

## Research Article

# The Impact of the Subsidy Policy on Total Factor Productivity: An Empirical Analysis of China's Cotton Production

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This paper develops one model to explore the relationship between the subsidy policy and the agricultural total factor productivity (TFP). It indicates that the agricultural TFP will be lower after the subsidy policy is implemented and there exists a negative relation between the subsidy and TFP, if subsidies are associated with the acreage. Using Malmquist index, this paper measures the changes of TFP in China's cotton production before and after the subsidy policy is implemented. The results verify that the subsidy policy could not increase but decrease the TFP of China's cotton production, not only in the whole country but also in major provinces of China. Based on the positive study, some policy implications are provided in the end of this paper.

## 1. Introduction

*1.1. Background.* China is the largest country in producing and consuming cotton in the world. From 2000 to 2010, China's average annual output of cotton reached 6.8 million metric tons, which accounts for almost 30% of global average annual cotton output (Chinese data are from "China Statistical Yearbook," National Bureau of Statistics of China; world data are from "Cotton and Wool Yearbook," USDA). After accessing to WTO, China has become gradually the largest importer of cotton. From 2002 to 2011, China imported cotton accumulated to 21.10 million metric tons (Figure 1), with average annual import of 2.13 million metric tons, which accounts for 27.3% of the quantity of global cotton import (the average annual trading quantity of world cotton from 2002 to 2011 is 7.8 million metric tons, according to the statistics of "Cotton and Wool Yearbook," USDA).

From 2002 to 2006, in the first 5 years after becoming WTO member, China imported more and more cotton (Figure 2), with the average annual growth rate of 144.8%; especially in 2006, China imported 3.64 million metric tons, which was 19 folds than that in 2002. The reason that China imported so much quantity of cotton is because of the huge

increase of China's export of textile after accessing WTO and, in particular, cancellation of "Multifibre Arrangement (MFA)". In 2005, China exported a total \$115.03 billion of textiles and garments, representing a 21% increase over the previous year; in 2006, China's exported textiles and garments reached \$143.97 billion, an increase of 25% over the year of 2005. But at the same time, China's cotton production had not been increased much enough (Figure 3). In order to motivate the farmers to produce more cotton to meet the constantly increasing requirement of cotton, China's government carried out one subsidy policy on cotton seed in high quality (simplified as "seed subsidy" in the following contents) in some areas in 2007 with 15 yuan RMB per mu (mu is a unit of measuring area in China, one hectare equal to 15 mus) and then fully implemented the subsidy policy in all cotton producing areas from 2009. The aim of the seed subsidy is to encourage farmers to buy the cotton seed in high quality so as to increase the output and the productivity. However, from 2008, China's cotton output showed consecutive reduction in three years. It apparently means that the seed subsidy policy has not gotten the devising aim to increase the productivity and the output of cotton. How to interpret this phenomenon? Is there any rule behind this phenomenon? This paper will

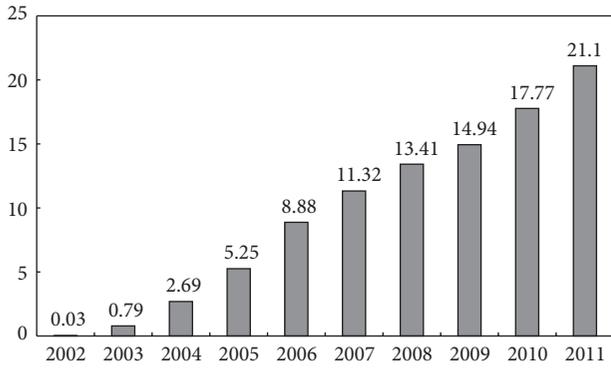


FIGURE 1: China's net accumulated import cotton from 2002 to 2011. Unit: million MTs. Data source: "China Statistical Yearbook," National Bureau of Statistics of China.

