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A Comparative Economic Study of the China's and Australia's Cotton Production

ABSTRACT

After providing information about the global importance of cotton as a textile and China's and Australia's contribution to global cotton production, this paper examines and compares trends in the time-series of cotton production of China and Australia for the period 1980-2007. In doing so, it takes account of changes in the area planted with cotton and its yield. Correlation estimates and decomposition analysis are used to determine the relative contribution to variations in the total output of cotton of changes in the total area planted with cotton and its yield in both countries. These relative contributions are found to be quite different for Australia and China. In addition, there is a comparative analysis of fluctuations in the production of cotton, in the area planted with cotton, and its yield for both countries. The level of Australian cotton production is shown to be much more volatile than China's principally because the area planted with cotton in Australia is so variable. Fluctuations in yield are found to be declining both for Australia and China. Theories and associated empirical results that help to explain cotton supply responses to the relative prices of crops (and also variations in the area planted with cotton) in China and Australia are outlined and discussed. A theoretical model is developed to help explain Australia's changing level of cotton production.

JEL Codes: Q00; Q10; Q11; Q13; Q18; Q19.

Keywords: Australia, agricultural economics, China, cotton production, cotton supply responses, fibre markets, fluctuations in agricultural production.

A Comparative Economic Study of the Chinese and Australian Cotton Production

1. Introduction

Cotton (a renewable and decomposable resource) is the major natural fibre used by the textile industry. Cotton's share of the world fibre market fell from 50 per cent in 1986 to 40 per cent in 2005 where it remains relatively stable. The total volume of cotton production and consumption continued to rise in the same period (Townsend & Gruere, 2007). Nevertheless, the long-term tendency has been for the share of natural fibres to total fibres to decline (Tables A1 and A2). By 2007 cotton's share of the fibre market had fallen to just under 38%. By 2007, artificial fibres accounted for approximately 60% of the consumption of the main textile fibres (Table A2). The strong substitution of synthetic fibres for natural fibres was already apparent in the 1960s and a steep decline in cotton's share of the fibre market occurred in the mid-1960s (Tisdell and McDonald, 1979, p.23). In the 16-year period 1960-61 to 1976-77 cotton's share of global fibre production by volume fell from 68.2% to just under 50% (Tisdell and McDonald, 1979, p.23). The downward trend in cotton's share of the global market continued but at a reduced rate and cotton still retains its position as the major natural fibre.

Cotton has served as an engine of economic growth in both industrial and developing countries worldwide (Wang & Chidmi, 2009). In Australia, in a non-drought year, the cotton industry generates in excess of $1 billion per year in export revenue, is one of Australia's largest rural export earners and helps underpin the viability of many rural communities（Cotton Australia，2008a）. It employs 10,000 Australians and directly supports 4,000 businesses that are reliant on cotton（Cotton Australia, 2008b）. In China, its output value accounted for 7-8% of the agricultural gross output value in 2002. In 2002, China's export of cotton textiles and garments was $26 billion, and

accounted for 35% of the value of total textiles and garments exported (Mao, 2006). From this, it can be also seen that cotton industries in Australia and China are important for both economies.

Some researchers have already noticed the significant roles played by the cotton industries of China and Australia in the world market, and have mainly discussed their international trade and industry organization of the cotton industries of the two countries. Few researchers have studied cotton production in both countries. Nevertheless, Chen (2004) studied the status of cotton, cotton research and cotton production in Australia and its implications for China. Chaudhry (2008) compared the cost and efficiency of cotton production in Australia with that of other countries. Carpio (2002) developed economic models to analyze the production response of cotton in India, Pakistan, and Australia. Some Chinese scholars have tried to increase awareness in China of Australian cotton management, methods and the results of Australian scientific research on cotton as well as applications (Tian, Cai & Liu, 2005a, 2005b; Yin, 2007).

In recent years, because of the changing natural environment and alterations in economic conditions, new situations have emerged in the cotton industries of China and Australia. Both are facing new challenges. Therefore, the purpose of the study is to examine the status quo and trends in the cotton industries of both countries, and to evaluate, quantify and analyze the causes of cotton production variations in Australia and in China.

2. Global Ranking of China's and Australia's Cotton Production

The cotton industry makes a significant contribution to both Chinese and Australian agriculture and both countries have a noteworthy role in the global cotton market. Australia is not only the major cotton-producing country in the Southern Hemisphere, but is also a major global exporter of cotton. During the five years from 1997 to 2001, the average production per annum of Australian cotton was 740 kilotonnes

(hereinafter referred to as Kt), which made up 3.75% of the world total production; the average annual export quantum was 697 Kt, which was 12% of the world export trade (Table A3). However, more recently Australia has declined in global importance as a producer and exporter of cotton (Table A3).

China is the main global cotton producer and the major consumer of cotton as well. In the five years from 2003 to 2007, the average output of Chinese cotton was 6,750 Kt per year, which was 27% of the world total on average; and every year 2,466 Kt of cotton were imported, which accounted for 30% of the world cotton trade. In the corresponding period, China's textile industry consumed 9,499 Kt of cotton annually, accounting for 38% of the total quantity of cotton consumed in the world (see Table A4). Although China is both the world's major producer and consumer of cotton, its global importance on a per capita basis is much reduced because China is the most populous country globally.

Table 1 shows the global position of the 10 major cotton producing countries. These are listed according to their average annual cotton production in a recent 5-year period (2002/03-2006/07).

