum_{i=1}^{N} [A_i \overline{M}_i^{\gamma}]^{\frac{1}{1-(\alpha+\beta)}} \right) - \frac{2-(\alpha+\beta)}{2-2(\alpha+\beta)} \mathrm{var}(\ln DI_i) - \gamma \ln M. \quad (10)$$

Equation (10) shows that the regional aggregate TFP has an inverse proportional relationship with both the household distortion, DI_i, and its dispersion, var(lnDI_i).

2. The Measurement of Distortions

Calculation of the distortion index in this paper follows the approach of Zhu et al. (2011), which is an extension of Hsieh and Klenow (2009). Macro-level official data and small-scale survey data have both been widely used in previous evaluations of agricultural efficiency. Fuller et al. (2000) suggest that the former approach is misleading because of overreporting in production and underestimation of inputs. The latter method, however, would not deliver enough information because of the limited survey area and because of the small number of samples. To offset the shortcomings of previous studies as a result of data limitations, the present study uses nationwide survey data collected by the China Family Panel Studies (CFPS) for year 2012. Excluding data with incomplete information and outliers for core variables, the final effective sample covers 3616 rural households from 23 provinces in China. According to the National Bureau of Statistics of China, four economic regions are determined in terms of their economic situation and corresponding development strategy; namely, the East, Middle, West and Northeast.[1] Among the total 3616 households, 766 households are located in the East, 965 in the Middle, 1351 in the West, and 534 in the Northeast.

The necessary parameters for the calculation of the factor distortion index include the following: (i) output and inputs in the production function (see Equation (1)); and (ii) prices of input factors (see Equations (5) and (6)). Output denotes a farm household's annual value of agricultural products. Input factors are capital, labor and farmland, measured by monetary unit. Capital is the sum of all the direct and indirect costs

[1]According to the regional division of the National Bureau of Statistics, the East region includes the provinces of Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong; the Middle includes the provinces of Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan; the West includes the provinces of Guangxi, Chongqing, Sichuan, Guizhou, Yunan, Gansu and Shanxi; and the Northeast includes the provinces of Heilongjiang, Jilin and Liaoning.

in agricultural production, consisting of (i) family-owned agricultural machinery; (ii) leasing of agricultural machinery and irrigation; (iii) seeds, fertilizers and pesticides; and (iv) other indirect costs, including fuel, transportation, processing, packing and taxes. Labor input consists of the opportunity cost of family labor and paying for hired laborers. Farmland input is the opportunity cost of household cultivated farmland.

It is worth noting that both physical capital inputs and intermediate inputs are included in total capital inputs. Capital input here was regarded as a whole because the distortion we measured is derived from the misallocation of capital and labor. Reflected as taxes on capital price, capital distortions are originally derived from the distorted capital market (Banerjee and Moll, 2010). Therefore, the sources of distortions for different capital components could be regarded as unified. Imperfections of the rural financial market and limited access to cheap credit make it difficult for farmers to obtain loans to increase capital input, either physical capital or intermediate capital (Zhu et al., 2011). Total capital input has also been used in previous studies examining agriculture distortions (Zhu et al., 2011; Chen, 2012). For example, capital input in the study by Zhu et al. (2011) consists of agricultural operating expenses, including immediate inputs like the cost of seeds, chemical fertilizer and pesticide, and physical inputs, such as expenses for purchasing small farm tools, mechanical operation and reparation. Chen (2012) used all of the direct and indirect costs for materials and services to represent capital input, which included the costs of all the means of agricultural production in the direct production process, expenses from purchasing services, and other physical and cash expenses of production.

Due to the absence of information on wage and farmland prices in the CFPS database, the opportunity costs of labor and farmland input are calculated based on data from the *National Report on Migrant Worker Monitoring and Survey*, *2013* (NBS, 2014) and the *China Agricultural Products Cost–Benefit Compilation of Information*, *2013* (NDRC, 2013). Both sources provide official nationwide statistics. The *National Report on Migrant Worker Monitoring and Survey* is a nationally representative annual report on Chinese migrant workers published by the National Bureau of Statistics of China, which provides statistics of demographic characteristics, employment and the income of migrant workers. The *China Agricultural Products Cost–Benefit Compilation of Information* is published by the National Development and Reform Commission, which reports concise data on production costs and benefits of major agricultural products.

