Journal of Agriculture and Ecology Research International
11(3): 1-17, 2017; Article no.JAERI.32153
ISSN: 2394-1073

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Conventional Inputs and Sectoral Productivity Growth in Agriculture: Evidence from Rural China

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Authors' contributions

This study was conducted in collaboration with all authors. Author OSM was responsible for the full draft including the statistical analysis. Author ZJ played the supervisory role and the project manager. Author TBU was in charge of data collection and editing. Author BK was responsible for proof reading. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2017/32153
Editor(s):
(1) Monica Rosa Loizzo, Department of Pharmacy, Health Sciences and Nutrition of University of Calabria, Italy.
Reviewers:
(1) Molatoli Thapelo Johannes, Huazhong Agricultural University, China.
(2) Subrata Kumar Mandal, CSIR-CMERI, Durgapur, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/18238

Original Research Article

Received 10th February 2017
Accepted 9th March 2017
Published 17th March 2017

ABSTRACT

Sustainable food production has become a subject of interest to policy makers in rural China in the quest to consolidate food security in the midst of an escalating population. Adopting Cobb-Douglas production function and employing cross-sectional data from 1990 to 2013, this paper measures the contribution of land, labor, fertilizer, agricultural machinery in addition with government investments to the growth of agricultural production. According to the results of the study, fertilizer application, labor and land contribute positively to total agricultural growth with elasticity of 1.48, 0.19 and 0.17 respectively from 1990 to 2013. A unit increase in price, investment in education and Research and Development also increase agricultural productivity growth by 0.4%, 0.74% and 0.03% respectively. An increase in fertilizer application contributes an average of 1.98%, 1.83%, 0.91% and 3.23% to crop, livestock, and fishery and forestry production respectively. A unit increase in farmlands also increases crop production by 0.8%, livestock production by 0.41% and fishery production by 0.23% during the entire period of study. In addition, fertilizer application,

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agricultural machinery and labor performed creditably on some selected farm products during the study period.

Keywords: Agriculture; productivity growth; conventional inputs; government expenditure.

1. INTRODUCTION

The poor performance of China's agricultural sector and the rapid increase in population growth have become a major challenge to policy [1]. Since 1978, there have been series of agricultural reforms in mainland China to ensure growth in the agricultural sector [2-4]. China initiated economic transition programs in its agricultural reforms, whereby, major farm productions were sub-divided into family units. The household responsibility system which was adopted by the government recorded a remarkable growth in China's agricultural sector [5]. However, to balance the increase in population growth and supply of food has compelled many studies to analyze the sources of this growth in mainland China [6]. A significant number of these studies have attributed the growth of agricultural sector to institutional changes made by the government and increased in the use of inputs on production growth from 1970s to the early 1990s [7-10]. Within the past decades, the success of the agricultural reform has led to a major shift in perception among major stakeholders most of whom hitherto held an erroneous perception that agriculture is an inferior partner when it comes to national development [11]. Literature maintains that food safety crises have compelled the governments to increase their food security policies and also made some changes in the regulatory controls [12,13]. For example, farmers in the agricultural sector are no more taxed but rather the sector is been financed by the government [14-16].

This paper seeks to investigate the impact of some conventional inputs such as land, labor, fertilizer application and agricultural machinery on growth of agricultural production during the mid-reform period (1990-1999) and the later part of the reforms (2000-2013). However, the major contributions of these conventional inputs to the agricultural growth cannot be underestimated since an increase in major agricultural inputs and total factor productivity contributed to about 40.6% and 55.2% to the growth of agricultural production respectively [6]. To achieve this goal, we measured the various effects of these conventional inputs on the entire growth of agricultural production and the various sub-sectors such as crop production, livestock production, fishery production and forestry production.

Again, we measured the contributions of these conventional inputs on the general growth of some major outputs of farm products, being: fruits, rice, wheat, corn, cotton, tobacco and tea. Moreover, we assessed how government investment in education, agricultural research and development and general price indices on some major outputs of farm products have contributed to the entire agricultural growth during the study period. This helped us to identify some significant changes in agricultural production, which have taken place during the study period. The next sections of the paper as follows; thematic areas of agricultural growth in rural China since 1970, outline of econometric models used, analysis of the data, discussion of major findings and conclusions.

2. AGRICULTURAL GROWTH IN RURAL CHINA SINCE THE REFORM PERIOD

Since the reform periods, there has been a rapid increase in the growth of agricultural production in mainland China. In terms of food production, China makes provision for more than one-fifth of the world's total population (approximately 1.3 billion people) with less than 7% of the word's arable land [17,18]. The total population of China is made up of 68% rural (Chinese Statistical Bureau 2005), and 47% of its labor force is in the agricultural sector. In 2008, China was able to produce 18% of the world's grain, 27% of its meat, 43% of its poultry and maize has accounted for a about 19% increase in the agricultural growth in 1776–1910.

The major contributions of agriculture to the development of Chinese economy is not only known to the food production but also serving as an employment for eight hundred million farmers in most of the rural areas [19]. The successful rural reforms in agriculture, the change from commune system to the household responsibility system (HRS) in the late 1970s and 1980s and the market reforms which revived and sustained the growth in agricultural sector have drawn the attention of many policy makers and researchers in the sector [2].

