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HOW FAST HAVE CHINA'S AGRICULTURAL PRODUCTION AND PRODUCTIVITY REALLY BEEN GROWING? NEW MEASUREMENT AND EVIDENCE

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ABSTRACT

Output in Chinese agriculture has grown rapidly for the last several decades, as reported by the Statistical System in China. However, reported total output is aggregated using constant prices, which has been proven to be inappropriate by many economists. As a result, growth rates of output reported by the government may be biased. This bias can be large, particularly at a time when relative prices of agricultural products were changed substantially as part of the policy reforms during the 1980s and 1990s. A similar problem exists in the aggregation of total input. Consequently, estimates of total factor productivity, an index of output minus input, can also be biased.

This study uses a more appropriate approach to measure growth in output, input and total factor productivity for Chinese agriculture. Using newly estimated production and productivity growth indexes, the impact of rural reforms are reassessed. The conventional approach overestimates the impact of the rural reforms on both production and productivity growth. Nevertheless, both production and productivity still grew at respectable rates during the reform period.

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1. INTRODUCTION

Agricultural output in China has been reported as growing rapidly in the last several decades, particularly since the rural reforms began in 1979. The State Statistical Bureau (SSB, 1996) reported that from 1952 to 1995, output grew at 4.25 percent per annum. Up until 1978, the annual rate was 2.83 percent per annum, and then jumped to 6.5 percent per annum from 1979 to 1995. This long-term growth rate was one of the highest growth rates achieved among all countries during the same period.

The aggregate output used to calculate these growth rates for Chinese agriculture is based on *gross value of agricultural output* (GVAO) reported by the State Statistical Bureau (SSB), the official government agency specialized in collecting, measuring, and reporting statistics in China. Many economists (both Chinese and Western) have also used GVAO in their studies on Chinese agriculture (Lardy, 1983; Perkins and Yusuf, 1984; Fan, 1990, 1991; Lin, 1988, 1992; World Bank, 1991). Several attempts have also been made to measure productivity growth in order to determine the impact of the recent reforms within the agricultural sector (Tang, 1984; Weins, 1982; Lin, 1987, 1992; Fan, 1990; Wen, 1993).

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GVAO is measured in constant prices ("comparable prices" is the term used by the Chinese statistical system) to represent total output in a particular year. But constant prices may not be the appropriate weights in aggregating total output as many economists have pointed out (Diewert, 1976; Lau, 1979; Jorgenson, 1995). In measuring total factor productivity growth, inputs must be aggregated to a total input index. The weights used to aggregate inputs in the previous studies are also often ad hoc, and are not derived from any empirical data (Tang, 1984; Wiens, 1982; Wen, 1993). As a result, estimates of total factor productivity, measured as aggregate output per unit of aggregate input, are likely to be biased. Biased estimates of production and productivity growth in Chinese agriculture can have serious consequences, as these indicators are often used to judge the performance of the agricultural sector and the success of the rural reforms in Chinese agriculture, and to guide public investment decisions.

The objective of this paper is to properly measure growth in output, input, and total factor productivity in Chinese agriculture, and to reassess the impact of the recent policy reforms on production and productivity growth. The paper is organized as follows. The first section reviews some of the measurement issues in production theory. It shows how estimates of aggregate output and input, and therefore measured total factor productivity, can be biased using constant prices as weights, a commonly used way of measuring aggregate output and input in practice. The second section is devoted to the measurement of output growth in Chinese agriculture using a more appropriate aggregation. The third section deals with the measurement of total inputs used in agricultural production. The fourth section measures total factor productivity growth and reassesses the impact of the rural reforms and institutional changes on productivity growth in the last several decades. A summary and conclusions are presented in the fifth and last section.

2. CONCEPTUAL FRAMEWORK

The agricultural sector in China produces a great number of products including major staple grains like rice, wheat, and corn; major livestock products such as meat, wool, and dairy products; and horticultural and fishery products. Aggregation is often needed in order to compare the performance of the whole agricultural sector over time and across countries or regions. Similarly, aggregation over inputs used in the agricultural sector is also necessary for several reasons, such as providing information for measuring technical changes and efficiency improvement, and for measuring total factor productivity.

Agricultural output in the Chinese statistical reporting system is measured as gross value of agricultural output (GVAO) using constant prices as weights. GVAO, often measured in current prices, is also measured and reported in constant prices,[1] for purposes of comparison over years. Then, production index and growth rate of output are often calculated based on GVAO.