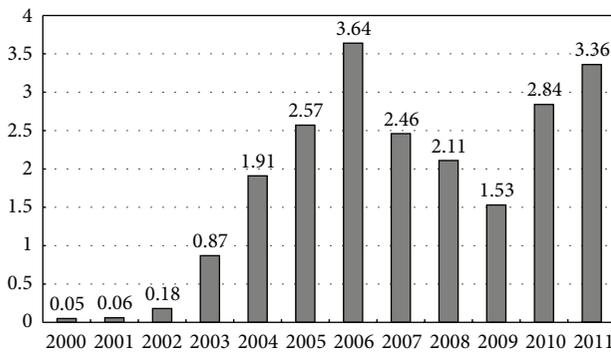


FIGURE 2: The import cotton of China from 2000 to 2011. Unit: million MTs. Data source: "China Statistical Yearbook," National Bureau of Statistics of China.

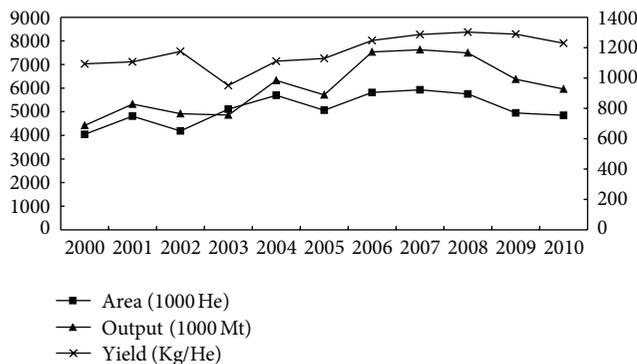


FIGURE 3: The situation of China's cotton production from 2000 to 2010. Data source: "China Statistical Yearbook," National Bureau of Statistics of China.

investigate the relationship between the subsidy policy and the productivity using a theoretical model and will positively analyze the impact of the subsidy policy on the total factors productivity (TFP) of China's cotton production.

1.2. *The Literature Review.* Regarding the relationship between the subsidy policy and agricultural productivity, there

are many empirical studies concluded one negative relationship existed between them. Giannakas et al. [1] found, using the data of farms in the Province of Saskatchewan, Canada, that subsidies had a negative effect on technical efficiency during the period of 1987 to 1995. Rezitis et al. [2] indicated that subsidies granted to Greek farmers had a negative impact on Greek farms' technical efficiency. Guyomard et al. [3] investigated the subsidies productivity changes of crop, beef meat, and dairy farms in French over the period of 1995 to 2002 using Malmquist Indices, and they indicated that the subsidies had a negatively influence on the technical efficiency scores but positively change in both technical efficiency and productivity. Sabir and Ahmed [4] used variance decomposition approach to estimate the impact of economic reforms on TFP growth for the overall economy of Pakistan, using time series data from 1972-1973 to 2001-2002. They included index of human capital, fertilizer subsidy, food subsidy as the independent variables, and index of TFP as the dependent variable. Their results showed that the impact of food subsidy was negligible with an elasticity coefficient of only 0.003; fertilizer subsidy had a negligible negative impact on TFP. Nivievskiy [5] analyzed the productivity growth in Ukrainian dairy farming and indicated the price supports that negatively impacted the efficiency. Latruffe et al. [6] applied a five-step approach to the investigation of the relationship between public subsidies, namely, CAP (common agricultural policy) direct payments, and managerial efficiency for French CAP and beef farms in 2000. The conclusion showed that there was a strong significant negative relationship between managerial efficiency and CAP direct payments. Mary [7] analyzed the impact of CAP subsidies on total factor productivity of French crop farms between 1996 and 2003, and the results also showed that several subsidies have a negative impact on productivity. But Kazukauskas and Newman [8] found that the decoupling policy had positive significant effect on the farm productivity. And Rizov et al. [9] found that subsidies impacted negatively the farm productivity in the period before the decoupling, reform was implemented; after decoupling the effect of subsidies on productivity was more nuanced as in several countries it turned positive.