Table 1 Sizes and ranks of the 10 major cotton producing countries by their volume of cotton production, area planted and yields

	Production		Area		Yield	
	Kt	rank	1000 ha	rank	Kg/ha	rank
China	6235.73	1	5409.98	2	1150.91	5
USA	4537.15	2	5181.00	3	872.48	7
India	3677.43	3	8424.27	1	430.98	10
Pakistan	2047.51	4	3065.28	4	665.50	9
Brazil	1197.72	5	990.11	6	1206.24	4
Uzbekistan	1079.93	6	1421.03	5	758.91	8
Turkey	861.29	7	668.06	7	1288.45	3
Australia	458.54	8	242.17	9	1893.47	1
Greece	366.65	9	355.56	8	1029.50	6
Syria	280.69	10	215.78	10	1298.30	2

Source: The National Cotton Council of America（NCC）, 2009.
Note: Quantitative data are 5-year averages for 2002/03-2006/07.

Table 1 shows that: China is the biggest cotton producer, Australia is the one with the highest yield per ha (hereafter referred to simply as yield) and India has the largest planted area of cotton. The planted cotton area of China ranks second and its yield ranks fifth in the world. The combined effect of these two factors makes the gross cotton production of China the largest globally. Although Australia's yield of cotton tops the world but, its planted area only ranked ninth. Thus, its total production in the period considered above ranked 8th. In the past, Australia occupied a higher global position but drought in recent years has severely reduced its level of production. In the 5-year period commencing in 1996/97, Australia was the third largest exporter of cotton globally (Carpio & Ramirez, 2002). Besides its high yield and the export quantum, the quality of Australian cotton is very high. Australia is regarded as a reliable supplier of high quality cotton（Chang & Nguyen,2002）

India planted the largest area of cotton, far more than other countries, but because it had the lowest yield of the 10 countries, its gross cotton production was less than the USA's. With yield twice that of India's and the third largest planted area of cotton globally, the total cotton production of the USA ranks second in the world. However, in the last few years, India's yield of cotton has risen rapidly, so that after 2006 its total production surpassed that of the USA. It is now the world's second largest producer of cotton.

3. Trends in Cotton Production, Planted Area and Yields in China and in Australia

3.1. *Main statistics for cotton production*

Cotton has been planted in Australia for over 150 years with the earliest experimental plantings being trialled in the vicinity of what is now Brisbane (Longhurst, 1996, pp. 2-3). Despite this, Australia did not commence large-scale commercial cotton production until the early 1960s. In earlier decades, Australia was a major net importer of raw cotton but now is a major net exporter. The latter reflects both the increased supply of Australian grown cotton and the decline in the manufacture of textiles and clothing in Australia. Australia's textile and clothing manufacturing has, to a large extent, moved offshore, principally to China (see Tisdell, 2007). Prior to the

1960s, Australia's production of cotton was little developed. The *Raw Cotton Subsidy Act* (1963) stimulated the development of Australia's cotton production in the 1960s (Samson, 2002; Constable, 2004) and its cotton production expanded rapidly until the beginning of this decade (Carpio, 2002) even after it was no longer subsidized.

China has a relatively long history of planting cotton. It was planted in large scale in the late Song Dynasty, that is about 900 years ago. Even before China began its economic reforms in 1979, China was a major global producer of cotton. In the period 1975-1976, for example, its production was the second highest in the world, higher than that of the USA and only slightly surpassed by that of the USSR and Eastern Europe combined (Tisdell and McDonald, 1979, p.25).

Our current study focuses on China's and Australia's primary cotton industries in the period since 1980. The basic statistics for area planted with cotton, its yield, and the volume of production of both these countries are set out in Table 2.

Table 2 Area planted with cotton, its yield and volume of production for China and Australia, 1980-2007

(Area: thousand ha, Yield: kg/ha, Production: Kt)

Year	China			Australia		
	Area	Yield	Production	Area	Yield	Production
1980	4,920	549	2700	84	1,183	99
1985	5,140	805	4137	177	1,458	263
1990	5,588	807	4507	279	1,552	442
1995	5,422	879	4769	301	1,425	437
2000	4,058	1,089	4420	527	1,553	819
2001	4,820	1,102	5313	404	1,800	741
2002	4,500	1,219	5487	220	1,663	373
2003	5,300	978	5182	196	1,888	378
2004	5,900	1,118	6598	314	2,080	666
2005	5,350	1,156	6184	336	1,814	621
2006	6,000	1,288	7730	145	2,027	300
2007	6,200	1,299	8056	63	2120	133

Sources: United States Department of Agriculture(USDA), Foreign Agricultural Service, 2009; and Australian Bureau of Agricultural and Resource Economics (ABARE) ， 2009

Notes: (1) Year: Aug. 1 - July 31.

(2) Due to statistical error, there is a small error between "planted area ×yield per unit" and "total production".

(3) See Table A5 for more specific and more complete data.

Fundamental changes have occurred in the recent three decades in the cotton production of these two countries. The planted area of cotton in Australia in 1980 was only 84 thousand ha resulting in production of 99 Kt of cotton. By 1998, the planted area rose to 534 thousand ha, a historical maximum, and in 2000 Australia's production reached its maximum output, 819 Kt. Subsequently, Australia suffered from serious drought, and consequently both the planted area of cotton and its volume of production declined sharply. In China, the planted area of cotton in 1980 was 4,920 thousand ha, and its production amounted to a mere 2,700 Kt. China's maximum planted area of cotton was achieved in 1984 (6,923 thousand ha) and in 2007 its maximum level of production was obtained (8,056 Kt). The trends in total production, planted area and yield of cotton in China and Australia are discussed below.