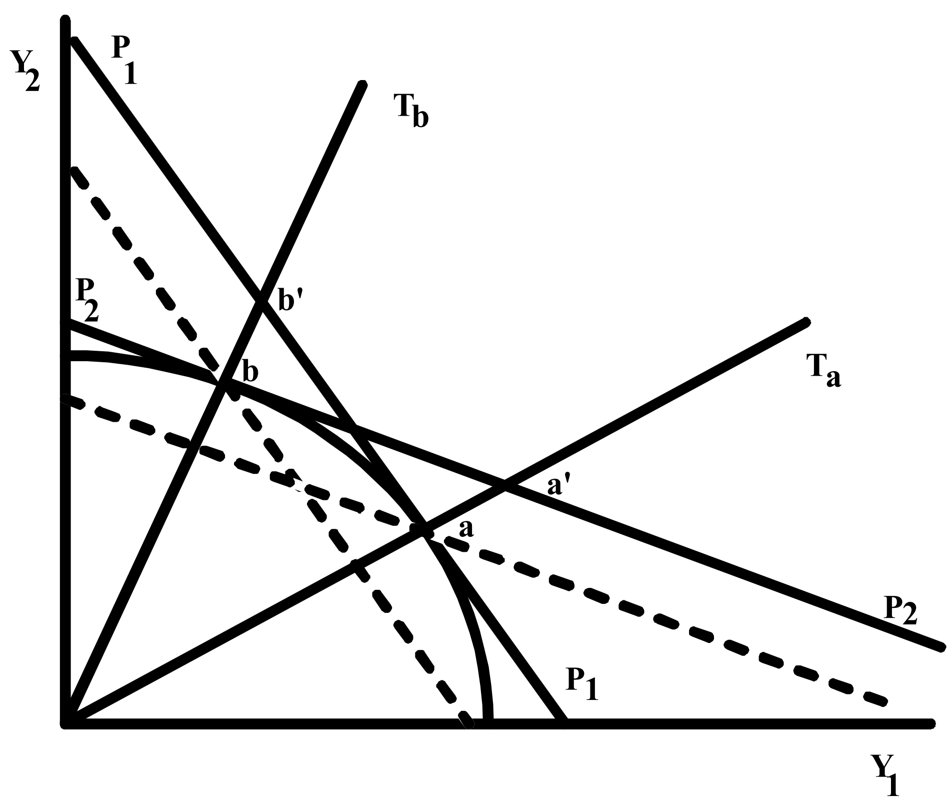
Many economists have pointed out that using constant prices to aggregate output may result in biased estimates of production growth. This potential bias is illustrated in Figure

[1] GVAO measured in current and constant prices are reported by various yearbooks published by State Statistical Bureau (SSB) and Ministry of Agriculture (MOA), for example, *China Statistical Yearbook* (SSB), *China Agricultural Yearbook* (MOA), *China Rural Statistical Yearbook* (SSB), and *China Agricultural Statistical Materials* (MOA).

1 where Q_0 represents a production possibility curve which indicates the different combination of products Y_1 and Y_2, using the same amount of inputs.[2] Profit maximizing producers choose different combinations of Y_1 and Y_2 based on the relative prices of the two products. Producers would choose point *a* in the production possibility curve when relative prices are P_1, and *b* when relative prices are P_2. If total output is aggregated using a linear aggregation of the two products weighted by their relative prices P_1, aggregate output at *a*

(equals to output at b') would be greater than that at *b*. But if P_2 is used in the aggregation,

Figure 1 Aggregation bias in output



[2] Alston *et al.* (1995) have also demonstrated the potential bias in aggregation of inputs and outputs when technical change is both present and absent.

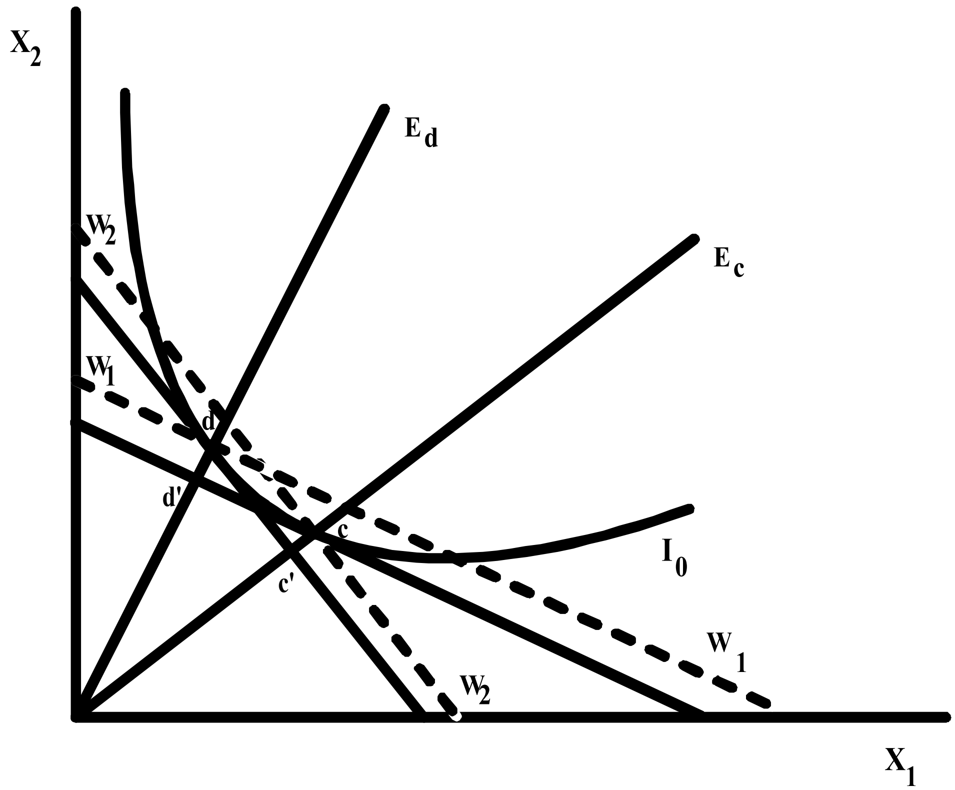
output at *b* (equals to output at a') would be greater than that at *a*. Different output measures are obtained using different price weights, although producers only move along the same production possibility curve.