As for China's agricultural subsidy policy, most Chinese literatures focus on grain production, and there are two different viewpoints in the literatures. The positive viewpoint considers that the subsidy policy increases the farmers income [10] and substantially enlarges the production of grain [11]. Subsidies for agricultural machinery and seed promote the production of grain [12], especially the subsidies for purchasing agricultural machinery significantly impact increasing revenue of farmers in large scale who use lots machines to plant and harvest [13]. However, the negative viewpoint thinks that subsidies do not have any influence on farmers to enlarge the investment on agriculture because there is not any causality between subsidies and the farmer's investment [14], since the subsidies could not offset the negative impact from increasing producing cost so subsidies do not have enough incentive function for farmers to enhance their willingness to produce more grain [15, 16]. Less literatures concern China's cotton subsidy. According

to the multiobjective optimization model with discrete data proposed in the references [17–22], Ding et al. [17] established a model of multiobjective linear optimization and simulated which subsidy could promote cotton production, using the data before 2007 and without subsidy in that period. They concluded that China should carry out multisubsidy instead of seed subsidy, such as subsidies for irrigation and machines.

Till now, no literature explores the relationship between subsidy policy and productivity in theory, and no literature has positively studied the relationship between subsidy policy and China's cotton productivity. This paper develops one mathematical model, which theoretically demonstrates the rule between the subsidies-related acreage and agricultural TFP. In order to verify the implication of the model, this paper will compare the TFP of China's cotton production before and after implementing the subsidy policy through measuring Malmquist index. The structure of this paper is as follows: Section 2 will derive and discuss one mathematical model which investigates the theoretical relationship between the seed subsidy and productivity; Section 3 will make an empirical study of subsidy on China's cotton TFP based on Malmquist index; at last, the paper will give the conclusion and some policy implications.

## 2. A Theoretical Model

In order to observe what happened in China's cotton productivity after implementing seed subsidy, we hereby establish two different profit functions.

At first, we consider the situation without subsidy. Supposing farmer's decision of planting cotton is based on price, so the planting area of cotton, which reflects the producing decision of farmers, is a function of price:

$$S_l = a + bp, \quad (1)$$

$S_l$  denotes the farmer's planting area,  $a$  is a constant that denotes the initial planting area, and  $p$  denotes the price of cotton. The parameter  $b$  is a marginal effect, which reflects a unit change of  $S_l$  upon  $p$  changing one unit, and  $b$  is a positive number, which means that farmers will enlarge the planting area along with the price increasing.

Suppose that yield is a Cobb-Douglas production function; in order to simplify the question, we assume that labor is only one factor of input:

$$y = El^\alpha. \quad (2)$$

Formula (2) describes the yield per unit planting area, in which  $y$  denotes the yield,  $l$  is the labor,  $\alpha$  is the elasticity of labor, and  $E$  is the labor efficiency which denotes the total factor productivity (TFP) in a certain. So, we get the profit function as follows:

$$\pi = pyS_l - C_0S_l. \quad (3)$$

In formula (3),  $\pi$  denotes the profit, and  $C_0$  denotes the producing cost per mu. Substitute  $S_l$  and  $y$  with formulas (1) and (2), respectively, we can get the profit function as follows:

$$\pi = pEl^\alpha (a + bp) - C_0 (a + bp). \quad (4)$$

Maximizing  $\pi$ , using first-order condition of function (3) with respect to  $p$  equal to zero, we can get the TFP function:

$$E = \frac{C_0b}{(a + 2bp)l^\alpha}. \quad (5)$$

Second, we consider the farmer's decision of producing under the subsidy policy. China's cotton seed subsidy is 15 Yuan per mu. This kind of policy means the more area of planting cotton the more subsidies getting from government. So, apparently, China's government wishes to increase the cotton production through stimulating farmers to enlarge their cotton planting area using subsidy. Then, the planting area is certainly a function of subsidy:

$$S_l = a + bp + cS_b, \quad (6)$$

$S_b$  denotes the subsidy, and the parameter of  $c$  is positive that means when the subsidy paid to the farmers, the planting area will be increased, which conforms the government's wish.