3.2. *Trends in total cotton output*

China's total production of cotton, is much greater than that of Australia, mainly because the area planted with cotton is much greater in China. In the non-drought years of Australia (for example, the 5 years from 1997 to 2001), China's planted area of cotton was 9-12 times greater than that of Australia, and its total production was 5-8 times higher (see Table A5). Hence, the unit of China's cotton production shown in Figure 1 is 10 times that of Australia.

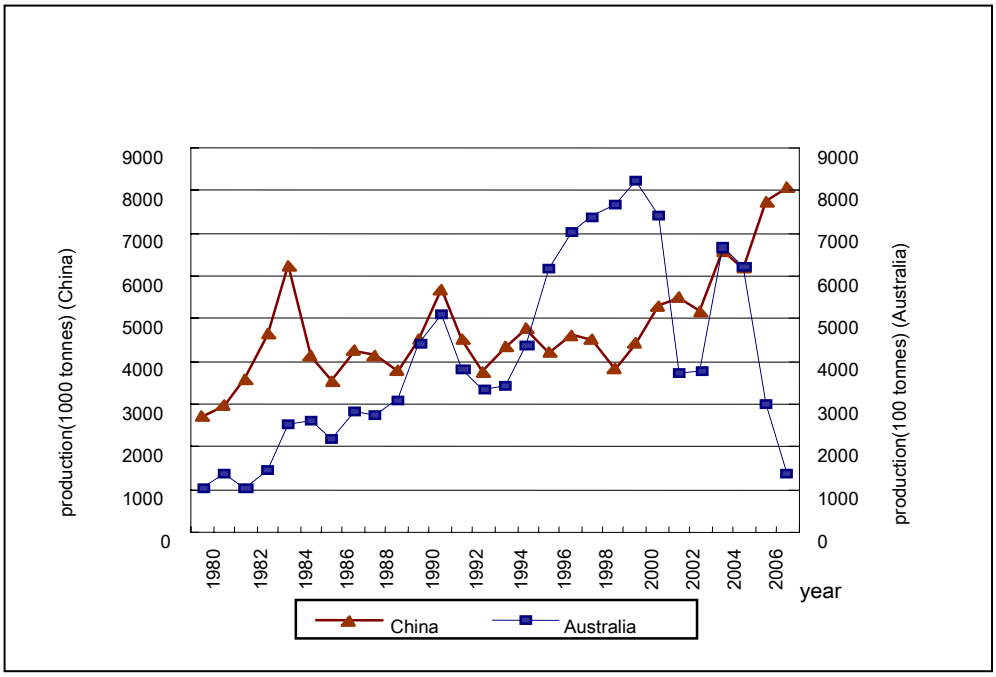

Figure 1 Variations in the total production of cotton in China and in Australia, 1980-2007. China's production relates to the left hand scale and Australia's to the right hand scale

(Source: Based on Table A5)

China's level of cotton production has shown an upward trend since 1980 and this upward trend has been fairly regular since 2000. But Australia's total production ascended fast before 2000 and then declined rapidly. Except for some rebound in the two years of 2004 and 2005, in 2007 Australia's total production hit a historical low. However，the situation of both countries is currently changing. After August, 2008, the global financial crisis led to a decline in China's exports of textiles and accordingly its demand for cotton fell. This depressed the cotton price and resulted in lack of confidence in the buying and selling of cotton (Sun, 2009). In Australia, with increased area planted to cotton, improved irrigation water supplies and fine, hot weather in most of Australia's cotton growing regions, Australian cotton production in 2008/09 is forecast to reach 314,700 tonnes, more than double the severely drought affected harvest of 2007/08 （ABARE，2009）. Nevertheless, Australian production will still remain well below its peak.

3.3. *Trends in the area of planted cotton*

From 1980 to 2007, the time series for the planted areas of cotton in China and Australia are as shown in Figure 2 where the left hand scale indicates the level of China's production and the right hand scale that of Australia.

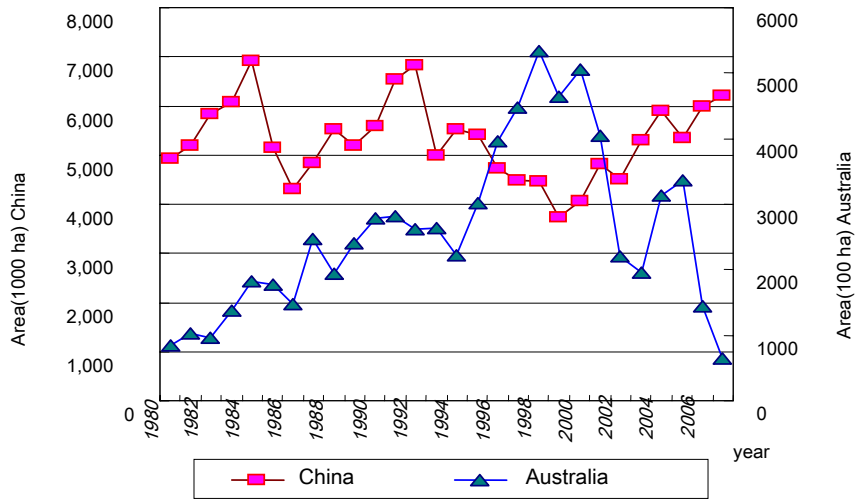

Figure 2 Time series for the planted area of cotton in China and in Australia (1980-2007) based on Table A5