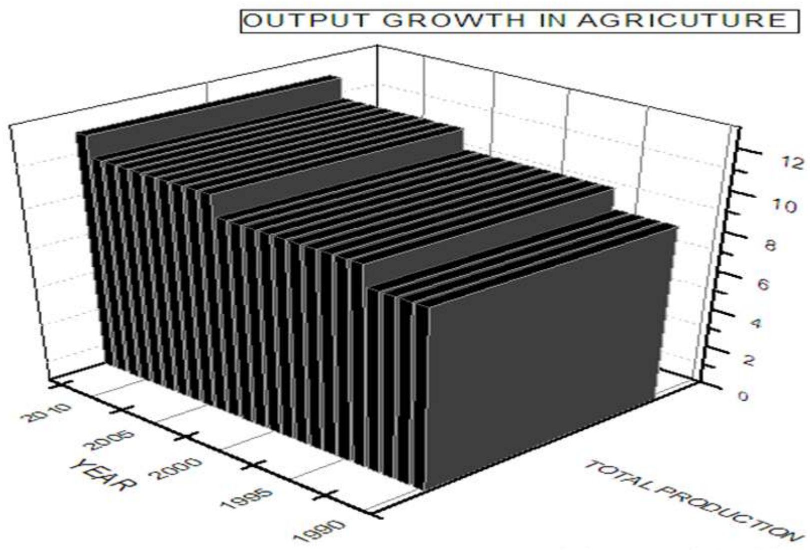

Fig. 1. Gross output value of agriculture in rural China, 1999 to 2013

The reduction in growth of the agriculture became thing of the past after 1978 when the annual agricultural GDP of 2.7% increased to 4.5% in 2010 and 7.1% during the initial stage of the reforms. However, at the later stage of the reform period (2006-2010), the annual contribution of the agricultural sector to the national GDP decreased drastically to 4.5%. The increase in crops' output is attributed to the use of new inputs and also a sudden change from grain production to more higher-value agricultural products such as poultry, fish, milk, eggs, tobacco, wheat, fruits and vegetables [8,20]. The growth of Total Factor Productivity in Chinese agricultural output averaged 2.7% and the used of farm inputs contributed 2.4% of agricultural growth, while the annual growth of agricultural total factor productivity which grew at the rate of 8.3% was attributed to technical progress [21]. Despite the general growth of agriculture production, some subsectors within the agricultural production have been recording lower output growth. For example, the grain output, which consist of maize, wheat, and rice, which was 4.7% during the early stage of the reform period (1979-1984), decreased to 2.5% at the later part of the reform period (2006-2010).

However, output growth of oilseed rose from 2.1% before the reforms (1970-1978) to 2.7% and from 1970-1978, that total factor productivity grew at 2.59% annually with technical change augmenting the growth by 5.48% while efficiency change reduced productivity growth by 2.78% decreased from 4.4% to 2.3% during the later part of the reforms [22,23]. The existing macroeconomic literature approaches Chinese agriculture by examining aggregate data only; see, e.g., [24-26,5,2] and [19] failed to provide a proper measure of the growth of the agricultural sector by analyzing the various sectors such as the livestock, crop, forestry and the fishery production as a whole.

In 1978, the Chinese government regulated the market prices by setting procurement prices for 113 agricultural commodities; and, at the retail level, the sales and prices of 158 commodities were controlled [27,28]. The central planning committee came out with two prices: "a quota procurement prices and an above-quota procurement price" [2]. For effective implementation of the price controls, unified procurement and unified sales with the people's Communes serving as the basic organizations in the rural China. During the later part of 1990, China declared self-sufficiency in grain production whereby cereal production from 1980 to 2005 increased by 80% [27,28].

3. MODEL ESTIMATION

This study employs a cross-sectional data from 1990-2013, to assess the contributions of land, labor, machines and fertilizers on the sectoral growth of agricultural production being cropping, livestock, forestry and fishery production, some major crops and on the entire agricultural growth in mainland China. To measure the effects of these conventional inputs on the growth of agricultural production, the study adopted Cobb-Douglas production function for the estimation as used by Lin, 1992. However, since we are dealing with cross-sectional data of 23 years, we estimated the marginal effect of an independent variables on the dependent variables, holding all of the other independent variables constant: $\frac{dy}{dx}$.

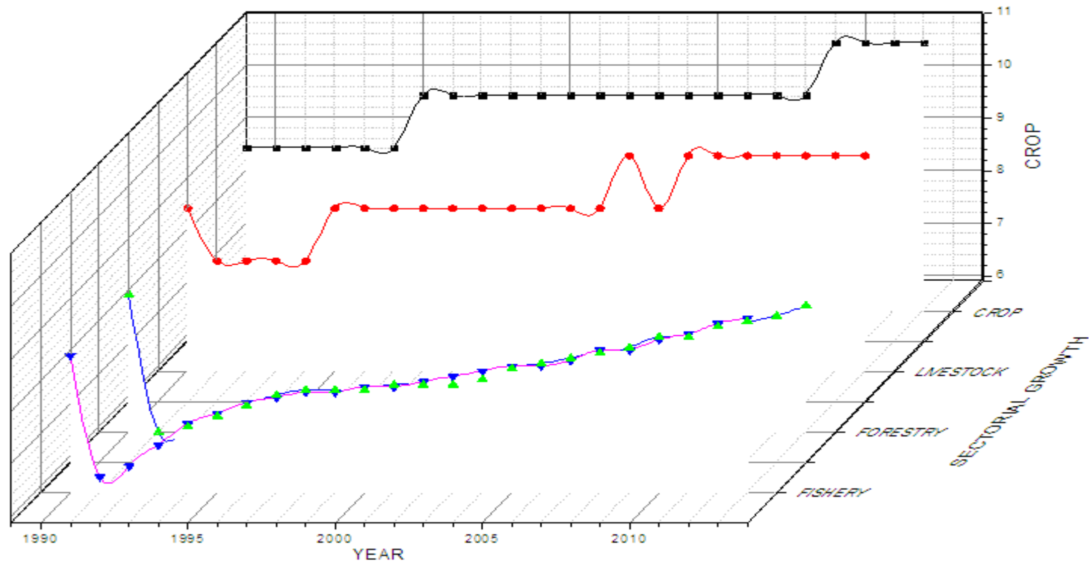

Fig. 2. Sectoral growth output value in agricultural production, 1999-2013
Source: [29]