So, we get another profit function as follows:

$$\pi = pyS_l + S_bS_l - C_0S_l. \quad (7)$$

Define  $y = E_s l^\alpha$  in formula (7), so, Maximizing  $\pi$ , using first-order condition of function (7) with respect to  $p$  equal to zero, and substituting  $S_l$  with formula (6), we can get the  $E_s$  (the TFP after subsidy is carried out) as follows:

$$E_s = \frac{C_0b}{(a + 2bp)l^\alpha} - \frac{(b + c)S_b}{(a + 2bp)l^\alpha}. \quad (8)$$

Apparently,  $E_s < E$  because  $(b + c)S_b/(a + 2bp)l^\alpha > 0$ . So, the TFP will be lower after the subsidy, and there is a negative relationship between the TFP and the subsidy. The above theoretical model reveals that the agricultural TFP will decline when subsidy is implemented if the subsidy is related to planting area.

## 3. Measuring China's Cotton TFP

**3.1. Model and Data.** Since the late 1990s, Malmquist index based on Data Envelopment Analysis (DEA) method has been widely used to measure and decompose the TFP, and it is convenient to apply DEA techniques to capture the effect of the technical inefficiency [18]. Malmquist index was put forward in 1953 by Malmquist [19], the Swedish economist and statistician, and then Caves et al. [20] and Fare et al. [21] developed Malmquist index to measure TFP.

**3.1.1. Definition and Decomposition of the Malmquist Index.** Malmquist index is a ratio of distance function in different periods. The distance function is a technical one with multi-input and multioutput without any assumptions in producer's behavior.

Assuming that  $X$  is a  $V$ -dimensional vector of input factors,  $Y$  is  $W$ -dimensional vector of output, and  $O(X)$  denotes the set of output, which is bounded, closed, and

convex. According to Shepherd [22], the output distance function  $D_o(X, Y)$  on the bases of  $O(X)$  is as follows:

$$D_o(X, Y) = \text{Min} \left\{ \phi : \left( \frac{Y}{\phi} \right) \in O(X) \right\}. \quad (9)$$

Let  $(X_o^t, Y_o^t)$  and  $(X_o^{t+i}, Y_o^{t+i})$  denote the input and output vectors, respectively, in period  $t$  and  $t + i$ ;  $D_o^t(X_o^t, Y_o^t)$  is the output distance function based on the technology in period  $t$ ;  $D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})$  is the output distance function in  $t + i$  with the technology in  $t$ .

If the technology changed from period  $t$  to  $t + i$ , the Malmquist index in respect of output in period of  $t$  is as follows:

$$M_o^t(X_o^{t+i}, Y_o^{t+i}, X_o^t, Y_o^t) = \frac{D_o^t(X_o^{t+i}, Y_o^{t+i})}{D_o^t(X_o^t, Y_o^t)}. \quad (10)$$

Similarly, the Malmquist index on the respect of output in period  $t + i$  is as follows:

$$M_o^{t+i}(X_o^{t+i}, Y_o^{t+i}, X_o^t, Y_o^t) = \frac{D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})}{D_o^{t+i}(X_o^t, Y_o^t)}. \quad (11)$$

Fare et al. [21] adopted geometric mean of Malmquist index in two periods as the definition in order to avoid errors existed in different periods which are selected random:

$$\begin{aligned} M_o(X_o^{t+i}, Y_o^{t+i}, X_o^t, Y_o^t) \\ = \left\{ \left[ \frac{D_o^t(X_o^{t+i}, Y_o^{t+i})}{D_o^t(X_o^t, Y_o^t)} \right] \times \left[ \frac{D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})}{D_o^{t+i}(X_o^t, Y_o^t)} \right] \right\}^{1/2}. \end{aligned} \quad (12)$$

Malmquist index could be decomposed as follows:

$$\begin{aligned} M_o(X_o^{t+i}, Y_o^{t+i}, X_o^t, Y_o^t) \\ = \left\{ \left[ \frac{D_o^t(X_o^{t+i}, Y_o^{t+i})}{D_o^t(X_o^t, Y_o^t)} \right] \times \left[ \frac{D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})}{D_o^{t+i}(X_o^t, Y_o^t)} \right] \right\}^{1/2} \\ = \frac{D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})}{D_o^t(X_o^t, Y_o^t)} \\ \times \left[ \frac{D_o^t(X_o^{t+i}, Y_o^{t+i})}{D_o^{t+i}(X_o^{t+i}, Y_o^{t+i})} \times \frac{D_o^t(X_o^t, Y_o^t)}{D_o^{t+i}(X_o^t, Y_o^t)} \right]^{1/2} \\ = \text{Ech}_o \times \text{Tch}_o, \end{aligned} \quad (13)$$

where  $\text{Ech}_o$  and  $\text{Tch}_o$  denote the efficiency change and the technical change from period  $t$  to period  $t + i$ , respectively.