It can be seen that in Figure 2 the pattern of the time series in the two countries' cotton planted area differs. The planted area of cotton in China varies within the range 4000 to 7000 thousand ha., and fluctuates around its mean of 5300 thousand ha with an approximate regular periodicity, and with damped convergence to its mean value. However, the cotton planted area of Australia displays an approximate parabola, rising from the 84 thousand ha in 1980 to the maximum area of 534 thousand ha in 1998 (small fluctuations occur in this period), and then descends to the 62.7 thousand ha in 2007. However, the area planted to cotton in 2008/09 is estimated to have more than doubled to around 164,400 hectares (ABARE, 2009) Therefore, the parabolic relationship may not continue.

The reasons for the differences in the trends might be that on one hand, China shows a high degree of political concern for its cotton industry (though not as much as for

grain), and it implements administrative and policy interventions in its cotton industry (for example, by its construction of cotton production bases, cotton seed projects and so on) which help to secure the stability of its planted area of cotton. Furthermore, variations in China's import quotas and tariffs on imported cotton dampen fluctuations in prices of locally produced cotton in China. On the other hand, in Australia, the flexibility of land use is relatively high. When the export market and the water resources can be fully guaranteed, the land used for planting cotton is increased quickly, for example, the area increased twice in the 5 years between 1994 and 1998. But in the last 7 years, because of its shortage of water, Australia has to plant drought-resistant crops in its former cotton fields. As a result, the planted area of cotton in 2007 was only 13% of that in 2000. Australian agricultural markets have been deregulated and there is little market protection for Australian farmers. Therefore, farmers' land-use decisions are driven primarily by free market forces.

3.4. *Trends in cotton yield*

Both China and Australia have a far higher cotton yield than the world average (see Figure 3).Yields have risen in both countries at a faster rate than the world average which has also been rising. Australia's cotton yield still remains much higher than China's, even thought the long-term rate of increase in the yield in China is higher.

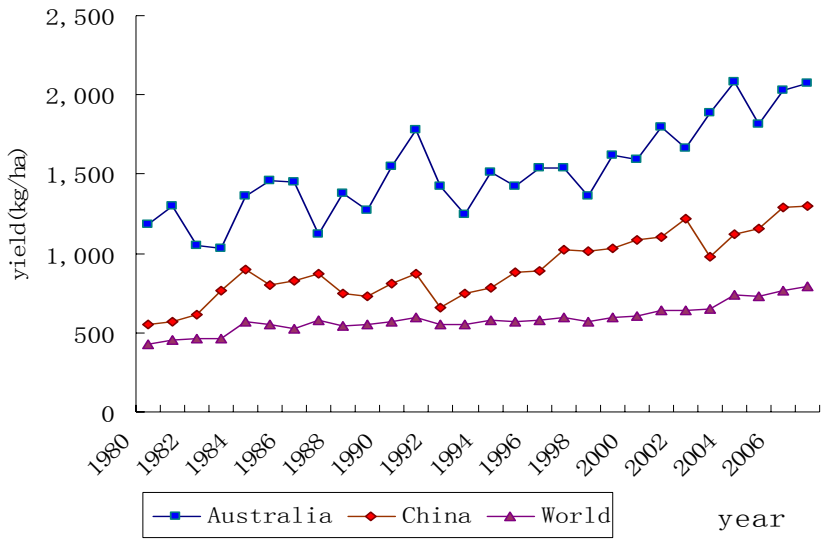

Figure 3 Time-series of cotton yield in China, in Australia and in the world, 1980-2007

Table 3 provides results for the linear results for cotton yield in China, Australia and the world as a function of time based on the data displayed in Figure 3. In this table, X represents time. In China's case, cotton yield has increased by 22.3 kg per year, for Australia by 29.9 kg per year and the global yield has risen by 9.8 kg per year (according to the linear trends shown in Table 3). The trend for both China and Australia is well above the world trend and the gap between Australia's yield and China's has tended to magnify with the passage of time. Whether these trends will continue in the future is unclear.

Table 3 Results of linear regression analysis of the relationship between cotton yield in kg/ha and time for the period 1980-2007 for China, Australia and the world

3.1. China

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-43481.4	4547.274	-9.56208	5.34E-10	-52828.5	-34134.4
X Variable 1	22.26546	2.281032	9.761136	3.5E-10	17.57673	26.95419
	R Square = 0.78562				F = 95.27978	

3.2. Australia

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-58149.1	7476.87	-7.7772	2.99E-08	-73518	-42780.2
X Variable 1	29.93131	3.750594	7.980419	1.85E-08	22.22185	37.64076
	R Square = 0.710103				F = 63.68709	

3.3. World

	Coefficients	Standard error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-18888.5	1839.927	-10.2659	1.22E-10	-22670.5	-15106.5
X Variable 1	9.769568	0.922955	10.58509	6.4E-11	7.872406	11.66673
	R Square = 0.811654				F = 112.0442	

On the other hand, if the natural log of yield rather than absolute yield is used as the dependent variable, it is found that the trend in the proportional change of China's cotton yield is higher than for Australia. This may reflect the fact that Australia begins initially with a much higher absolute yield of cotton than China.