Figure 2 shows the potential bias that arise from input aggregation where I_0 represents an isoquant in which the same amount of output is produced using different input combinations of X_1 and X_2. Cost-minimizing producers choose input combinations based on relative input prices, W_1 and W_2. If producers face relative prices W_1, then the optimal combination of inputs would be at point *c*. If relative prices change to W_2, the optimal combination of inputs would be at *d*. This shift is the producers' response to input price changes (the substitution effect) along the same isoquant. But using different relative prices as weights yields different input aggregates. For example if relative prices W_1 are used as weights, aggregated input at *d* is greater than that at *c* (equals to output at d'). Conversely, if relative prices W_2 is used, aggregate input at *c* is greater than that at *d* (equals to output at c'). The resulting productivity index using these biased estimates of aggregate output and input is also biased even when there has been no change in quantities of either inputs or outputs.

In order to minimize the potential bias caused by relative price changes, several approaches have been developed by numerous economists. The method commonly used is the Törnqvist-Theil index. The formula for a Törnqvist-Theil index of aggregate output is:

$$lnQI_t = \sum_i 1/2 * (S_{i,\,t} + S_{i,\,t-1}) * \ln(Y_{i,\,t} / Y_{i,\,t-1}), \qquad (1)$$

Figure 2 Aggregation bias in input



where $lnQI_t$ is the log of the aggregate output index at time t over time t-1, $S_{i,t}$ and $S_{i,t-1}$ are output i's shares in total production value at time t and t-1, respectively. $Y_{i,t}$ and $Y_{i,t-1}$ are quantities of output i at time t and t-1, respectively. The Törnqvist-Theil index described in (1) is a discrete approximation to the continous Divisa index and possesses a number of desirable properties. Diewert (1976) and Lau (1979) have proved that the Törnqvist-Theil index is an exact approximation for the more general class of translog aggregator functions. Unlike the Laspeyres and other fixed price weight indices, it is invariant to the choice of base year. Another advantage of such an index is that any substantial change in relative prices over time is accommodated by rolling weights. This is particularly relevant at a time when relative prices of agricultural products changed substantially in China during the 1980s and 1990s.

Total factor productivity is defined as aggregate output minus aggregate input. Again, the Törnqvist-Theil index can be used to aggregate both inputs and outputs.

$$lnTFP_t = \sum_i 1/2 * (S_{i,t} + S_{i,t-1}) * \ln(Y_{i,t}/Y_{i,t-1}) - \sum_i 1/2 * (W_{i,t} + W_{i,t-1}) * \ln(X_{i,t}/X_{i,t-1}) \quad (2)$$

Where $lnTFP_t$ is the log of total factor productivity index at time t over time $t\text{-}1$, $W_{i,t}$ and $W_{i,t-1}$ are the cost shares of input i in total cost at time t and $t\text{-}1$, respectively, and $X_{i,t}$ and $X_{i,t-1}$ are the quantities of input i at time t and $t\text{-}1$, respectively.

3. MEASURES OF OUTPUT GROWTH

The State Statistical Bureau (SSB) and the Ministry of Agriculture (MOA) of the Chinese government report total agricultural output as GVAO. As defined by SSB, GVAO refers to total volume of output of farming, forestry, animal husbandry, and fishery in value terms, which reflects the scale of and the achievements made in agricultural production during a given period of time. The scope of statistics on farming, forestry, animal husbandry, and fishery are as follows:

Farming is defined as cultivation of farm crops and other agricultural activities. Farm crops include grains, cotton, oil-bearing crops, sugar crops, bast fiber plants, tobacco, vegetables, medicinal herbs, melon and gourd crops, and cultivation and management of tea plantations, mulberry fields, and orchards. Other agricultural activities are defined as harvesting wild vegetation fruits, fiber, gum, resin, oil-bearing plants, grass, wild medicinal herbs, fungus plants, and rural household non farming activities.

Forestry refers to planting trees of various kinds (excluding tea plantations, mulberry fields and orchards), collection of forestry products, and cutting and felling of bamboo and trees by villages and other cooperative organizations. *Animal husbandry* refers to raising and grazing of all animals except fishing and cultivating, and hunting and raising of wild animals. *Fishery* refers to cultivation and catching of fish and other aquatic animals and cultivation and collection of seaweed and other aquatic plants.

GVAO is obtained by first multiplying the output quantity of each product or by-product by its price, resulting in the output value of each single item. The sum of output value of all products of farming, forestry, animal husbandry, and fishery equals to GVAO. As indicated in section 2, GVAO measured in constant prices cannot reflect the real growth of agricultural production. In this study, we use the Törnqvist-Theil index to measure production growth in Chinese agriculture for the last several decades. There are several hundred agricultural products covered by SSB, and this paper will try to cover as many products as possible. The following is a list of the commodities covered in this study.

Crops are divided into grain and cash crops. Grain crops include rice, wheat, corn, sorghum, millet, soybean, tubers, and other miscellaneous grains. Cash crops include cotton, hemp, rapeseed oil, peanut oil, sesame seed oil, sunflower seed oil, huma oil, tea nut oil, tung nut oil, silk cocoons, sugarcanes, sugarbeets, apples, bananas, citrus, grapes, other fruits, tea, tobacco, and vegetables. *Livestock* includes pork, beef, mutton, poultry, cow milk, goat milk, egg, wools, cattle hides, goat skins, sheep skins, pig castings, hog bristles, and honey.

Fishery products are total weights of both sea and fresh water fish and other aquatic animals produced in a year measured in tons.[3] *Forestry products* are excluded in this study. The exclusion of forestry does not bias the estimates much because it accounts for only 3 percent of total SSB's GVAO in 1995.