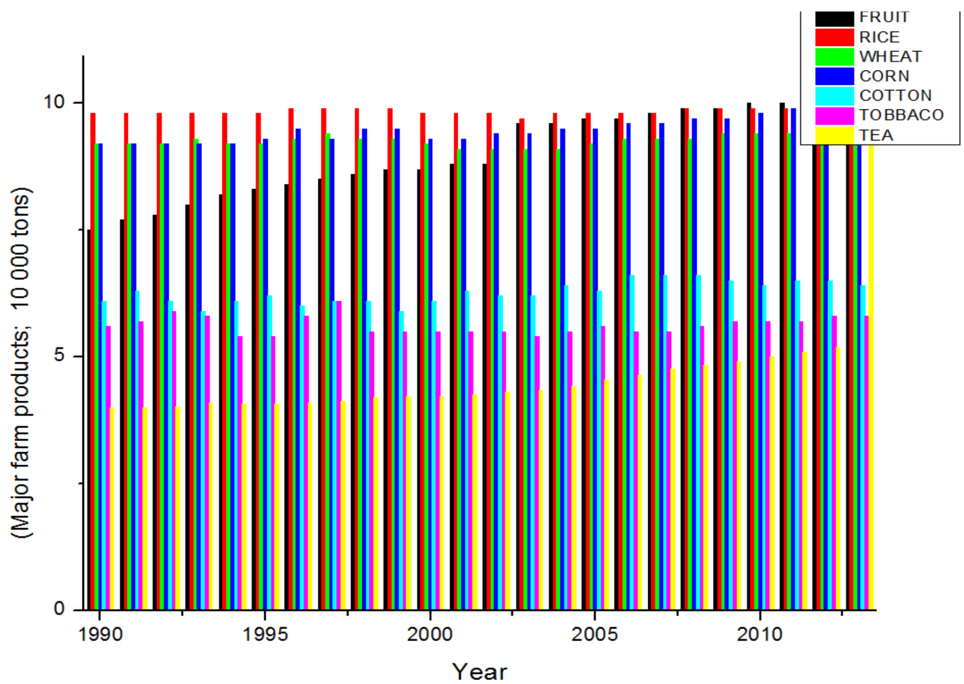

Fig. 3. The growth trends of some major farm products in rural China, (1999-2013)
Source: [29]

Table 1. Sources of agricultural productivity growth in China

Author(s)	Period	Data Type	Land	Labor	fertilizer	Irrigation	Capital	Machine	Power	Education	Investments
[19]	1979-2002	Provincial	0.438			0.481					
[30]	1978-1985	Provincial	0.317	0.367			0.227				
[31]	1975-1996	National	0.4	0.17	0.11			0.16			
	1975-1997		0.13	0.24	0.18			0.21			
	1975-1998		0.34	0.23				0.22			
[32]	1985-1986	Provincial		0.09	0.31			0.09			
[33]	980-1990	National	0.36	0.23	0.24	0.17		0.04		2.3	
[19]	1965-1978	National	-1.8	12.5	38				24.3		25.2
	1979-1984		-0.8	5.6	12				7.8		19.1
	1985-1993		0.1	6.2	9.1				5.5		14.1
	1965-1993		0.1	7.5	21.7				12.9		19.5
[2]	1979-1984	National	-1.75	4.52	32.2		10.82				
	1984-1987		-38.24	-70.07	53.71		44.73				
[34]	1965-99	National	0.36	0.28	0.43	0.06		0.06			

Table 2. Definition of the explanatory and dependent variables used in the study

Variable	Unit	Definition	Source
Total Output Value	100 million Yuan	Gross output value of total agricultural production	China Statistical Yearbook 2014
Crop Output Value	100 million Yuan	Gross output value of total farming	China Statistical Yearbook 2014
Livestock Output Value	100 million Yuan	Gross output value of animal husbandry	China Statistical Yearbook 2014
Fishery Output Value	100 million Yuan	Gross output value of fishery	China Statistical Yearbook 2014
land	10 000 hectares	Total cultivated or sown area	China Statistical Yearbook 2015
labor	10 000 persons	Workers engage in farming, forestry, animal husbandry and fishery and rural employ persons in agriculture	China Statistical Yearbook 2014
Fertilizer	10 000 tons	Consumption of chemical fertilizers such as nitrogenous, Phosphate, potash and compound.	China Statistical Yearbook 2014
Machinery	10 000kw	Total power of agricultural machinery	China Statistical Yearbook 2014
Irrigation	1 000 hectares	Total Irrigated Areas	China Statistical Yearbook 2014
Education	10 000 Yuan	Total government investment in education	China Statistical Yearbook 2014
AR&D	100 million Yuan	Expenditure in R&D in Crops, fishery, forestry and agriculture	China Statistical Yearbook 2014
Price		General price indices by means of agricultural production	China Statistical Yearbook 2014
Major Farm Products	10 000 tons	Output of major farm products	China Statistical Yearbook 2014

Source: [29]