Usually, Malmquist Index could be gotten by DEA method. DEA is the nonparametric mathematical programming approach to frontier estimation. Assume that there are data on  $K$  inputs and  $M$  outputs on each of  $N$  decision making units (DMUs). The  $K \times N$  input matrix,  $X$ , and

the  $M \times N$  output matrix,  $Y$ , represent the data of all  $N$  DMUs. The purpose of DEA is to construct a nonparametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. For each DMU, we would like to obtain a measure of the ratio of all outputs over all inputs, such as, where  $u$  is an  $M \times 1$  vector of output weights, and  $v$  is a  $K \times 1$  vector of input weights. To select optimal weights, we specify the mathematical programming problem:

$$\begin{aligned} \text{Max}_{u,v} \left( \frac{u' y_i}{v' x_i} \right), \\ \text{s.t.} \begin{cases} \frac{u' y_j}{v' x_j} \leq 1, & j = 1, 2, \dots, N, \\ u, & v \geq 0. \end{cases} \end{aligned} \quad (14)$$

In order to avoid an infinite number of solutions, imposing  $v' x_j = 1$ , and using the duality in linear programming, we can derive an equivalent envelopment form as follows:

$$\begin{aligned} \text{Min}_{\theta, \lambda} \theta, \\ \text{s.t.} \begin{cases} -y_i + Y\lambda \geq 0, \\ \theta x_i - X\lambda \geq 0, \\ \lambda \geq 0, \end{cases} \end{aligned} \quad (15)$$

where  $\theta$  is a scalar standing for the efficiency score for the  $i$ th DMU. It will satisfy  $\theta \leq 1$ , with a value of 1 indicating a point on the frontier and hence a technically efficient DMU. So, calculating Malmquist Index in any adjacent two years ( $i = 0, 1$ ) equal to solving the DEA model of the following four distance functions:

$$[D_o^t(X_o^t, Y_o^t)]^{-1} = \text{Max } \phi,$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^N \theta_j X_{oj}^t \leq X_o^t \\ \sum_{j=1}^N \theta_j Y_{oj}^t \geq \phi Y_o^t \\ \theta_j \geq 0, & j = 1, 2, \dots, N, \end{cases}$$

$$[D_o^{t+1}(X_o^{t+1}, Y_o^{t+1})]^{-1} = \text{Max } \phi,$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^N \theta_j X_{oj}^{t+1} \leq X_o^{t+1} \\ \sum_{j=1}^N \theta_j Y_{oj}^{t+1} \geq \phi Y_o^{t+1} \\ \theta_j \geq 0, & j = 1, 2, \dots, N, \end{cases}$$

$$\begin{aligned}
 & [D_o^t(X_o^{t+1}, Y_o^{t+1})]^{-1} = \text{Max } \phi, \\
 \text{s.t. } & \begin{cases} \sum_{j=1}^N \theta_j X_{oj}^{t+1} \leq X_o^t \\ \sum_{j=1}^N \theta_j Y_{oj}^{t+1} \geq \phi Y_o^t \\ \theta_j \geq 0, \quad j = 1, 2, \dots, N, \end{cases} \\
 & [D_o^{t+1}(X_o^t, Y_o^t)]^{-1} = \text{Max } \phi, \\
 \text{s.t. } & \begin{cases} \sum_{j=1}^N \theta_j X_{oj}^{t+1} \leq X_o^t \\ \sum_{j=1}^N \theta_j Y_{oj}^{t+1} \geq \phi Y_o^t \\ \sum_{j=1}^N \theta_j = 1, \quad \theta_j \geq 0, \quad j = 1, 2, \dots, N. \end{cases}
 \end{aligned} \tag{16}$$

In the above models,  $X$  denotes input vectors,  $Y$  denotes output vectors,  $\phi$  ( $0 < \phi < 1$ ) is a scalar, which denotes the efficiency of technology of  $j$  decision-making unit under the condition of constant return to scale, and  $j = 1, 2, \dots, N$ ,  $\theta_j$  is a constant vector.