The quantity data are taken from various issues of *China s Statistical Yearbook* and *China s Agricultural Yearbook*. The prices for rice, wheat, and corn since 1985 are reported recently by the *China Agricultural Development Report*. Prices for other products and those for rice, corn, and wheat prior to 1985 are taken from *China Commodity Price Yearbooks* (various issues), *China Trade and Price Statistical Materials, 1952-83, China Domestic Marketing Statistical Yearbooks* (various issues), and USDA *Agricultural Statistics of the People's Republic of China, 1949-90.*

Table 1 presents three estimates of agricultural production growth for Chinese agriculture. The SSB index was reported by the SSB in various statistical yearbooks. The index measured in 1980 constant prices and the Törnqvist-Theil index are calculated by the author. The difference between SSB index and index measured in 1980 prices is solely due to the commodity coverage because the methodology used in aggregating these two indices are the same. The largest difference is 8.7 percent which occurs in 1995, indicating that the commodity coverage of this study is very close to that of SSB.

Table 1 Different measures of production growth in Chinese agriculture, 1952-95

[3] It would be desirable to disaggregate fishery into individual products. But it is practicably impossible due to a large number of various fishery products. It does not cause bias in aggregating total output to great extent because fishery accounts for only 8 percent of total production value even in 1995.

Year	SSB Index	1980 Prices Index	Törnqvist-Theil Index
1952	100.00	100.00	100.00
1953	102.89	100.13	99.93
1954	106.38	104.14	102.84
1955	114.34	113.56	112.38
1956	119.10	118.98	117.54
1957	123.62	119.54	118.95
1958	125.78	124.79	124.78
1959	105.29	110.79	111.47
1960	90.31	91.42	92.09
1961	90.23	81.50	82.15
1962	95.80	88.63	88.79
1963	107.16	97.70	96.83
1964	122.30	110.56	108.99
1965	132.19	121.10	117.83
1966	144.45	132.51	129.23
1967	146.68	137.42	133.28
1968	142.63	140.95	135.94
1969	142.75	147.07	140.93
1970	156.23	148.67	142.71
1971	171.04	154.13	146.94
1972	168.36	154.34	146.68
1973	182.26	165.87	156.99
1974	188.50	175.49	165.34
1975	194.14	181.52	170.09
1976	191.80	179.69	167.37
1977	190.42	181.15	168.28
1978	206.65	200.25	184.53
1979	223.39	215.62	197.03
1980	220.51	222.94	202.25
1981	233.47	239.84	216.34
1982	258.98	262.80	234.75
1983	278.14	279.53	248.71
1984	307.73	309.35	271.51
1985	314.71	325.07	278.14
1986	322.41	329.80	281.26
1987	339.14	351.24	296.16
1988	349.63	365.62	299.47
1989	359.86	356.74	315.37

Table 1 (continued)

Year	SSB Index	1980 Prices Index	Törnqvist-Theil Index
1990	389.66	421.97	344.30
1991	413.69	437.08	360.07
1992	443.12	469.91	375.88
1993	493.59	518.46	404.58
1994	539.50	587.18	435.73
1995	598.78	650.78	479.98
Annual Growth Rates			
1952-78	2.83	2.71	2.38
1979-84	6.62	7.49	6.62
1985-95	6.64	7.19	5.61

The difference between the index measured in 1980 prices and Törnqvist-Theil index is due to the aggregation bias as discussed in the previous section. Prior to the beginning of the 1960s, the difference between these two indices is small, being less than 2 percent. But the disparity grows larger over time, particularly since the reforms; the difference increases from less than 8 percent in 1978 to more than 26 percent in 1995. This implies that part of the rapid growth in China's agricultural output measured in constant prices may be due to aggregation bias. There have been rapid price changes in agricultural products in Chinese agriculture since the reforms. Some of the substitution effects (or price effects) may have been captured as part of the production increase if constant prices are used in the aggregation. Although still growing at a respectable rate, the appropriately measured production growth is lower than that measured using constant prices. Agricultural production growth would be at least 0.77 percent per annum lower from 1979 to 1984 (6.62 percent instead of 7.49 percent), and at least 1.58 percent lower per annum from 1985 to 1995 (5.61 percent instead of 7.19 percent).

4. MEASURES OF INPUT GROWTH

In order to aggregate total input, both quantities and prices of inputs are required. Quantities are easy to obtain as SSB has been consistently publishing these input data since 1950s (Table 2). But prices of inputs are not readily available. Certain statistical techniques are required to extrapolate price data for some inputs.

QUANTITIES OF INPUTS

Labor Input. Labor input is measured in person-year equivalent of workers directly engaged in production in farming, animal husbandry, and fishery. The labor used in rural industry is excluded from agricultural labor input.

Land Input. Land input is measured by area sown rather than arable land because the arable land data is extremely inaccurate. Sown area is land on which crops are planted and from which a harvest is expected. Because land is frequently sown two or even more times a year depending on climate and soil quality, sown area is substantially larger than arable land. Therefore, sown area also indicates land quality more accurately.