Following [35], Cobb Douglas production function can be written as

$$Y = AK^{\frac{1}{4}}L^{\frac{3}{4}}, \quad (1)$$

With an assumption that the formula $Y = F(K, L)$ shows the relationship between output Y, capital K and labor L. Assume that F is continuously differentiable. That is for every output price level p, wage rate w, and capital rental rate r, let $K*(r,w,p)$ and $L*(r,w,p)$ maximizing profit,

$$p^{F(K,L) - rK - wL}$$

The first order conditions for an interior maximum are

$$P^F K(K^*, L*) = r \quad (2)$$

$$P^F L(K^*, L*) = w \quad (3)$$

Where F_K represents the partial derivation of F with respect to its first variable K, and F_L is with respect to L. With the assumption that the fraction of output paid to labor is a constant α . According to Cobb Douglas α =0.75, the constance can be written

$$(1-\alpha)pF(K*, L*) \quad (4)$$

$$\alpha pF(K*, L*) = wL \quad (5)$$

However, dividing (1) by (2) gives the following equation

$$\frac{1}{K^*} = \frac{F_K(K*, L*)}{(1-\alpha)F(K*, L*)}, \quad (6)$$

We now use the chain rule to notice that $\frac{d}{dx} In(f(x)) = \frac{f'(x)}{f(x)}$ for any function f .

Because of this (5) can be rewritten as

$$\frac{\vartheta}{\vartheta K} InF = \frac{F_K}{F} = \frac{1-\alpha}{K*}, \tag{7}$$

Which is the same as

$$\frac{\vartheta}{\vartheta L} InF = \frac{\alpha}{L*}, \tag{8}$$

This means that p,r and w have been eliminated. So the equation above hold for (K*,L*) that can result as profit maximization.However, if this is all of R_+^2, then we can trea t (7) –(8) as a system of partial differencial equations. Since $f\frac{1}{x} = In(x) + c,$ where c is a constance of integration, we have

$$InF(K,L) = (1-\alpha)InK + g(L) + c, \tag{9}$$

Where g(L)is a constant of integration that may depend on L; and

$$InF(K,L) = \alpha InL + h(K) + c',\ 7' \tag{10}$$

Where h(K) is a constant of integration that may depend on K. Combining these pins down g(L)and h(K), namely

$$InF(K,L) = (1-\alpha)InK + \alpha InL + C \tag{11}$$

Or, exponenting both sides and letting

$$A = e^C, \tag{12}$$
$$F(K,L) = AK^{1-\alpha}L^{\alpha}.$$

The study will adopt Cobb Douglas production functions in logarithm form as follows:

Equation (13) models the effects of land, machines, fertilizer and labor on the growth of entire agricultural production in rural China.

$$In\ G_{it} = \beta_0 + \beta_1 In\ (Land_{it}) + \beta_2 In(Labour_{it}) + \beta_3 In(Fertilizer_{it}) + \beta_4 In\ (Machine_{it}) + \beta_5\ Ln\ Edu_t + \beta_6\ Ln\ ARD_t + \beta_7\ Ln\ Price_t + \beta_8 T_{it} + \varepsilon_{it} \tag{13}$$

Table 3. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Total output value	24	10.28333	0.740544	8.9	11.5
Crop output Value	24	9.683333	0.668982	8.5	10.8
Livestock output value	24	9.120833	0.744241	7.7	10.3
Forestry output Value	24	7.133333	0.717282	5.9	8.5
Fishery output value	24	7.9875	0.781477	6.2	9.2
Labor	24	10.24583	0.383325	8.5	10.4
Fertilizer	24	8.383333	0.214003	7.9	8.7
Land	24	11.80417	0.705555	8.5	12
Machine	24	10.91667	0.422896	10.3	11.6
Price	24	4.658333	0.08297	4.6	4.9
Education	24	8.033333	1.23206	6.1	10
ARD	24	13.3375	1.771713	10.1	15.3
Fruits	24	9.016667	0.857533	7.5	10.1
Rice	24	9.8375	0.057578	9.7	9.9
Wheat	24	9.2625	0.105552	9.1	9.4
Corn	24	9.4875	0.245503	9.2	10
Cotton	24	6.266667	0.216025	5.9	6.6
Tobacco	24	5.625	0.177544	5.4	6.1
Tea	23	4.663913	1.250366	3.99	10.13
Time	24	12.5	7.071068	1	24

Table 4. Correlation matrix of the variables

Variables	Total	Crop	Livestock	Forestry	Fishery	Labor	Fertilizer	Land	Machine	Price	Education	Ard	Fruits	Rice	Wheat	Corn	Cotton	Tobacco	Tea
Total output Value	1.00																		
Crop output Value	1.00	1.00																	
Livestock output value	0.97	0.97	1.00																
Forestry output Value	0.67	0.68	0.82	1.00															
Fishery output Value	0.84	0.85	0.94	0.94	1.00														
Labor	0.24	0.21	0.01	-0.55	-0.28	1.00													
Fertilizer	0.85	0.85	0.94	0.93	0.99	-0.26	1.00												
Land	0.44	0.42	0.22	-0.37	-0.10	0.96	-0.07	1.00											
Machine	0.97	0.96	0.97	0.72	0.86	0.16	0.88	0.35	1.00										
Price	0.07	0.06	0.05	-0.06	-0.05	0.05	-0.07	0.14	-0.07	1.00									
Education	0.98	0.98	0.97	0.72	0.86	0.18	0.87	0.37	0.99	-0.01	1.00								
Ard	-0.37	-0.34	-0.40	-0.30	-0.36	-0.09	-0.42	-0.10	-0.48	0.16	-0.45	1.00							
Fruits	0.96	0.94	0.95	0.66	0.82	0.23	0.83	0.41	0.97	0.03	0.97	-0.52	1.00						
Rice	0.48	0.52	0.45	0.35	0.40	0.06	0.41	0.18	0.38	-0.02	0.42	0.32	0.30	1.00					
Wheat	0.51	0.55	0.48	0.43	0.42	0.01	0.43	0.15	0.43	-0.04	0.48	0.20	0.40	0.81	1.00				
Corn	0.93	0.94	0.92	0.74	0.82	0.08	0.83	0.29	0.92	-0.01	0.93	-0.28	0.88	0.62	0.65	1.00			
Cotton	0.71	0.68	0.73	0.59	0.61	0.01	0.65	0.18	0.75	0.11	0.76	-0.55	0.77	0.14	0.27	0.66	1.00		
Tobacco	0.02	0.03	-0.03	0.02	-0.06	0.03	0.00	0.03	-0.02	-0.25	0.01	0.27	-0.07	0.50	0.59	0.15	-0.08	1.00	
Tea	0.59	0.60	0.58	0.53	0.54	0.01	0.54	0.14	0.60	-0.13	0.60	-0.04	0.52	0.37	0.43	0.68	0.36	0.21	1.00