According to the *National Report on Migrant Worker Monitoring and Survey*, *2013*, in 2012, the average monthly wage of migrant workers was 2286 yuan in the East, 2257 yuan in the Middle, and 2226 yuan in the West. Regional division in this report placed Liaoning Province in the Eastern region, and Jilin and Heilongjiang Provinces in the Middle region. Therefore, the average monthly wages of migrant workers in Liaoning, Jilin and Heilongjiang Provinces are 2286, 2257 and 2257 yuan, respectively. The opportunity cost of farmland is measured by the average commuted cost in grain production reported in the *China Agricultural Products Cost–Benefit Compilation of Information*, *2013*. In 2012, the average cost of grain production was 166.19 yuan per mu.[2]

It is worth noting that two proxies were used in the previous studies to represent wage data for agricultural workers: wages for agricultural hired laborers and wages for migrant workers (Yang et al., 2016). Besides the problem of missing variables in the CFPS, there are two main reasons for the use of wages for migrant workers to represent labor price. First, wages for migrant workers are generated over the long term and remain at a relatively smooth level, while wages for agricultural hired laborers are seasonal, with large variance. Second, wages for migrant workers in the *National Report on Migrant Worker Monitoring and Survey*, *2013* exhibit differences across regions, and are a better fit for our model. In addition, regional daily wages for migrant workers in the report are in the range of 74.2–76.2 yuan. Whereas the survey data in previous studies show that the daily wages for agricultural hired laborers are in the range of 18.42–99.06 yuan (Zhu et al., 2011; Yang et al., 2016), wages for migrant workers adopted in our study (74.2–76.2 yuan) are within the reasonable range to reveal the opportunity cost of agricultural labor.

"Farmland price" mostly stands for the monetary equivalent of farmland in previous analyses of costs and benefits of agricultural production (Chen, 2012). To represent farmland price, we chose the average farmland cost of three major grain crops: corn, wheat and rice. Farmland cost in the *China Agricultural Products Cost–Benefit Compilation of Information*, *2013* is the sum of rent for transferred farmland and the monetary equivalent for self-operated land.

The total output, the total input and every single factor input per household are reported in Table 1. With rising labor costs, labor input was the main component of aggregate production costs; next was capital investment, and farmland was the smallest input across the four regions. Among the total 3616 households, the average output was 11,791.16 yuan; the capital input was 6010.18 yuan, the labor input was 27,534.10 yuan and the farmland input was 2154.61 yuan. Wide differences in agricultural productivity and factor allocation existed among regions.

There were especially stark contrasts in the Northeast and the West. On average, the highest output was seen in the Northeast, which was more than 50 percent higher than

[2]Mu is a unit of farmland size in the Chinese system of weights and measures. Here, 1 mu = 0.067 ha.

in the other three regions. Output in the West ranked the lowest. As for input factors, households in the Northeast had the largest capital input and the smallest labor input. In contrast, households in the West incurred the highest labor and farmland costs. Although the average monthly wage for migrant workers was the highest in the East, at 2286 yuan, the capital and farmland inputs both ranked the lowest among all four regions.

Table 1. Descriptive Statistics of Output and Inputs per Household Across Regions (yuan)

Region	Total output	Total input	Capital		Labor		Farmland	
			Mean	%	Mean	%	Mean	%
East	10,994.85	34,078.27	5379.98	15.79	27,377.73	80.34	1320.56	3.88
Middle	10,977.35	30,733.88	5553.44	18.07	23,232.83	75.59	1947.61	6.34
West	10,959.28	43,048.38	6010.01	13.96	34,326.75	79.74	2711.62	6.30
Northeast	16,508.69	28,401.99	7739.97	27.25	18,346.13	64.59	2315.89	8.15
Total	11,791.16	35,698.89	6010.18	16.84	27,534.10	77.13	2154.61	6.04

Source: The data come from the CFPS database (2012), the NBS (2014) and the NDRC (2013).