Table 2 Trend of input use in Chinese agriculture, 1952-95[1]

Years	Land	Labor	Chemical Fertilizer	Manurial Fertilizer	Pesticides	Machinery	Draft Animals	Irrigated Areas
	million ha	million person-years	'000 tons	'000 tons	'000 tons	billion watts	million heads	million ha
1952	141	173	295	26,376	14	0	51	20
1953	144	177	592	27,753	26	0	55	22
1954	148	182	802	29,206	66	0	57	23
1955	151	186	1,255	30,009	144	1	56	25
1956	159	185	1,608	30,433	136	1	55	32
1957	157	193	1,794	30,237	451	1	54	27
1958	152	155	2,708	29,091	350	2	50	67
1959	142	163	2,533	30,000	504	3	47	55
1960	151	170	3,164	28,677	290	4	41	45
1961	143	197	2,242	28,478	211	5	38	37
1962	140	213	3,105	29,573	276	8	40	31
1963	140	220	4,483	30,948	430	10	40	31
1964	144	228	5,363	31,718	544	13	41	32
1965	143	234	8,812	33,068	775	11	43	33
1966	147	243	12,582	27,629	630	13	45	34
1967	145	252	13,128	28,375	484	14	47	35
1968	140	261	10,129	29,092	637	16	48	36
1969	141	271	13,611	29,535	1,023	19	50	37
1970	143	278	15,811	37,017	1,150	22	49	38
1971	146	284	18,142	37,713	1,323	28	50	39
1972	148	283	20,931	38,076	1,314	37	51	40
1973	149	289	25,553	39,009	1,279	48	51	41
1974	149	292	24,051	39,503	1,484	59	52	42
1975	150	287	26,579	39,709	1,358	75	51	43
1976	150	286	28,850	39,315	1,348	86	50	44
1977	149	284	31,920	39,413	1,466	103	50	45
1978	150	290	43,681	39,966	1,464	118	50	45
1979	148	298	52,476	40,703	1,514	134	50	45
1980	146	306	58,649	41,112	1,527	147	51	45
1981	145	311	61,768	41,633	1,507	157	55	45
1982	145	316	68,120	42,051	1,582	166	58	44
1983	144	317	73,845	41,912	1,224	180	61	45
1984	144	317	74,959	42,341	824	195	64	44
1985	144	303	73,105	43,297	649	202	66	44

Table 2 (continued)

Years	Land	Labor	Chemical Fertilizer	Manurial Fertilizer	Pesticides	Machinery	Draft Animals	Irrigated Areas
	million ha	million person-years	'000 tons	'000 tons	'000 tons	billion watts	million heads	million ha
1986	144	305	79,960	44,783	659	230	69	44
1987	145	309	83,772	46,059	774	248	71	44
1988	145	315	89,311	47,802	736	266	72	44
1989	147	324	97,091	48,904	740	281	74	45
1990	148	333	105,514	49,412	750	287	76	47
1991	150	342	112,503	49,628	761	294	77	48
1992	149	340	114,799	49,537	795	303	78	49
1993	148	333	123,419	49,607	849	318	81	49
1994	148	327	130,079	49,679	871	338	85	49
1995	150	323	140,658	49,755	900	361	88	49
Annual Growth Rates								
1952-78	0.23	2.00	21.19	1.61	19.58	28.31	-0.08	3.17
1979-84	-0.58	1.24	7.39	0.79	-11.46	7.82	5.06	-0.25
1985-95	0.43	0.64	6.76	1.40	3.32	5.98	2.93	1.12
1952-95	0.14	1.46	15.42	1.49	10.17	19.34	1.28	2.12

Sources of basic data: China Statistical Yearbooks, 1982-94; USDA China Data Base.

[1] Land is sown areas to crop production. Fertilizer is measured as standard weight. Pesticides prior to 1988 are quantities sold by the Supply and Marketing Cooperatives.

Machinery Power Input. It refers to total mechanical power of machinery used in farming, animal husbandry, sideline occupations and fishery, including ploughing, irrigation and drainage, harvesting, farm product processing and transportation, plant protection, stock breeding, and fishery. It excludes machinery used for non-agricultural purposes such as township- and village-run industry, construction, non-agricultural transportation, scientific experimentation and teaching.

Draft Animal Power. It is measured as the total number of draft animals at the end of the year which are used for agricultural activities and rural transportation. It usually includes water buffalos, cattle, horses, donkeys, mules and camels.

Chemical Fertilizer Input. Chemical fertilizer is measured in standard weights which are obtained by converting actual weights into the following standards: ammonium sulfate (20 percent nitrogen), super-phosphate (18.7 percent P_2O_5), and potassium sulfate (40 percent K_2O).

Manurial Fertilizer Input. The data for manurial fertilizer are calculated by the author. FAO (1977) estimated that one animal (horse unit) produces about 4 tons of manure per year and a person produces 0.25 tons per year. The elemental nutrient component of manure is about 2.2 percent while the manure actually used is about 75 percent of total availability. Therefore, the quantity of manurial fertilizer used per year in pure nutrients was estimated as [{(0.25 x Rural Population) + (4 x Numbers of Livestock)} x 0.022 x 0.75], which transforms the weights in pure nutrients into standard weights.

Irrigation Input. Irrigation input is the total irrigated area in agriculture, i.e., level land which has a water source and sufficient sets of irrigation facilities to lift and move adequate water for irrigation purposes under normal conditions.

PRICES OF INPUTS

Labor Price. Labor price is measured as the daily wage. Wages for 1953, 1957, 1962, 1965, and from 1975 to 1995 annually are reported by the State Price Bureau in its *Cost Production Survey*. The gaps are estimated using geometric extrapolation. The annual labor cost is calculated by multiplying the daily wage by 300 days.