The equation (14) models the effects of land, machines, fertilizer and labor on the growth of some major products in agriculture.

$$In\ G_{it} = \beta_0 + \beta_1\ Ln\ Labor_{it} + \beta_2\ Ln\ Fertilizer_{it} + \beta_3\ Ln\ Machine_{it} + \beta_4\ Ln\ Land_{it} + \beta_5\ T_{it} + \varepsilon_{it} \quad (14)$$

Where *G* is gross value of agricultural output*, i* and t measure the sectoral, the total agricultural outputs respectively, and the coefficient, *In* demonstrates that the various outputs and other conventional inputs used are in natural logarithm form since different figures from different sectors were used for the analysis. This helps to solve the problem of heteroskedasticity since there are large differences among the sizes of the observations. Government investments in education and intramural expenditure on Agricultural Research and Development *(A&RD)* and general price indices for means of agricultural production, which may influence agricultural growth, were also included in the model estimation. Also, the ε_{it} and β are the error term and parameter to be measured respectively, β , (i= 1,2,3,…n) are the parameters which will measure the elasticity of the respective variables with respect to agricultural production with the assumption that $\beta_0 > 0$.

4. ANALYSIS AND DISCUSSION OF RESULTS

This section presents the vivid account of calculation and analysis of the growth derived from the additional units of the conventional inputs used being land, labor, fertilizer and machine and also the government expenditure on education, agricultural research and the changes in the prices of some farm products. Since we employed Cobb-Douglas production function for the equations in the system, covariance estimator of Ordinary Least Squares (OLS), which is the most appropriate linear unbiased estimator, is used for the estimations.

4.1 The Whole Study Period: (1990-2013)

The estimated results shown in Table 5 are for the whole study period (1993-2013). The regression results and goodness of fit are satisfactory. From column 2 to column 5, the significant variables being education, price indices and agricultural research and development are dropped, which helps us to measure the actual effects of the conventional inputs used in our estimation on the output growth of the various subsectors in agriculture. The first column of Table 5 reports the total output growth in agriculture. Apart from labor, land and agricultural machinery all the remaining variables are statistically significant as expected with adjusted R^2 as high as 0.989. Whilst machine had negative effect on the total growth of agricultural production, labor, fertilizer, land, education and price indices, while investment in agricultural research had positive effect on the growth of agricultural production. This implies that a unit (1%) increased in labor, application of fertilizer, land being crop sown area, government investment in education, general price indices for means of agricultural production and intramural expenditure on research and development in agriculture increased agricultural production by 19.3%, 1.478%, 0.172%, 0.738%, 0.401% and 0.025% respectively.

However, agricultural machines had a negative effect on the output growth with elasticity of -0.363 but recorded positively on the output growth of forestry and fishery.. However, the results of agricultural machinery confirms the existing studies which maintained that an increased in the use of agricultural machinery has induced agricultural development despite the high cost of production faced by the agricultural machinery industry [36]. Fertilizer was the highest contributor to the growth of total agriculture production followed by investment in education during the study period. The second column of Table 5 reports the growth in crop production. The results show that, except agricultural machinery, all the other three variables used for the estimation are statistically significant with adjusted R^2 of 0.970. The impact of labor and machine on crop output were negative as compared to that of fertilizer and land which were positive with the coefficients 1.986 and 0.800 respectively with fertilizer been the highest contributor to the growth of crops' output.

Results from column 3 of Table 5 present the output growth in livestock production. The coefficients of these results are statistically significant. Results from this regression indicate that over the period of 1990 to 2013, fertilizer still plays a pivotal role in Chinese agricultural production and land on the livestock's production. From Table 5, an increased in

Table 5. Modeling the effect of conventional inputs and government expenditure on the agricultural growth over the whole study period (1990-2013)

Variable	Total	Crop	Livestock	Fishery	Forestry
1990-2013	**1**	**2**	**3**	**4**	**5**
*ln*Labor	0.193	-0.849**	0.659**	-0.742**	-0.143
	(0.634)	(2.588)	(2.037)	(3)	(0.359)
*ln*Fertilizer	1.478**	1.986**	1.83**	0.914**	3.234**
	(4.529)	(4.268)	(3.997)	(2.612)	(5.737)
*ln*Land	0.172	0.8**	0.439**	0.226	0.008
	(0.904)	(3.8)	(2.174)	(1.464)	(0.031)
*ln*Machine	-0.363	-0.685	0.414	0.711	0.387
	(-0.711)	(0.937)	(0.598)	(-1.343)	(0.455)
*ln*Education	0.738**				
	(2.839)				
*ln*Price	0.401**				
	(1.538)				
*ln*AR&D	0.025**				
	(2.024)				
Time trend (t)	-0.48	0.059**	0.069**	0.106**	-0.013
	(0.884)	(1.288)	(1.526)	(3.099)	(0.232)
Adjusted R^2	0.992	0.97	0.977	0.985	0.968
S.E of Regression	0.7786	0.11531	0.11346	0.08673	0.13968