To measure the distortions, the price of capital is specified as the interest rate of a 1-year loan in 2012 of 6.56 percent. As mentioned above, the wage for labor is the average monthly wage of migrant workers reported in the *National Report on Migrant Worker Monitoring and Survey*, *2013*. Farmland price is the average converted monetary cost of farmland in the three main grain crops reported in the *China Agricultural Products Cost–Benefit Compilation of Information*, *2013*. We separately calculate household capital distortion, labor distortion and an aggregate distortion index (*DI*). Table 2 shows the results across regions, including the distortion level (reflected by means) and distortion dispersion (reflected by standard deviations).

Table 2. Capital, Labor and Aggregate Distortions per Household across Regions

Regions	Capital distortion		Labor distortion		Aggregate distortion index (*DI*)	
	Mean	SD	Mean	SD	Mean	SD
East	1.6382	1.0761	0.0010	0.0009	0.0696	0.0415
Middle	1.8283	1.1713	0.0008	0.0007	0.1594	0.0853
West	1.7897	1.3191	0.0009	0.0008	0.1114	0.0729
Northeast	1.6578	0.9174	0.0009	0.0007	0.0577	0.0292
Total	1.7484	1.1794	0.0009	0.0008	0.1074	0.0763

Sources: Authors' own calculation based on data from the CFPS database (2012), the NBS (2014) and the NDRC (2013). SD, standard deviation.

Although there are no large gaps across regions in terms of capital and labor distortions, relatively high means and dispersions of capital distortion are exhibited in the Middle and Western regions, suggesting lower capital allocative efficiency. However, the Middle has a slightly higher mean but lower standard deviation and it cannot be determined which region has the heaviest capital distortion. The Eastern region shows both the highest mean and dispersion of labor distortion, suggesting the worst situation in regard to labor allocation. The Middle and the Northeast regions perform relatively better in labor allocative efficiency.

As shown in Table 2, the Middle region has the worst situation in terms of factor allocative efficiency, with the highest mean and dispersion of the distortion index. In contrast, the Northeast performs best, with the lowest distortion mean and dispersion. There is a large gap of 176 percent in the distortion level between the Middle (mean of $DI_i = 0.1594$) and the Northeast (mean of $DI_i = 0.0577$). Noticeable gaps in distortions across regions indicate that there is serious regional segmentation, which is consistent with the findings of Zhu et al. (2011). Zhang et al. (2013) also conclude that allocative efficiency of agricultural factors was higher in the East and Northeast in China.

Total factor productivity gains will be achieved by hypothetically eliminating distortions, which has been verified in earlier attempts in various countries (see Table 3). Hsieh and Klenow (2009) measured the gaps of TFP in India and China compared with the USA and conclude that TFP gains of 40–60 percent in India and 30–50 percent in China could be achieved by reallocating factors according to the input model of the USA. Similarly, other studies have found that 50 percent or more of the TFP difference between rich and poor countries could be explained by the distortion effect (Banerjee and Duflo, 2004; Restuccia and Rogerson, 2004). Furthermore, even though the resource allocation in a rich country is taken as the model, it is still not perfectly efficient. Comparison between rich and poor countries could eliminate the gaps in marginal products generated from factors omitted from the model and measurement errors in both the distorted country and the undistorted country (Hsieh and Klenow, 2009). Hsieh and Klenow (2009) demonstrate that the USA could make 30–43 percent TFP gains by fully equalizing marginal products across plants. Correspondingly, TFP would be boosted by 86–115 percent in China and 100–128 percent in India.