Chemical Fertilizer Price. Chemical fertilizer price is measured as yuan per standard ton. The data after 1978 are reported by *China Agricultural Development Report* (1995 and 1996), and those prior to 1978 are reported in the *China Trade, Marketing, and Price Statistical Materials, 1952-1983.*

Manurial Fertilizer Price. It is estimated using the cost of manurial fertilizer from *Production Cost Survey* and quantities estimated in Table 2.

Power Input Price. Data on agricultural machinery prices measured as yuan per horsepower after 1985 are reported in *China Marketing Statistical Yearbooks*. Those prior to 1985 are estimated by the author using the price index of agricultural production materials reported in various statistical yearbooks published by SSB. The horsepower price is also used to calculate draft animal prices.

Irrigation Price. It is measured as the irrigation fee per irrigated hectare. Irrigation fees per hectare are reported in the *Production Cost Survey*, while irrigated areas are reported in various *China Statistical Yearbooks* of SSB.

Land Price. Since there has been no land market in China, we use the residual of total production value net of costs for labor, fertilizer, machinery, and irrigation on a per unit of land base as the land price.

AGGREGATION OF INPUTS

Total input in agriculture is usually aggregated using the shares of inputs as weights (Table 3). Changes in input shares show that Chinese agriculture has experienced a rapid technical transformation in the last several decades. Farmers have increased their use of modern inputs such as chemical fertilizer, pesticides, and machinery. The share of chemical fertilizer has increased from almost none in 1952 to more than 12 percent of the total production cost in 1995. The share of machinery has also increased from almost zero in 1957 to more than 12 percent in 1977. The declining share of machinery in recent years is mainly a result of more efficient allocation of inputs by farmers when production was decentralized to households. This is consistent with Fan and Ruttan's (1992) findings that centrally planned economies often overuse capital. The rapid decline of pesticide use since 1982 is mainly due to the improvement of pesticide quality and more efficient application by farmers, in turn due to changes in production objectives from maximizing yield during the pre-reform period to maximizing profit during the reform period.

Meanwhile, the importance of traditional inputs like labor, manurial fertilizer, and draft animals has declined rapidly. The labor cost share declined from more than 50 percent in the 1950s to only 28 percent in 1995. Manurial fertilizer and draft animals, which played big roles in Chinese agricultural production in the 1950s (accounting for 30 percent of the total cost) account for less than 2 percent of the total cost in 1995. The land share has increased over time, indicating that land value has increased over time and land has become more scarce.[4]

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[4] The factor shares presented here are comparable with those reported by Fan (1990). The only exception is the land share which showed a declining trend in Fan (1990). The difference mainly comes from different data sources and the calculation method.

Table 3 Changes in cost shares of inputs in Chinese agriculture, 1952-95[1]

	Land	Labor	Chemical Fertilizer	Manurial Fertilizer	Pesticides	Machinery	Draft Animals	Irrigated Areas
1952	0.19	0.51	0.00	0.11	0.00	0.00	0.18	0.01
1953	0.19	0.51	0.01	0.11	0.00	0.00	0.18	0.01
1954	0.16	0.54	0.01	0.10	0.00	0.00	0.18	0.01
1955	0.18	0.53	0.01	0.09	0.01	0.00	0.16	0.01
1956	0.22	0.52	0.01	0.09	0.01	0.00	0.14	0.01
1957	0.25	0.50	0.01	0.08	0.02	0.00	0.13	0.01
1958	0.40	0.38	0.02	0.06	0.01	0.00	0.11	0.01
1959	0.29	0.47	0.02	0.07	0.02	0.01	0.12	0.01
1960	0.17	0.58	0.02	0.07	0.01	0.01	0.12	0.01
1961	0.11	0.66	0.02	0.07	0.01	0.02	0.11	0.01
1962	0.07	0.68	0.02	0.06	0.01	0.02	0.11	0.01
1963	0.10	0.66	0.03	0.06	0.02	0.02	0.10	0.01
1964	0.17	0.61	0.02	0.05	0.02	0.03	0.08	0.01
1965	0.21	0.58	0.03	0.04	0.02	0.02	0.07	0.02
1966	0.27	0.53	0.04	0.03	0.02	0.02	0.06	0.02
1967	0.25	0.55	0.04	0.03	0.01	0.02	0.07	0.02
1968	0.25	0.56	0.03	0.03	0.01	0.02	0.06	0.02
1969	0.23	0.56	0.04	0.03	0.02	0.02	0.06	0.02
1970	0.20	0.57	0.05	0.04	0.02	0.03	0.06	0.02
1971	0.21	0.56	0.05	0.04	0.02	0.03	0.06	0.02
1972	0.18	0.57	0.06	0.04	0.02	0.04	0.06	0.02
1973	0.20	0.53	0.06	0.03	0.02	0.05	0.05	0.03
1974	0.22	0.51	0.06	0.03	0.02	0.06	0.05	0.03
1975	0.24	0.49	0.06	0.03	0.02	0.07	0.05	0.03
1976	0.20	0.50	0.07	0.03	0.02	0.08	0.05	0.03
1977	0.18	0.49	0.07	0.03	0.02	0.10	0.05	0.03
1978	0.22	0.46	0.08	0.03	0.02	0.09	0.04	0.04
1979	0.31	0.41	0.08	0.02	0.01	0.07	0.03	0.04
1980	0.29	0.44	0.08	0.02	0.01	0.07	0.03	0.04
1981	0.29	0.45	0.07	0.02	0.01	0.07	0.02	0.04
1982	0.26	0.48	0.08	0.02	0.01	0.07	0.02	0.05
1983	0.26	0.48	0.07	0.01	0.01	0.07	0.02	0.05
1984	0.25	0.48	0.08	0.02	0.01	0.07	0.02	0.05
1985	0.30	0.44	0.08	0.02	0.01	0.07	0.02	0.05