**3.1.2. Data Description.** The importance of nonparametric Malmquist index analysis is that the selected variables should reflect the input and output of cotton production perfectly. We will use the labor values (standard working day), direct material costs and overhead expenses per mu as the input factors, and cotton yield per mu as the output. In order to get the accurate conclusion, we will measure the TFP of China's cotton production not only for the whole country but also for every major producing cotton province. So, we choose the input-output data of the whole nation and provinces of Hebei, Shandong, Anhui, Jiangxi, Hubei, Hunan, and Xinjiang which are the main areas to plant cotton in China. All the data are available from "China Statistics Yearbook," which is published by National Bureau of Statistics of China, and from "Agricultural Costs and Benefits" which is edited by China's National Development and Reform Commission. The Malmquist index is solved and decomposed by software DEAP 2.1.

**3.2. Positive Results.** Figure 4 presents the results of Malmquist index of China's cotton production from 2001 to 2010. Before the implementation of subsidy policy from 2001 to 2006, the average annual growth rate of Malmquist index was 2.6%. The Malmquist indices increased in most of years, especially increased up to 15.6% and 10.8% in 2001 and 2006 than in 2000 and 2005, respectively. At the same time, according to the decomposition results of Malmquist index, the average annual value of technological change (Techch) increased by 4.7% (see Figure 5).

However, after the implementation of the cotton seed subsidy policy from 2007, the average annual values of

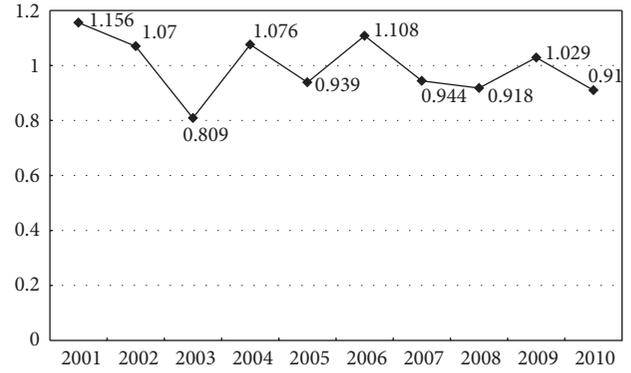


FIGURE 4: China's cotton production Malmquist index.

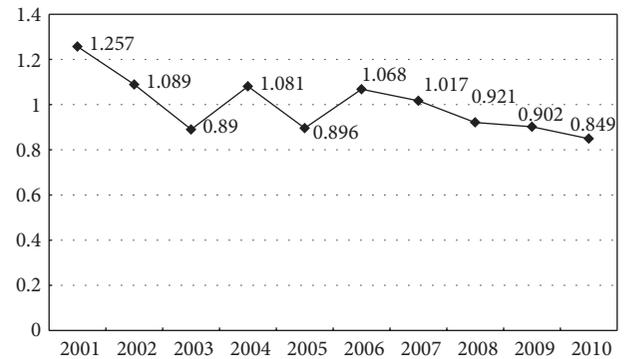


FIGURE 5: China's cotton production technological change.

national Malmquist index decreased by 5.0% from 2007 to 2010. Particularly, in 2010, the decrease rate was up to 9.0%. The average annual changing rate of Techch was  $-7.8\%$  from 2007 to 2010.

In order to further test the change of cotton productivity, we continue calculating the Malmquist index and the technological change of major provinces in China. Figures 6 and 7 report that all the provinces we selected were in the situation of declining Malmquist indices after the implementation of seed subsidy (the details are shown in Table 1). From 2007 to 2010, the average annual changing rates of Techch in the provinces of Hebei, Shandong, Anhui, Jiangxi, Hubei, Hunan, and Xinjiang decreased 3.8%, 7.2%, 9.8%, 8.4%, 6.3%, 10.8%, and 2.1%, respectively, and the Malmquist indices decreased, 3.2%, 6.6%, 8.6%, 8.6%, 8.3%, 6.8%, and 2.1%, respectively.