Table 3. Literature Reviews on Factor Allocation and Total Factor Productivity (TFP)

Literature	Region	Period	Field	Results of TFP gains (%)
Busso et al. (2012)	10 Latin America countries	1977–2006	Manufacture	45–127
Gong and Hu (2013)	China	1998–2007	Manufacture	11–57
Hsieh and Klenow (2009)	China; India	1998–2005; 1987–1994	Manufacture	30–50 40–60
Zhu et al. (2011)	China	2003–2007	Agriculture	20–30
Chen (2012)	China	2004–2010	Agriculture	6–36
Adamopoulos et al. (2017)	China	1993–2002	Agriculture	40–120
Present study	China	2012	Agriculture	26–151

Generally speaking, there are different levels of distortions in agricultural production across regions in China. Reduction of factor distortion is a potential source of improving agricultural production efficiency. Determinants of factor distortion deserve special attention.

III. Empirical Analysis of the Determinants of Distortions

1. The Model and Data

To examine the determinants of underlying distortions across regions in China, linear regression with cross-sectional data is used in our regression analysis:

$$\begin{aligned}\ln DI_i &= \beta_0 + \beta_1 Cas + \beta_2 Sav + \beta_3 Fas + \beta_4 Far + \beta_5 Nfi + \beta_6 Efl + \beta_7 Machine \times L \\ &+ \beta_8 Intermediate \times M + \beta_9 L \times M + \sum \theta_j X_i + \varepsilon_i\end{aligned}, \quad (11)$$

Where DI_i is the distortion index of household *i* representing the factor distortion level. The definitions and means of variables used in the regression analysis are reported in Table 4.

Table 4. Definitions and Means of Variables

Variables	Definition	Unit	East	Middle	West	Northeast	Total
Cas	Ratio of agricultural machinery input to total capital input	%	24.87	29.71	25.21	17.88	25.26
Sav	Amount of household saving	Thousand yuan	9.78	6.18	4.39	9.16	6.71
Fas	Area of farmland	Mu	7.95	11.72	16.32	13.94	12.96
Far	Cost of renting 1 mu of farmland	Thousand yuan/mu	0.35	0.33	0.37	0.36	0.35
Nfi	Ratio of household non-farm income to total income	%	57.98	59.58	55.08	38.99	54.52
Efl	Householder's labor input weighted by education level[3]	Month	13.84	11.10	14.23	8.95	12.53
Crs	Whether household obtains loans from banks or private organizations	Yes = 1, No = 0	0.05	0.08	0.17	0.11	0.11
Age	Age of householder	Year	50.35	50.92	46.31	48.71	48.75
Lap	Ratio of labor force to household population	%	44.87	39.63	43.28	49.79	43.61

Despite the relatively higher capital investment in the Northeast (see column 4 in Table 1), that region has the lowest ratio of machinery services to total capital and high farmland costs. The cheapest labor inputs could partly explain agricultural benefits in the

[3]The householder is the person responsible for making decisions and managing household business in a family. In the CFPS database, the one who answered the family questionnaire is considered as the householder.

Northeast (see column 6 in Table 1), but all other regions have similar capital structures. The highest output in the Northeast could be attributed to its favorable capital–labor ratio. Table 4 reports the summary statistics of variables across regions. All regions have similar farmland rent. The size of farmland ranges from the smallest area of 7.95 mu in the East to the largest of 13.94 mu in the West.

In our econometric model, *Cas* denotes capital structure; namely, the ratio of agricultural machinery input to total capital, including machinery, seeds, fertilizers and pesticides. *Sav* is household saving, representing the flow of household capital. A high ratio of saving or consumption may lead to underinvestment in agricultural production.

From the perspective of factor reallocation, asset markets merit explicit consideration, especially the land markets (Banerjee and Moll, 2010). Farmland size and farmland rent payments will affect distortions. However, these effects have not attracted enough attention in previous studies. *Fas* denotes farmland size. *Far* is the rent of transferred farmland, denoting the rent per mu paid or gained from the transferred farmland or planned-to-be-transferred farmland. Farmland rent could be regarded as the cost of adjusting farmland input. Farmers will make decisions on leasing in or out farmland according to the level of farmland rent, which, finally, affects farms' scale of production.