There are at least two reasons for rising yields in China. First, cotton production in China has become increasingly concentrated in the areas more favourable for the growth of cotton. In the 1980s, the geographical location of cotton production in China began to move from its south to the north and after the 1990s, it began to move from east to west (Lu, 2006). Consequently, the planted area of cotton in Xinjiang, the most agreeable region for the growth of cotton in China is on the rise. According to National Bureau of Statistics of China (NBSC), in 1980/81, the area of cotton fields in

Xinjiang was 4.0% of the cotton area of China, but this proportion increased to 23.7% in 1996/97 and to 32.4% in 2006/07. The expansion of the cotton planting in areas environmentally more suitable to cotton **plus** the effects of technological progress resulted in the yield of Chinese cotton rising continually. In Australia, because of its already high yield level， some people thought that the cotton yields in Australia were near a maximum in 2001 (Carpio, 2002). However, Australia's yields have risen substantially since 2001 due to technological progress and improved management.

Different statistical methods or reliance on different periods lead to different estimates of the annual average growth rates of cotton yield in China. According to the research completed by Mao (2006), the annual average growth rate of Chinese cotton yield from 1990 to 2004, was 2.4%, while Lu (2006) found that from 1978 to 2005, the annual average growth rate is 3.4%.

4. Analysis of the Relative Influence of Changes in Planted Area and Yield to Variations in Total Cotton Production

4.1. *Correlations between aggregate cotton production, area and yield*

The variations in the total production of cotton can be attributed to changes in its planted area and its yield. The relationships between total production, planted area and yield can be investigated. Figure 4 and Figure 5 show the values of these variables for Australia and China respectively. Each of the variables is graphed on a different scale.

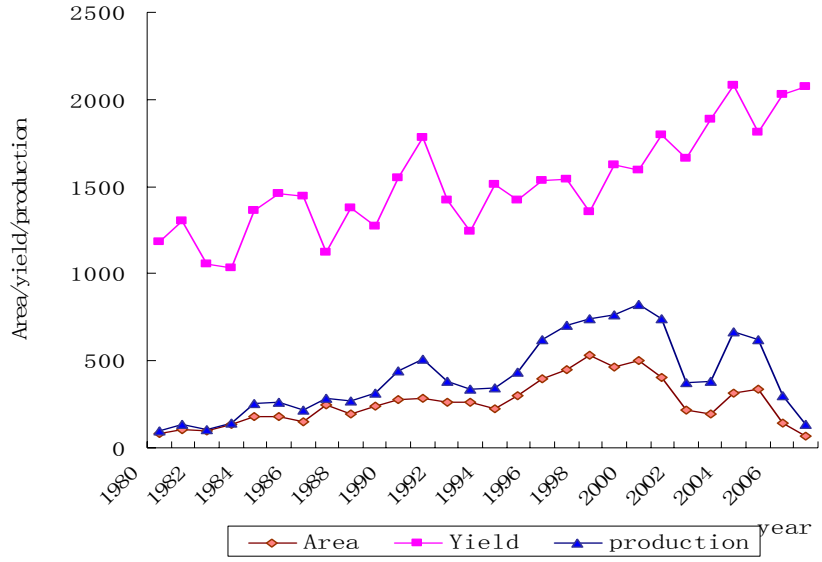

Figure 4 Time series of planted area, yield and total production of cotton in Australia 1980-2007

Notes: (1)Source----Table A5 (2)Area—1000 ha; Production ---Kt; Yield---- Kg/Ha

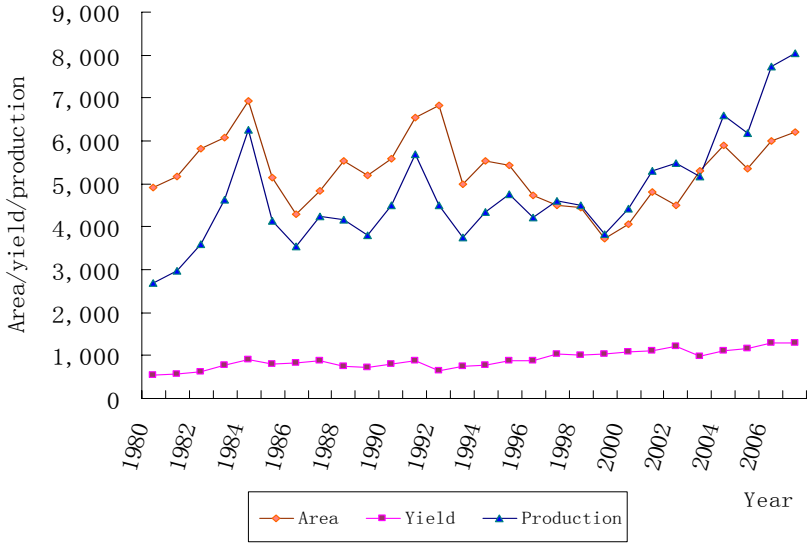

Figure 5 Time series of planted area, yield and total production of cotton in China, 1980-2007

Notes: (1)Source---Table A5 (2)Area—1000 ha; Production ----KT; Yield---- Kg/Ha

In Figure 4, it is observed that variations in the planted area and in the total production are extremely similar, which indicates that they are closely linked in Australia; in Figure 5, the nature of the interdependence in China between the total production of cotton and the area planted and yield is not as apparent. However, the position can be clarified by estimating correlation coefficiencers. Table 4 and Table 5 present the correlation coefficients of planted area, yield and total production derived from the statistical data in the period from 1980 to 2007 for Australia and China respectively.