Note: Figures in parenthesis are the calculated t-values.
*Absolute t-values are in parenthesis. *P< 0.10, **P< 0.05, ***P< 0.01*

fertilizer application by one unit, increases the growth of agricultural output by 1.986 units and 0.800 units from 1990 to 2013. From the results estimate in column 4 of Table 5, the application of fertilizer has a positive and significant effect on forestry production with estimated coefficient of 0.914 as compared to the estimate of land, which is significant but recorded negatively. Labor and agricultural machinery also has negative impact on forestry growth during the study period.

Results from column 5 of Table 5 also show that the contribution of labor on forestry production declined with coefficient of -0.143, which was not statistically significant. However, apart from fertilizer application, which is statistically significant, land and machine are insignificant but have positive effect on fishery production with estimated coefficients 3.234, 0.008 and 0.387 respectively.

4.2 In Sub-periods: 1990-1999 vs. 2000-2013

We also ran the model separately for both mid-reforms period (1990-1999) and late reforms period (2000-2013) to measure whether there are significant changes in the both the total output of agriculture and sectoral outputs with changes in land, labor, fertilizer, machine, investment in education, agricultural research and development and price indices for agriculture over time. The results are reported in Tables 6 and 7.

4.2.1 Land

The contribution of land to the growth of agricultural production has been enormous during the mid and later part of the reform periods. The result from column 1 of Table 7 indicates that, land has been a major contributor to agricultural productivity growth at the later part of reform period with elasticity 0.211, which means a unit increase in land positively affect the output growth of agricultural production at the late reform period. On the other hand, land had less impact on the outputs growth of all the major sub-sectors in agricultural production during the mid-reform period with elasticity -0.606 -0.790, -0.346 and -0.373 respectively. Surprisingly, land had positive effect on the growth of crops, livestock, fishery and forestry production during the later part of the reforms. From Table 7, an increase in land by one unit (1%) increased the outputs of major sectors in agriculture averagely 0.1%, 0.53%, 0.958% and 0.701% respectively. This supports the findings Razavi [37], which revealed that land is a major indicator of

Table 6. Modeling the effect of conventional inputs, government expenditure in education and agricultural R&D and the general price indices on the agricultural growth during mid- reform period (1990-1999)

Variable	Total	Crop	Livestock	Fishery	Forestry
1990-1999 (Mid-Reforms)	**1**	**2**	**3**	**4**	**5**
*ln*Land	-0.99**	-0.606	-0.79	-0.346	-0.373**
	(1.222)	(0.562)	(0.137)	(0.731)	(1.467)
l*n*Fertilizer	1.115**	1.761**	1.188	2.08	1.162**
	(1.036)	(2.094)	(0.267)	(2.025)	(2.107)
*ln*Labor	0.272	0.599**	0.344**	-0.195	-0.38**
	(0.904)	(2.31)	(2.305)	(0.616)	(2.239)
*ln*Machine	-1.186	-0.646	-1.43	-1.676**	-0.225
	(0.956)	(0.552)	(0.33)	(1.167)	(-0.291)
*ln*Education	1.863**				
	(2.216)				
*ln*Price	-0.141				
	(0.251)				
*ln*AR&D	0.041**				
	(2.216)				
Time trend (t)	-0.172	0.097**	0.192	0.224**	0.075**
	(0.691)	(1.001)	(0.144)	(1.818)	(1.191)
Adjusted R^2	0.98	0.949	0.935	0.967	0.991
S.E. of Regression	0.069	0.1053	0.1155	0.1286	0.0691

Note: Figures in parenthesis are the calculated t-values.
*Absolute t-values are in parenthesis. *P< 0.10, **P< 0.05, ***P< 0.01*

agricultural productivity growth. However, despite the major contribution of land to the growth of agricultural production, land fragmentation has been a major problem facing smallholder farmers in rural China [38].

4.2.2 Fertilizer application

Again, from Table 6, fertilizer elasticity was positive and statistically significant during the mid-reform period (1990-1999). This means that a unit increased in fertilizer application increases the growth of agricultural by 1.115%. From 1996, the major achievements in food production in rural China since have been possible due to application of fertilizer [39]. In addition, China's fertilizer distribution has changed drastically due to the development of market economy and the adjustment of agricultural mix, which has increased fertilizer application from 22.0% (1980) to 31.8% (1993). This is likely to increase the consumption of fertilizer by 70 mt/a if China's population is controlled under 1.6 billion in 2030 [40]. Nevertheless, after the middle part of the reforms, fertilizer application contributed poorly to the growth of agricultural production with elasticity of -0.025 from Table 6. However, results from Table 6 indicate that the contribution of fertilizer applications to the various sectoral outputs in agriculture production at the later part of the reforms (2000-2013) increased enormously with elasticity of 0.393, 0.728 and 0.954 on crop, livestock, fishery and forestry production respectively. The general contribution of fertilizer on the entire agricultural growth at the late reform era indicates that a unit increased in fertilizer application results in an increase in output growth of agriculture. However, the impact of fertilizer application on crop productions is negative. Studies maintained that the application of fertilizer as a major means to increase the agricultural growth is now receiving low attention due to an increased use of technology, improvement in crop production and ensuring food quality [3,7,41-44].