In the labor market, entry barriers and wage inequality faced by rural laborers are claimed to be the essential reasons for misallocation (Dong et al., 2014). *Nfi* is the ratio of non-farm income to total household income, representing distortion in the labor market. *Efl* serves as the effective labor input of the householder, which is computed using the householder's agricultural working hours weighted by the education level. According to Abler and Sukhatme (2006), human capital plays an essential role in improving agricultural efficiency.

The interactive effects of input factors should receive more attention in explaining agricultural allocative efficiency. Based on the induced development model proposed by Hayami and Ruttan (1985), the constraint of inelastic land supply for agricultural development can be eliminated by the progress of biotechnology, and the restriction caused by the inelastic labor supply can be solved by mechanical technology. $Machine \times L$ is the interaction of machinery input and labor input. $Intermediate \times M$ is the interaction of the intermediate cost of seeds, fertilizers and pesticides and farmland input. $L \times M$ is the interaction of labor input and farmland input.

Here, X represents the other control variables, including the credit constraint (*Crs*), householder's age (*Age*) and labor proportion (*Lap*), and a dummy variable for provinces. The credit constraint indicates whether a household can obtain loans from banks or private organizations, which reflects the distortion in the capital market. The labor proportion denotes the ratio of the labor force to the household population, where the labor force includes family members between the ages of 16 and 60 years according to the National Bureau of Statistics of China. The dummy variable for provinces is used to control other factors not directly reflected in the model. Considering the differences in regional production and factor allocation, the model estimates are divided into subregions.

2. Regression Analysis Results

Agricultural TFP has long puzzled researchers in China. Resource endowments, technology and human capital should be responsible for aggregate productivity growth (Griliches, 1964). By contrast, underinvestment in modern industrial inputs (Hayami and Ruttan, 1970), a shortage of infrastructure (Kumar and Rosegrant, 1996), and low levels of R&D and education (Lusigi and Thirtle, 1997) are the main sources of low agricultural TFP in developing countries. Various types of friction distort factor allocation (Aoki, 2008), such as the effect of an imperfect factor market, unbalanced financial policy (Caballero et al., 2006), credit constraints (Banerjee and Duflo, 2004) and a lack of labor mobility (Hayashi and Prescott, 2008). Following the regression model outlined above, the impacts of different factors on distortions across regions are examined empirically in detail.

Table 5 displays the OLS regression results for the determinants of distortions across regions. Overall fitness of each model is guaranteed with a very robust F-statistic. Given the results for multiple collinear tests (VIF < 10 for each regression) and the heteroscedasticity-consistent standard errors, the OLS model is proved to be stable and effective.

In general, the factors underlying distortion among regions are the same as for the aggregate. Still, there are differences in factor impacts present across regions, which are accounted for mainly by the capital structure, household saving, farmland size, farmland rent, nonfarm income, age of householders and family labor proportion.

(1) Effect of Capital Structure

Additional mechanical equipment is required to break the low equilibrium with factor allocative inefficiency in agricultural production (Hayami and Ruttan, 1970). We find a significant positive impact of capital structure on reducing distortion, which is in line with the earlier finding of Cai and Du (2009). Agricultural machinery input is necessary for modernizing agriculture and having a larger proportion of machinery input could improve allocative efficiency through substituting for labor. Although intermediate inputs like pesticides and fertilizers contribute to the improvement of labor and farmland productivity, they do little for allocative efficiency gains (Li, 2014); the overapplication of fertilizer has, in fact, led to allocative inefficiency due to deterioration of land.