Table 4 Correlations of planted area, yield and total production of cotton in Australia, 1980–2007

	Area	**Yield**	**Production**
Area	1		
Yield	0.138799	1	
Production	0.956143	0.387715	1

Table 5 Correlations of planted area, yield and total production of cotton in China, 1980–2007

	Area	**Yield**	**Production**
Area	1		
Yield	-0.06938	1	
Production	0.488792	0.830259	1

The correlation coefficient between total cotton production and the planted area of cotton in Australia is 0.956143, while the correlation coefficient between total production and yield is only 0.387715. This implies that the total production of Australian cotton depends heavily on the planted area and much less so on yield. However, the situation is different for China (Table 5): the correlation coefficient between China's total production of cotton and its planted area in China is merely 0.488792 while its correlation coefficient between total production and yield is 0.830259. This implies that the cotton production of China is co-determined by yield and planted area, but that yield is more closely related to China's total production of cotton. Thus, in Australia's case variations in the area planted with cotton is the major influence on the level of Australia's cotton production whereas in the case of China, it is yield.

The relation between the total production and the planted area of cotton in Australia can also be further explained by the regression of the linear equation.

$$y = c_0 + c_1 x + \mu \quad (1)$$

Where, y is the total production of cotton in Australia in Kt, x represents the area in thousands of hectares, μ is the random error term, c_0 and c_1 are undetermined coefficients.

From the linear regression based on the statistical data from 1980 to 2007 for Australia, we obtain

$$\hat{y} = -18.6178 + 1.645501\ x \quad (2)$$

$$s(\hat{c}_i) = (28.23748) \quad (0.098014) \quad (3)$$

$$t(\hat{c}_i) = (-0.65933) \quad (16.78839) \quad (4)$$

$$R^2 = 0.915543, \quad S.E = 65.66342, \quad df = 27 \quad (5)$$

Consequently, (1) the total level of cotton production and its planted area highly correlated in Australia's case, R^2=0.915543，which indicates that the linear fit is a close one in Australia's case; and (2) when the area planted with cotton increases by one unit, the total production increases by 1.65 units. The scatter plot (Figure 6**)** more clearly reflects the close relationship between the level of production and area planted with cotton in Australia. Regression analysis shows that there is little connection between Australia's cotton yield and its level of cotton production.

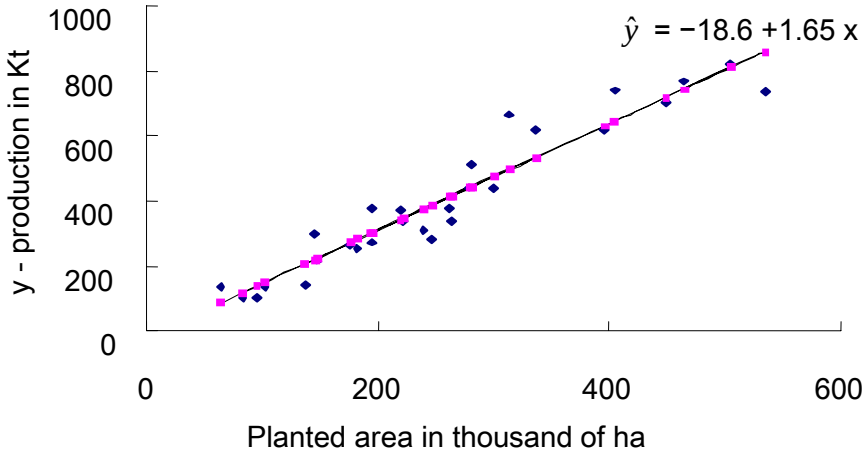

Figure 6 Scatter plot and curve of regression of production and area in Australia

Applying similar regression analysis to China, no close fit is found between the level of production and the planted area or yield. The results indicate that China's level of cotton production co-determined by the two factors. However, further insights can be obtained by applying decomposition analysis to the data as used, for example, by Tisdell (2008).

4.2. *Decomposition of production*

4.2.1. In China

Between 1980 and 2007, China's cotton production rose by 5350Kt. This increase can be decomposed into three components (Tisdell, 2008): (A) that due to the increase in the plant area; (B) that due to the rising yield; (C) that due to the multiplicative impact of increased area and rising yield. These items are identified in Figure 7 by the areas marked A, B and C respectively. It is found that higher yields accounted for the largest proportion of the increase (68.49%) in China's cotton production between 1980 and 2007, increased area contributed 13.1% of the increase, and the combination of rising area and yield comprised 18.41% of the growth. Thus overall in this period, both rising area and yield were important for the growth of China's production of cotton, but the higher yield made the greater contribution. This is in line with Table 5. Thus, these results accord with those obtained from the correlation analysis, namely that

increased yield has been the dominant contributor to the growth in the level of cotton production in China.