4.2.3 Labor

The impact of labor on the growth of agricultural production is highly significant during the sub-periods under study. The results from Table 6 indicate a positive estimated parameter during the two sub-periods under studied with their coefficients 0.272 at the mid-reform period and 0.342 during the late reform. This means that 1% increase in labor increase agricultural production by 0.272% and 0.342% respectively. During the mid-reform period (1990-1999), labor elasticity

Table 7. Modeling the effect of conventional inputs, government expenditure in education and agricultural R&D and the general price indices on the agricultural growth during late reform period (2000-2013)

Variable	Total	Crop	Livestock	Fishery	Forestry
2000-2013 (Late reforms)	1	2	3	4	5
*ln*Land	0.211	0.1**	0.53	0.958**	0.701**
	(0.412)	(1.125)	(0.434)	(1.136)	(1.365)
*ln*Fertilizer	0.025	-0.393	0.928	0.728**	0.954
	(0.053)	(0.476)	(0.844)	(1.957)	(2.061)
*ln*Labor	0.342	0.983**	0.941**	0.998**	0.599**
	(0.94)	(1.886)	(1.343)	(2.046)	(2.029)
*ln*Machine	0.143	-0.016	-0.329	0.028	-0.118**
	(0.244)	(0.19)	(0.32)	(2.038)	(1.273)
*ln*Education	0.05**				
	(1.342)				
*ln*Price	0.413**				
	(3.576)				
*ln*AR&D	0.02**				
	(1.438)				
Time trend (t)	0.97**	0.117**	0.164**	0.232**	0.159**
	(1.73)	(2.191)	(2.321)	(2.684)	(5.334)
Adjusted R^2	0.996	0.968	0.966	0.972	0.992
S.E of Regression	0.0258	0.0756	0.0939	0.065	0.0396

Note: Figures in parenthesis are the calculated t-values.
*Absolute t-values are in parenthesis. *P< 0.10, **P< 0.05, ***P< 0.01*

on crop production was 0.599%, which increased to 0.983% during the late reform period with an implication that a percentage increase in labor after the reforms increases crop production. This confirms the fact that as farm labor increases, agricultural productivity growth also increases [45]. The labor elasticity also increased from 0.334 during the mid-reform period to 0.941 at the later part of the reforms on livestock production, Table 6. This means that an increase in labor positively affected the productivity growth of livestock production during the two sub-periods. However, the effect of labor on both fishery production and forestry production were unspeakable with the estimated coefficients of -0.195 and -0.381 respectively during the middle part of the reforms from Table 6. However, during the late reform period, land contribution was satisfactory on both the fishery and forestry production with elasticity of 0.998 and 0.599 respectively.

4.2.4 Agricultural machinery

A highly industrialized country like China benefits a lot from the use of sophisticated agricultural machinery in terms of food production. However, from Table 7, while fertilizer and labor had a positive effect on the agriculture production during the late reform periods, agricultural machinery performed poorly on the output growth of agriculture despite its impressive performance from 1990-2000. The elasticity of agricultural machinery increased from -1.186% during the mid-reform period to 0.143% at the late reforms. This showed an appreciable increase in its performance on the output growth of the entire agricultural production. This means that a unit change in agricultural machinery contributes to 0.143 unit growth in agricultural production during the later part of the reforms (2000-2013). Agricultural machinery also had a significant effect on the output growth of the various sub-sectors in Chinese agriculture. The estimated coefficients of agricultural machinery increase from -0.646 to -0.016 on crop output, -1.430 to 0.329 on livestock output, -1.676 to 0.028 on fishery output and -0.225 to -0.118 on forestry output from Table 6 and Table 7. It also had a positive impact on almost all outputs of the selected farm crops with the exception of fruit, Table 8.

Table 8. Modeling the effects of conventional inputs on major farm products over the two reform periods

Variables	Fruits		Rice		Wheat		Corn		Cotton		Tobacco		Tea	
	coef.	**t**	**coef.**	**t**	**coef.**	**t**	**coef.**	**t**	**coef.**	**t**	**coef.**	**t**	**coef.**	**t**
1990-1999														
Land	-0.131	-0.438	0.187	2.429	0.334	1.348	0.044	0.157	-0.518	-1.097	1.418	1.656	0.039	0.302
Fertilizer	1.210	2.419	0.125	0.972	0.453	1.502	-0.038	-0.081	-0.428	-0.541	1.570	1.096	-0.420	-0.194
Labor	0.351	2.030	-0.088	-1.976	-0.114	-1.089	-0.380	-0.236	0.238	0.871	-0.512	-1.034	-0.019	-0.194
Machine	0.905	2.086	0.181	1.616	-0.080	-1.305	0.750	1.864	-0.059	-0.086	-1.409	-1.135	0.410	2.210
Adj. R2	0.960		0.836		0.510		0.698		0.423		0.781		0.790	
S.E of Reg.	0.081		0.209		0.490		0.075		0.128		0.232		0.035	
2000-2013														
Land	-3.862	-1.519	-0.100	-0.295	-0.254	-0.611	0.352	1.094	-1.378	-1.010	-0.283	-0.624	21.818	1.630
Fertilizer	2.744	1.467	-0.052	-0.206	-0.127	-0.279	0.006	0.025	1.460	1.454	0.170	0.510	-4.658	-4.473
Labor	-2.978	-1.971	0.526	2.567	1.167	1.120	-0.037	-0.193	-1.500	-1.844	0.927	3.430	4.473	0.561
Machine	-0.596	-0.430	0.173	0.932	0.720	1.129	1.094	6.227	-0.634	-0.852	0.225	0.908	13.491	1.847
Adj. R2	0.782		0.764		0.794		0.984		0.419		0.896		0.349	
S.E of Reg.	0.229		0.031		0.058		0.029		0.123		0.410		1.209	

*Note: Absolute t-values are in parenthesis. *P< 0.10, **P< 0.05, ***P< 0.01*

4.2.5 Price Indices and government expenditure

We also measured the effects of changes in the general prices indices of some farm produce and the government investments on agricultural production during the sub-periods under studied. The results show that education serves as a major contributor to the agricultural productivity growth with elasticity 1.863, followed by agricultural research and development with the elasticity 0.04, Table 6.