Table 5. Estimation Results of OLS Model

Variables	East	Middle	West	Northeast	In total
Cas	–0.576***	–0.713***	–0.906***	–0.783***	–0.771***
	(0.102)	(0.096)	(0.093)	(0.121)	(0.051)
Sav	0.002***	0.002**	0.002**	0.001	0.002***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Fas	0.002*	0.002	0.001*	0.007*	0.001**
	(0.001)	(0.001)	(0.001)	(0.004)	(0.000)
Far	0.058	0.086*	0.035	0.044	0.053**
	(0.063)	(0.052)	(0.032)	(0.031)	(0.021)
Nfi	–0.153***	–0.128***	–0.075**	–0.044	–0.099***
	(0.047)	(0.035)	(0.037)	(0.048)	(0.024)
Efl	-0.000	–0.004*	-0.001	–0.006	–0.003**
	(0.002)	(0.002)	(0.002)	(0.004)	(0.001)
Machine × *L*	0.002	–0.003	0.002	0.008**	0.002
	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)
Intermediate × *M*	0.145***	0.077***	0.054*	0.111	0.090***
	(0.037)	(0.018)	(0.030)	(0.077)	(0.019)
L × *M*	–0.137***	–0.079***	–0.063**	–0.167**	–0.089***
	(0.042)	(0.025)	(0.030)	(0.068)	(0.020)
Crs	–0.160*	–0.106*	0.032	0.062	–0.018
	(0.088)	(0.061)	(0.045)	(0.064)	(0.031)
Age	0.001	–0.002	–0.002	0.001	–0.001
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Lap	–0.076	–0.044	–0.013	–0.020	–0.031
	(0.079)	(0.077)	(0.077)	(0.079)	(0.039)
Province	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	–2.002***	–1.093***	–0.987***	–1.812***	–1.912***
	(0.343)	(0.300)	(0.332)	(0.421)	(0.199)
Probability > *F*	0.000	0.000	0.000	0.000	0.000
R^2	0.233	0.214	0.221	0.244	0.419
Observation	766	965	1351	534	3616

Notes: ***, ** and * represent statistical significance at 1, 5, 10-percent levels, respectively. The numbers in parentheses are heteroscedasticity-consistent standard errors.

Capital is still the scarcest factor of agricultural production in China because of the difficulty obtaining financial support as a result of asymmetric information and transaction costs (Yang and Mo, 2011). Household saving is positively related to factor distortion across regions, and the effects are significant in the East, Middle and West. This indicates that the capital flowing out of rural areas has aggravated the factor distortion. In China, capital is flowing out of rural areas by virtue of bank saving and consumption. Furthermore, salaries earned by migrant workers are typically used to support their parents and for child-rearing rather than for productive investment (Zhao, 2002). Households with higher saving rates have less demand for capital investment in agricultural production. Only 17.2 percent of rural households invested in agricultural production in 2004 (Liu and Ma, 2006).

Credit constraint refers to whether a household can obtain loans from banks or private organizations. The lagged development of the credit market is noticeable in China. In the East and Middle regions, where the rate of obtaining loans is relatively low (see line 8 in Table 4), the credit constraint has a significantly negative effect on distortion. This suggests that increased supply of loans for farmers in these regions would reduce distortions, which is consistent with earlier findings that capital distortion is mainly caused by financial constraints (Banerjee and Duflo, 2004). However, there are insignificant positive impacts in the West and Northeast. The insignificant effect of the credit constraint in these two regions also provides evidence for the fact that loan funds obtained by farmer households are not invested in agricultural production, and, therefore, allocative efficiency cannot be improved in this way.

(2) Effect of Farmland Size

The present study shows that there is a positive relationship between farmland size and factor distortion, and the effects are significant across regions except in the Middle, indicating that a moderate scale operation is a necessary precondition for efficiency improvement. The relationship between efficiency and farm size has been a contentious issue in previous studies. Many researchers find that large-scale farms are more efficient at allocating resources (Kumbhakar, 1993), while some researchers argue that there is an inverse relationship between farm size and agricultural efficiency in developing countries (Berry and Cline, 1978). Other studies even refute the significant relationship between farmland size and agricultural efficiency (Bagi and Huang, 1983). It has been demonstrated that, with the resource endowments of intensive labor and land scarcity, a small-scale operation alleviates the misallocation by developing intensive and meticulous farming and making up for the seasonal shortage of agricultural labor supply (Wan and Cheng, 2001).