## 4. Conclusion and Policy Implications

**4.1. Conclusion.** Subsidy is an important policy carried on the agricultural department in many countries, especially in developed countries. However, most literatures found that the subsidy could reduce, instead of increasing, the agricultural TFP. There is the same phenomenon that existed in China's cotton industry. The output of China's cotton had been decreasing from 2008 to 2010 after implementing seed subsidy policy in 2007. This paper develops one mathematical model to theoretically interpret what would happen about

TABLE 1: China's cotton Malmquist index and technical change.

	Year	2001	2002	2003	2004	2005	2006	2001–2006 average	2007	2008	2009	2010	2007–2010 average
Country	Malmquist index	1.156	1.07	0.809	1.076	0.939	1.108	1.026	0.944	0.918	1.029	0.91	0.95
	Techch	1.257	1.089	0.89	1.081	0.896	1.068	1.047	1.017	0.921	0.902	0.849	0.922
Hebei	Malmquist index	0.975	0.94	0.899	0.987	0.911	1.341	1.009	1.088	0.931	0.954	0.898	0.968
	Techch	0.975	1.133	0.877	1.077	0.938	1.11	1.018	1.146	1.025	0.856	0.82	0.962
Shandong	Malmquist index	1.055	0.919	0.902	0.893	0.987	1.307	1.011	0.936	1.001	0.962	0.835	0.934
	Techch	1.151	1.108	0.895	1.066	0.876	1.115	1.035	1.065	0.918	0.897	0.831	0.928
Anhui	Malmquist index	1.354	1.083	0.55	1.201	0.77	1.192	1.025	1.004	0.712	1.045	0.896	0.914
	Techch	1.291	1.083	0.809	1.047	0.828	1.077	1.023	0.923	0.942	0.909	0.852	0.907
Jiangxi	Malmquist index	1.17	1.097	0.833	0.967	1.111	1.13	1.051	0.848	0.883	1.053	0.87	0.914
	Techch	1.513	1.007	0.754	1.188	0.814	1.072	1.058	0.973	0.93	0.938	0.822	0.916
Hubei	Malmquist index	1.678	1.196	0.868	0.946	1.135	1.149	1.162	0.925	0.978	0.935	0.831	0.917
	Techch	1.493	1.142	0.835	1.239	0.828	1.149	1.114	0.925	1.015	0.98	0.826	0.937
Hunan	Malmquist index	1.669	1.306	0.865	0.848	0.751	1.275	1.119	0.802	0.787	1.36	0.777	0.932
	Techch	1.25	1.072	0.865	1.014	0.826	1.071	1.016	0.923	0.903	0.932	0.808	0.892
Xinjiang	Malmquist index	0.918	1.209	0.968	0.968	1.101	1.059	1.037	0.964	0.983	1.048	0.921	0.979
	Techch	0.918	1.209	0.968	0.968	1.101	1.059	1.037	0.964	0.983	1.048	0.921	0.979

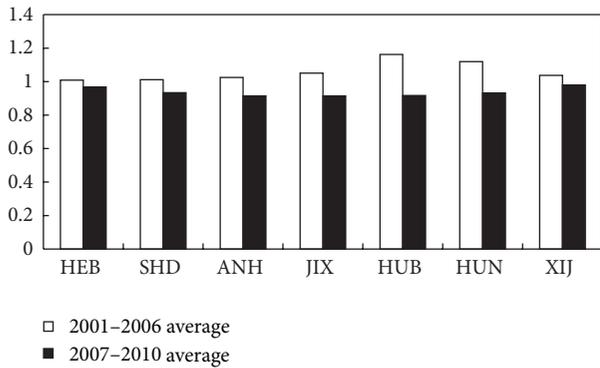


FIGURE 6: Cotton Malmquist indices in China's major province. Notes: HEB, SHD, ANH, JIX, HUB, HUN, and XIJ, respectively, represent the provinces of Hebei, Shandong, Anhui, Jiangxi, Hubei, Hunan, and Xinjiang.