However, price has less effect on agricultural production with the elasticity of -0.141 during the mid-reform period (1990-1999). In order to reduce the literacy rate and increase agricultural production in rural China, the Chinese government has invested a lot of resources into education and research and development to improve the technical know-how of the rural people [19]. From Table 7, government investment in education and research and development decreased the output growth of agricultural production during the late reform period of the study. The price indices of agricultural products also recorded positively on agricultural production with the estimated coefficient of 0.413. This shows that the implementation of price control system by the government contributed creditable to agricultural productivity growth during the late reform period.

4.3 Major farm Products: 1990-1999 vs. 2000-2013

We again estimate the changes in conventional inputs used (land, labor, fertilizer and machines) and how it affects the growth outputs of some major farm products such as fruits, rice, wheat, corn, cotton, tobacco and tea. The results presented in Table 8 show that land records positively to the output growth of all the major crops used in the study with the exception of fruits and cotton outputs. The estimated coefficients are 0.187 on rice production, 0.334 on wheat production, 0.044 on corn production, 1.418 on tobacco production and 0.039 on tea production with the tobacco production recorded the highest impact during the mid-reform period. It means that a unit changed in land inputs led to 1.418% increased in the tobacco production. However, at the later part of the reforms (2000-2013), the performance of land on the various crops reduced drastically with a negative growth in almost all the various crops used with the exception of corn production and tea production.

In addition, fertilizer application was found to have positive effect on the growth of fruits production with elasticity 1.210, rice production with elasticity 0.125, wheat production with elasticity of 0.453 and tobacco production elasticity 1.570, Table 8. After the mid-reform period, fertilizer elasticity on fruits production increased to 2.744, with the elasticity of corn and cotton production increased from -0.038 and -0.428 to 1.460 and 0.170 respectively during the late reform period, whilst the rest of the crops recorded negatively on output growth. The labor elasticity on both fruits and cotton also decreased from 0.351 and 0.238 during the mid-reform period to -2.744 and 0.170 respectively at the late reform periods. However, the labor contribution to rice, wheat, and tobacco and tea production increased with the elasticity of 0.526, 0.167, 0.927 and 4.473 respectively and the rest of the crops recorded negative impact at the late reform period (2000-2013).

The machine elasticity decreased from 0.905 and 0.181 during the mid-reform period to -0.596 and 0.173 on fruits and rice production at the later part of the reform. The elasticity of wheat, corn, tobacco and tea production increased from -0.080, 0.750, -1.409 and 0.410 during the mid-reform period (1990-1999) to that of 0.720, 1.094, 0,225 and 13.491 respectively after that period of reforms. The major contributor to food production since 1999 has been ascribed to the expansion of cereal production (rice, wheat, and maize) due to an introduction of high yielding varieties, cropping intensification being double or triple cropping and more importantly through the use of irrigation and fertilizer application [39].

5. CONCLUSION

The study investigated the effects of conventional inputs, government spending and general price indices on agriculture productivity growth whereby, the outputs of some major sub-sectors such as crop, livestock, forestry and fishery production were measured. Econometrically, we modeled the behaviors of land, labor, fertilizer, machines, government investment in education and agricultural R&D, general price indices on farm products and agricultural growth over the study periods. The study revealed that, the performance of land from 2000-2013 was quite appreciable as compare to the mid-reform period. However, the mild performance of land during the mid-reform period is attributed to the fragmentation of landholding in rural China because of egalitarian principles used for the proportional distribution of land to the various households and the conversion of agricultural land to non-agricultural purposes.

In addition, fertilizer application as a primary driver of agricultural growth had significant effect on the output growth of agriculture during the late reform period. This might come from the creation of awareness of the effect of excessive fertilizer application on the soil environment, some greenhouse vegetables, which have compelled many farmers to improve upon crop productivity and to ensure food security and environmental quality by the use of environmental friendly farming practices in rural China. Again, labor had a positive impact on the growth of agricultural productivity during the two sub periods studied. In as much as the off-farm employments by young and educated people are increasing in rural China, the contribution of labor to the farming sector is enormous. This is possible due to the set of agricultural market reforms in rural China, which has increased the income of rural farmers and consequently resulted in creation of large surplus labor supply. Concisely, the contribution of agricultural machinery to the productivity growth of agriculture appreciated after the mid-reforms and the coefficients for the various subsectors being significant. Finally, government investments in education and agricultural research and development and the general price indices on major farm products had a substantial marginal impact on the growth of agricultural outputs during the whole period and the two sub-periods of reforms. According to the results, the government expenditure in education has been the dominant force championing agricultural productivity growth after the fertilizer application during the sub- periods under studied. Nevertheless, during the entire study period (1990-2013), the general investment made by the government and price control system had a mild impact on the growth of the output of agricultural production.

ACKNOWLEDGEMENT

For comments, suggestions and data collection, we thank Dr. Emmanuel Opoku Marfo, Dr. Henry Asante Antwi, Li Na, Chen Cong, Dr. Kwame Amoako Oduro, Li Junqiang and Liu Jiayi. National Natural Science Foundation of China (NSFC) funded this research work, with grant number 71473106.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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