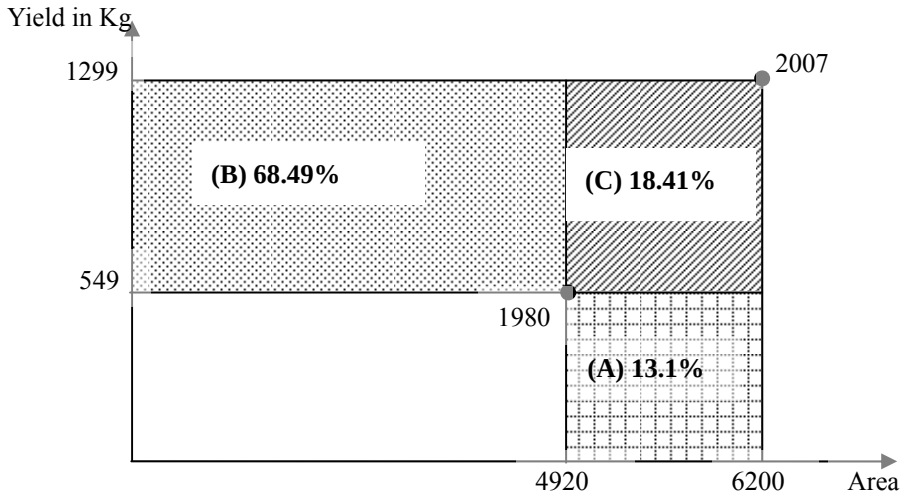

Figure 7 Decomposition of sources of the growth in cotton production in China between 1980 and 2007

4.2.2. In Australia

Because Australia has experienced growth and decline in its volume of cotton production, it is analytically useful to divide its time-series into two stages. One is for the period from 1980 to 2000 when the production rose, the other is for the period from 2000 to 2007 when Australia's production declined. In the first stage, Australian cotton production between 1980 and 2000 rose by 720 Kt to 819 Kt. This increase can be decomposed into three components in a similar way to that done for China (see Figure 8).

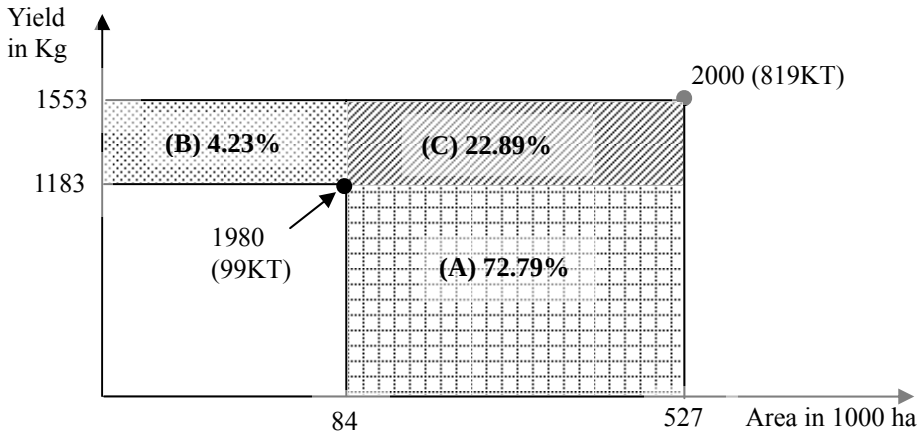

Figure 8 Decomposition by sources of increased cotton production in Australia between 1980 and 2000

From Figure 8, it is found that increased area accounted for the largest proportion of the increase (72.79%) in Australia cotton production between 1980 and 2000, higher yields contributed only 4.32% of the increase and the combination of rising area and yield comprised 22.89% of the growth. Thus, in contrast to the results for China, area planted was by far the major contributor to increased output of Australian cotton in the period 1980-2000.

In the second period (2000 to 2007), Australia cotton production decreased by 686 Kt, from 819KT to 133KT. This was the outcome of the combined action of decreasing area and increasing yield. During this period, cotton yield rose from 1553kg/ha to 2120kg/ha, but the area planted with cotton fell from 527 thousand ha to 63 thousand ha. This resulted in Australian production decreasing by 686Kt. As illustrated in Figure 9, the decreased area accounted for -105% of the production change, and the rising yield contributed 5% to the production change.

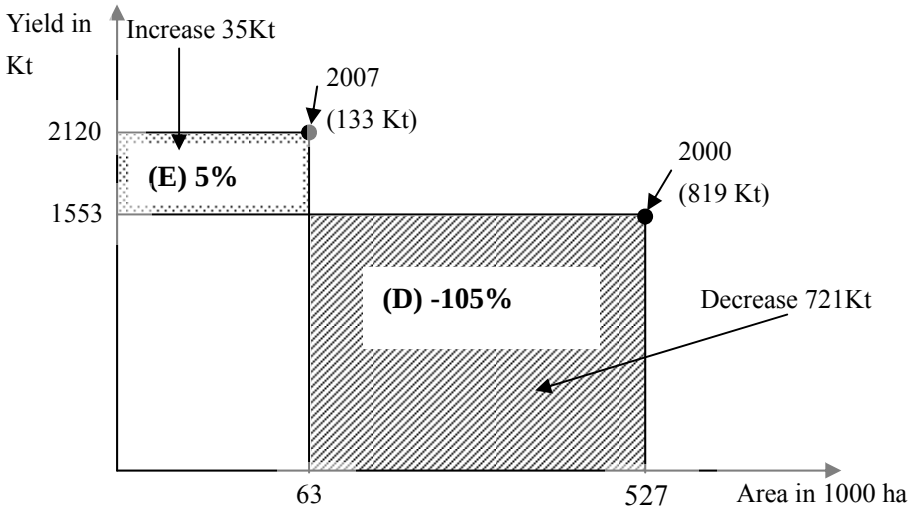

Figure 9 Decomposition of change in cotton production in Australia between 2000 and 2007

Thus, it is clear that the major factor associated with changes in the total volume of cotton supply by Australia alterations have been made in the area planted with cotton. This has been true both during periods of expansion in the level of Australian cotton production as well as in periods of contraction. In China's case, the major contributor to alterations to its supply of cotton in the period 1980-2007 have been changes in its yield of cotton.