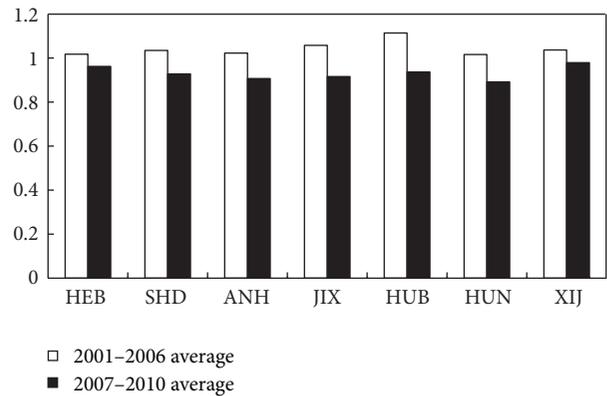


FIGURE 7: Cotton technological changes in China's major province. Notes: HEB, SHD, ANH, JIX, HUB, HUN, and XIJ, respectively, represent the provinces of Hebei, Shandong, Anhui, Jiangxi, Hubei, Hunan, and Xinjiang.

the TFP after the subsidy policy was implemented. The model indicates that TFP would be lower after the subsidy was implemented, and there exists a negative relationship between the subsidy policy and TFP if the subsidy is related to planting area. Using the input-output data of China's cotton production, this paper calculates the Malmquist index, which is the representative of the TFP and the technology progress of the whole country and major provinces from 2001 to 2010. The conclusion is that the TFP of China's cotton production decreased after seed subsidy was implemented from 2007, not only in the whole country but also in major provinces in China. So, the seed subsidy policy has failed to effectively increase the TFP of China's cotton production.

**4.2. Policy Implications.** The positive conclusion of this paper could give us many important policy implications. Firstly, the subsidy policy could not increase the agricultural TFP,

providing the subsidy related to the acreage. China's cotton seed subsidy is given to farmers according to their planting area; the only one effect of the seed subsidy is to encourage farmers to add acreage instead of adding other inputs, and of course, enlarging area is no means of increasing TFP. On the contrary, subsidy policy would breed inertia to farmers, because farmers could get the subsidy from government as long as they plant cotton, regardless how much yield they would harvest. Secondly, subsidy could be regarded as one kind of income, which has the feature of stickiness as wage. So, the quantity of subsidy paid to farmers should be increased constantly; otherwise, farmers would not be satisfied with the government. From the above mentioned two aspects, we could understand why there is a negative relationship between the subsidy, which is related to planting area, and the productivity because the subsidy could not motivate farmers to produce zealously and efficiently.

Agriculture is a weak industry, which is often influenced by the natural and economic environment. Because the supplying elasticity is generally higher than the demanding elasticity, agricultural production would be always in huge fluctuation without any intervention. Subsidy policy is one of the government intervening measures which could keep stable agricultural production and market. But if the government wants to encourage farmers to improve agricultural productivity through the subsidy policy, they would get the opposite result because the subsidy policy has no function to increase the TFP, as this paper indicated, as long as subsidy is related to the acreage. So, in order to increase the agricultural TFP, promoting the investment in research and development of agriculture and enhancing the technical progress in agriculture would be a better way than the subsidy policy.

**4.3. Further Discussion.** This paper makes a significant work in studying agricultural subsidy policy, especially in interpreting the relation between the subsidy policy and agricultural TFP through developing a theoretical model. But there are lots of interesting works should be developed. First, the mathematical model induced in this paper is under the supposition of subsidy related to the acreage. If loosening the assumption, which kind of relationship exists between the subsidy policy and agricultural TFP should be further investigated. Second, this paper only tests China's cotton production using Malmquist index, but other agriculture products, such as rice, wheat, soybean, maize, and pork, should be also needed to measure so as to efficiently verify the model. So, we will continue to extend the model and apply it in many agricultural productions not only in China but also in USA, EU, Japan, and so forth so as to perfect the model and obtain much more policy significance.

### Authors' Contribution

Y. W. Tan conceived and developed the mathematical model and wrote the paper; J. B. Guan Collected the data, Measured the Malmquist index using the software DEAP 2.1; H. R. Karimi Perfected, analyzed, and corrected the paper.

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