Farmland plays an essential role in the enhancement of agricultural production efficiency (Chen, 2012). Although transfer of farmland is encouraged by the Chinese Government, only 21.5 percent of farmland was transferred in 2012. Given the even distribution of arable land under China’s household responsibility system, the extension of farm size is constrained by farmland availability (Zhu et al., 2011). Constrained by small-scale farms, the increase of capital input aggravates distortions across regions. More laborers are trapped in small farming, which restricts the enhancement of allocative efficiency. The situation in China is similar to what occurred in Japan: “without a significant increase in land area per worker, it would be impossible for Japanese agriculture to increase technical inputs to the U.S level” (Hayami and Ruttan, 1970, p. 906).

Farmland rent is positively related to the distortion and shows a significant impact in the Middle region, which is consistent with the finding of Chen (2012). This suggests that for those households leasing in farmland, the more they pay for leasing in farmland, the more difficult it is to adjust farmland input. For households leasing out farmland, rental income is not likely to be an input into future agricultural production. Both situations would lead to higher levels of factor distortion. Development of the farmland rental market plays an important role in optimizing factor allocation in the context of increasing numbers of migrant workers (Laha and Kuri, 2011), which provides opportunities for migrant workers to lease out farmland, thereby reducing the distortions.

(3) Effects of Labor Migration and Effective Labor

We find that the effect of the non-farm income proportion on distortion is significantly negative, consistent with earlier findings of Zhu et al. (2011) and Hayashi and Prescott (2008). A larger proportion of non-farm income indicates that more work opportunities are found outside the agricultural sector (Dong et al., 2014). The household registration system and labor market segmentation in China reduce non-farm work opportunities (Hayashi and Prescott, 2008), which has exerted a negative effect on labor migration (Yuan and Xie, 2011). As occurred in Japan, policies discouraging labor migration from the agricultural sector during 1885–1940 led to limited capital accumulation and slow growth (Hayashi and Prescott, 2008).

Effective labor input has a negative effect on distortion and is found to be significant in the Middle, consistent with previous findings (Dong et al., 2014, Laha and Kuri, 2011). Human capital investment is critical for producers to make proper adjustments (Abler and Sukhatme, 2006). Considering the effects of non-farm income proportion and effective labor input simultaneously, releasing the surplus agricultural labor and training the small farmers to be skilled are appropriate ways to reduce distortions. Although not significant, householders' age is negatively related to the distortion level for the total sample, as well as in the Middle and West, while there are positive effects in the other two regions. The trade-off between the higher efficiency of younger laborers and the rich experience of older workers for reducing agricultural distortions could not be empirically examined in this model.

(4) Interactive Effects of Factors

The coefficient of the term $L \times M$ can be interpreted as the amount of change in the slope of the regression of labor when farmland changes by one unit. The interactive effect of labor and farmland is significantly negative in each region, indicating that there is a complementary impact of the combination of labor and farmland in alleviating production inefficiency. The complementary effect of labor and farmland inputs has been verified by Du et al. (2013), who argue that the increase in labor return in non-farm work will impact negatively on the input of other factors; namely, there is a complementary relationship between labor and farmland inputs in the aspect of efficiency enhancement.

In contrast, the interactive effects of machinery input and labor (*Machine* × *L*) are positive, except for in the Middle region, indicating that there are substitutive impacts of machinery and labor in alleviating distortions, especially in the Northeast. In the process of modernizing agriculture, additional inputs of mechanical equipment and production technologies are required to break the original factor allocation, which may lower the allocative efficiency of agricultural production (Schultz, 1964). Because of difficulty in increasing substitutionary inputs like agricultural machines, the constraints of small-scale operation, imperfection of factor markets and decentralized organization, farmers have chosen reduced multiple cropping indexes or have even abandoned arable farmland to overcome the constraint of labor shortage (Li et al., 2008). Furthermore, the substitution effect of machinery to labor is restricted by the natural and geographic conditions and the aging and feminization of agricultural labor (Li and Zhao, 2009).