Table 3 (continued)

	Land	Labor	Chemical Fertilizer	Manurial Fertilizer	Pesticide s	Machinery	Draft Animals	Irrigated Areas
1986	0.30	0.42	0.08	0.02	0.01	0.07	0.02	0.06
1987	0.30	0.42	0.08	0.02	0.01	0.07	0.02	0.06
1988	0.35	0.37	0.09	0.02	0.01	0.07	0.02	0.06
1989	0.36	0.36	0.09	0.01	0.01	0.07	0.02	0.06
1990	0.35	0.36	0.09	0.01	0.01	0.07	0.02	0.06
1991	0.26	0.40	0.13	0.02	0.01	0.07	0.02	0.06
1992	0.25	0.42	0.13	0.02	0.01	0.07	0.02	0.06
1993	0.29	0.40	0.12	0.02	0.01	0.07	0.02	0.06
1994	0.42	0.31	0.11	0.01	0.01	0.05	0.01	0.06
1995	0.44	0.28	0.12	0.01	0.01	0.05	0.01	0.06

[1] The share of land cost is calculated as residual of gross agricultural production value net of costs for labor, machinery, fertilizer, pesticides, draft animals, and irrigation.

Total input is aggregated using both Törnqvist-Theil approach and 1980 constant prices (Table 4). The weights are factor shares from Table 3. The 1980 constant price index overestimates growth in total input use by more than 1 percent per annum from 1952 to 1995. This bias was especially large during the pre-reform period (by almost 2 percent per annum), because the constant price index captures part of the substitution effects among inputs in input growth.

5. MEASURES OF TOTAL FACTOR PRODUCTIVITY AND REASSESSMENT OF THE PERFORMANCE OF THE AGRICULTURAL SECTOR

Given estimates of aggregate output and input growth, total factor productivity growth can easily be calculated, using both 1980 constant prices and the Törnqvist-Theil index (Table 4). The 1980 constant price index underestimates total factor productivity growth by 0.40 percent per year from 1952 to 1995, but this bias varies greatly over time. From 1952 to 1978, the constant price index overestimates the decline in total factor productivity by more than 1.58 percent per annum, while it overestimates the growth in total factor productivity by more than 0.84 percent from 1979 to 1984, and by 1.71 percent from 1985 to 1995. This overestimate of total factor productivity growth leads to a distorted impression of the effects of the rural reforms on productivity growth. In addition, the 1980 constant price index shows little difference in the annual growth rate of total factor productivity between the two phases of the reforms. The Törnqvist-Theil index shows that the growth in total factor productivity has substantially slowed during the second phase of the reforms. Using these newly-estimated growth rates of production and total factor productivity, the next section analyzes and reassesses the impact of various institutional changes on production and productivity growth in Chinese agriculture during the last several decades.

THE FIRST FIVE-YEAR PLAN PERIOD (1953-57)[5]

During this period, total factor productivity in Chinese agriculture increased steadily, due to both institutional and technological changes.[6] Large-scale land reform was one of the

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[5] Review of policy reforms and institutional changes in Chinese agriculture here is taken from MOA and SSB *Forty Years of Rural China*.

[6] Note that different measures of TFP would give the opposite conclusion about TFP growth during this period.

Table 4 Measures of aggregate input and total factor productivity indices, China, 1952-95

	1980 Constant Price Index		Törnqvist-Theil Index	
	Input	TFP	Input	TFP
1952	100	100	100	100
1953	112	89	104	96
1954	122	85	108	95
1955	134	85	111	102
1956	143	83	112	105
1957	151	80	116	103
1958	148	85	104	120
1959	150	74	104	107
1960	160	57	105	88
1961	166	49	113	73
1962	179	50	121	74
1963	191	51	126	77
1964	202	55	132	82
1965	212	57	137	86
1966	224	59	142	91
1967	230	60	145	92
1968	230	61	147	93
1969	244	60	154	91
1970	255	59	160	89
1971	267	58	166	88
1972	276	56	169	87
1973	289	57	176	89
1974	294	59	179	92
1975	300	61	181	94
1976	304	59	184	91
1977	310	58	188	90
1978	323	62	197	94
1979	334	65	204	96
1980	342	65	209	97
1981	347	69	212	102
1982	353	74	216	109
1983	357	78	219	114
1984	358	86	220	124

Table 4 (continued)

	1980 Constant Price Index		Törnqvist-Theil Index	
	Input	TFP	Input	TFP
1985	350	93	215	130
1986	357	92	219	128
1987	364	96	223	133
1988	371	99	227	132
1989	382	93	234	135
1990	392	108	240	143
1991	400	109	246	147
1992	401	117	247	152
1993	400	129	247	164
1994	401	146	249	175
1995	405	161	252	190
Annual Growth Rates				
1952-78	4.62	-1.83	2.65	-0.25
1979-84	1.40	5.94	1.45	5.10
1985-95	1.49	5.62	1.63	3.91
1952-95	3.31	1.11	2.18	1.51

first priorities of the newly-formed Communist government. Soon after 1949, land was confiscated by the government without compensation and re-distributed to peasant farmers. Beginning in 1952 some small-scale peasant farmers voluntarily pooled their land and other resources into a cooperative mode of operation, after they realized that the production scale was too small for certain agricultural operations. Farmers had free entry and exit in these forms of cooperatives. This was soon followed by government efforts to develop large, collective operations and 96 percent of China's agricultural production was collectivized by

1956. Home gardens on private plots -- constituting about 5 percent of all arable land at this time -- were also farmed by households, the produce from which could be sold on free markets.

At the same time, the government increased its investments in rural areas, averaging 2.2 billion 1990 yuan per year (Fan, 1996). These investments were mainly used by the government to improve the irrigation and drainage system nationwide. The procurement prices of agricultural products were also raised by more than 3.8 percent per annum during this period.

THE GREAT LEAP FORWARD PERIOD (1958-60)

During this period, the government promoted even larger scales of production. The commune system in agricultural production was established. The average communal unit had grown to 5,000 households covering 10,000 acres with food being allocated as much on the basis of need as on accumulated work points. Production decisions were made by commune leaders, and the role of farmers was to supply labor to the communes. Work on private plots was also prohibited at this time. Both production and productivity declined sharply due to these policies. Agricultural production declined by 14 percent per annum, and total factor productivity by 15 percent per annum.

ADJUSTMENT PERIOD (1961-65)

From 1961 to 1965, agricultural production recovered through a series of adjustments made by the government, and production grew at 9.4 percent annually, and total factor productivity at 4.1 percent. Large scale production was decentralized to smaller production teams consisting of only 20-30 neighboring families. This smaller production unit under the commune became the basic unit of operation and accounting. Decisions regarding farm operations, including the adoption of new technologies, were primarily made by unit leaders. This collective system of production remained in place until the late 1970s.

THE CULTURAL REVOLUTION PERIOD (1966-76)

During this period, production and productivity growth was again depressed by inappropriate policies. Production was centrally controlled by the government and was executed by production teams. Farmer's income were not closely tied to their production effort. Virtually all inputs and output markets were controlled by the government. Market exchanges of land between different production units in the collective system were also outlawed. Because farmers' incentives were low, inefficiency in agricultural production was rampant. Production grew at 2.7 percent, while there were almost no gain in total factor productivity.

THE FIRST PHASE OF REFORM (1979-84)

The rural reforms initiated in late 1978 occurred in two, reasonably distinct phases. The first phase of reforms focused primarily on decentralizing the system of agricultural production while during the second stage emphasis was given to liberalizing factor and output markets.

Due to the poor performance of the agricultural sector in the previous two decades, the central government decided to reform the rural areas in 1978. During the initial stage of the reforms, state procurement prices of agricultural products were raised, and rural markets were reopened for farmers to trade their produce from their private plots. After two years of experimentation, the government began to decentralize agricultural production from the commune system to individual farm households in 1981. By 1984, more than 99 percent of production units had adopted the household production responsibility system.

In addition to decentralization of the production system, the government began to reform the agricultural procurement system. Prior to 1984, virtually all commodities were subject to various government procurement programs. Beginning in 1985, this procurement system was changed from a mandatory to a voluntary contract system, whereby procurement quantities for certain key commodities were determined by mutual agreement between individual farmers and the government. The procurement systems for secondary commodities was abolished. The number of products covered by the government procurement system was reduced from 113 to 38.

It is expected that both technical efficiency (from the decentralization of production) and allocative efficiency (from price and marketing reforms) increased during this first stage of reforms. Production increased by more than 6.6 percent per annum, and productivity by 5.1 percent per annum.

THE SECOND PHASE OF REFORMS (POST-1984)

The second phase of reforms was designed primarily to liberalize the country's (agricultural) pricing and marketing systems. Based on the successful reform of the procurement system in 1984, the government reformed the markets for vegetables, fruits, and fishery products in 1987. The number of commodities subject to government procurement programs declined further from 38 in 1985 to only 9 in 1991. In 1993, the grain market was further liberalized and the grain rationing system that had been in existence for 40 years was abolished. In 1993, more than 90 percent of all agricultural produce was sold at market-determined prices, a graphic indication of the degree to which agriculture in China has been transformed from a command-and-control enterprise to a largely free-market sector. It is expected that farmers' allocative efficiency improved substantially during this period of reforms. As a result, agricultural production and productivity continue to rise rapidly with growth rates of 5.6 percent and 3.9 percent per annum respectively (although lower than those during the first phase of the reforms).

6. CONCLUSIONS

Output in Chinese agriculture has grown rapidly for the last several decades, as reported by the Statistical System in China. However, reported total output is aggregated using constant prices, which has been shown to be inappropriate by many economists. As a result, growth rates of output reported by the government may be biased. This bias can be large, particularly at a time when relative prices of agricultural products were changed substantially as part of the policy reforms during the 1980s and 1990s. A similar problem exists in the aggregation of total input. Consequently, estimates of total factor productivity, an index of output minus input, can also be biased.

This study uses a more appropriate approach, the Törnqvist-Theil index approach, to measure growth in output, input and total factor productivity for Chinese agriculture. The conventional approach (constant price approach) overestimates both aggregate output and input, resulting in biased estimates of total factor productivity growth. The conventional approach overestimates the impact of the rural reforms on both production and productivity growth, and underestimates the rates of loss during the Great Leap Forward and the Cultural Revolution. Nevertheless, both production and productivity still grew at respectable rates during the reform period.

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