Similarly, the interactive effects of farmland and intermediate capital inputs of seeds, fertilizer and pesticides (*Intermediate* × *M*) are positive and significant, except in the Northeast, indicating the substitution effects of capital and farmland on the reduction of distortions. Through the substitution of the capital inputs of seeds, fertilizer and pesticides for the relatively scarce farmland, the development of land-saving technology could eliminate the constraints of agricultural production efficiency. Fertilizer input has a substitution effect on soil fertility. The decline in fertilizer price relative to farmland has led to the shift of the isoquant curve by substituting fertilizers for farmland. The progress of biotechnology and chemical technology is more effective than mechanical technology at improving agricultural efficiency (Jiang, 2007). The increased input of fertilizer, seeds and pesticides in the 1980s and 1990s has provided evidence of the effective substitution of capital for farmland (Feng, 2000).

Particular attention needs to be paid to the positive relationship between farmland size and distortion. The coefficients of *Intermediate* × *M* show that an increase in farmland size will intensify the impact of capital on factor distortion. This fits with Schultz's (1964) argument that a low equilibrium with optimal allocation has been achieved within a given institutional framework and with available resources, and in the transformation from traditional agriculture to modern agriculture, new inputs in agriculture will lead to an increase in productivity and a decrease in allocative efficiency.

IV. Conclusion and Policy Implications

Using the household survey data from CFPS for 2012, the present paper explores the allocative efficiency of agricultural production from the perspective of factor distortion and examines its underlying determinants across regions. Several conclusions can be drawn as follows.

Sizeable differences exist in the capital and labor distortions in China's agricultural production across regions. There are higher capital distortions in the Middle and West, and labor distortion is the highest in the Eastern region. The highest aggregate distortion level is shown in the Middle region, while the Northeast performs relatively well.

Improving allocative efficiency is vital for agricultural growth in China. It is important to eliminate capital distortion by developing the rural financial market and enhancing the accessibility of financial services. Labor distortion should be alleviated through increasing non-farm employment opportunities and improving farmers' skills by providing training. There is an urgent need to create an institutional infrastructure to improve general education in rural China and to train scientific and technical professionals.

Given the institutional settings in China, small farmers fail to respond rationally to price changes. The growth in farmland size will increase the levels of distortions across regions. Farmland rent has a positive impact on factor distortion. Development of a farmland leasing market is important for disclosing information on farmland costs.

In addition, the regional differences deserve special attention from both policy-makers and researchers. In the Western region, although the average farmland size is the largest, improvement in productivity has not been achieved because of the high level of distortions resulting from the imperfect financial market development and the shortage of non-farm labor opportunities. Farmer households in the East and the Middle are facing credit constraints. Special attention should be paid to the development of rural financial markets. In the Northeast, the distortion is significantly related to the substitutive effect of machinery and labor inputs rather than the substitution of intermediate capital and farmland. Increasing the machinery input in this region is an effective way to reduce distortions.

In sum, there are positive impacts from increases in machinery input, non-farm income proportion, and effective labor input in regards to reducing distortion in all four regions. Household saving, farmland size and farmland rent are positively related to factor distortion across regions. There is a complementary effect between labor and farmland in alleviating production inefficiency, and a substitution effect between intermediate capital and farmland, as well as machinery input and labor. The situation in China is that agricultural growth has been dominated by the intensive investment of intermediate capital, rather than the adoption of advanced mechanical technologies. Due to the constraint of a low equilibrium with optimal factor allocation in small-scale opreations in China, the increase in farmland has aggravated the distortion caused by overusing intermediate inputs.

The substitution effects of factors, especially between capital and labor, are potential sources of economic growth. With increasing numbers of workers transferring out of rural areas, the augmentation of farmland size is vital for the enhancement of the allocative efficiency of production factors in agriculture production. To expand the scale of operation appropriately is also crucial for overcoming the trap of agricultural involution, featured by excessive application of intermediate capital in field cultivation to increase per hectare output but lead up to factor misallocation.

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