The supply of cotton fluctuates from year to year. Let us now consider this fluctuation in China and Australia and consider the elements that are associated with this fluctuation.

5. Overall Variations and Year-to-year Variations in Cotton Supply in Areas Planted with Cotton and in Yields in China and Australia

5.1. *Introduction to the analysis*

Inspection of Figures 1-3 indicate considerable year-to-year variation in the quantity of cotton produced in China and Australia and also yearly alterations in the planted area and the yield of cotton. It is worth undertaking a comparative analysis of these features. Variations in the annual figures for these variables for the whole of the period 1980-2007 are measured. However, those variations include the trends in the variables. If the degree of stability of these variables is of most interests, it is more

relevant to study year-to-year changes in the relevant variables. Therefore, both overall variations in supply area planted and yield for the period 1980-2007 will be considered as well as the nature of yearly variations in these variables.

5.2. Overall stability and year-to-year variation of cotton production

In the period 1980-2007, China's annual supply of cotton showed much less comparative variation than Australia's. In China's case, its coefficient of variation was 27% but in Australia's case this was 54%. However, absolute variation was greater for China because of its much larger volume of output (see Table 6).

Table 6 Statistical values for annual total production of cotton, 1980 - 2007

Values	China	Australia
Average（Kt）	4774.071	407.2143
Standard Deviation（Kt）	1278.883	221.7233
Coefficient of Variation	0.267881	0.544488
Average Absolute Annual percentage change	15.81706	25.55032

The yearly percentage changes in supply are for many purposes a better indicator of the degree of instability in cotton supply. These are graphed in Figure 10 and their average value is stated in Table 6. On average, these variations are much greater for Australia than for China. Therefore, the quantity of Australia's cotton supplies displays greater volatility than China's. This is also obvious from visual inspection of Figure 10.

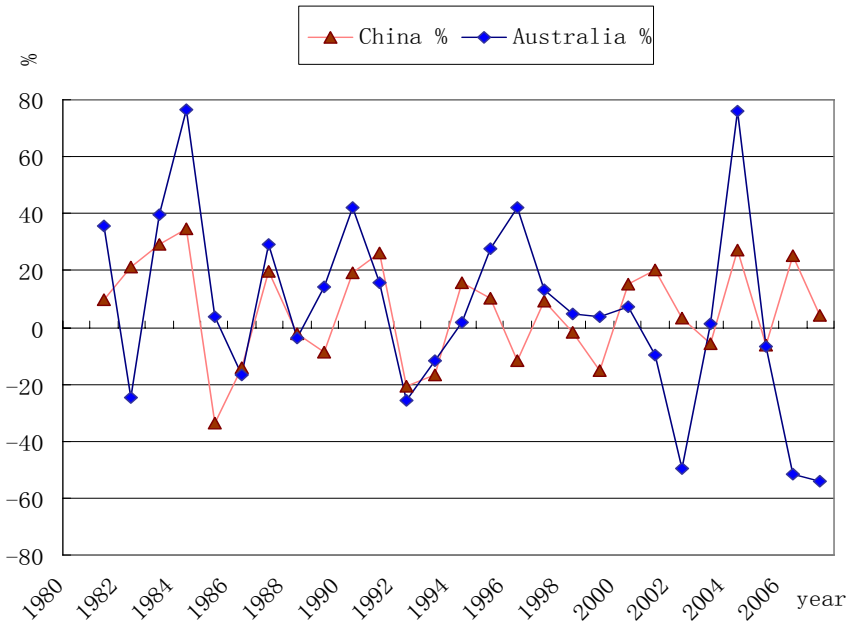

Figure 10 Annual growth rate of cotton production in China and Australia

If we examine the pattern of yearly variations in supply shown in Figure 10, several features are evident. First, the cycles of Australia's growth rates display a much greater amplitude than in China's case. Furthermore, the range of China's growth rates (-34% to 35%) are much lower than for Australia (-54% to 76%). Secondly, the frequency of cycles is on the whole greater in China's case and so Chinese cycles tend to be of shorter duration than those of Australia. Because variations in total cotton production are the combined result of alterations in the area planted with cotton and yields, let us consider variations in these variables.

5.3. Overall stability and year-to-year variation in planted area of cotton

From Table 7, it can be seen that during the period 1980-2007, the relative variation in the area planted to cotton in China was much lower than in Australia. For China, the coefficient of variation was 15% but for Australia it was 50%! However, the absolute variation in China was greater (S.D. 801.4) than in Australia (S.D. 129) because the area planted with cotton is much higher in China.

Table 7 Statistical values for the annual planted area of cotton, 1980-2007

Values	China	Australia
Average（1000ha）	5300.036	258.7857
Standard Deviation（1000ha）	801.4185	128.9296
Coefficient of Variation	0.15121	0.49821
Average Absolute Annual Percentage Change	11.19437	24.28204

Average absolute annual percentage changes in the area planted with cotton are much greater in Australia than in China (see Table 7). Figure 11 indicates that the volatility of variations in the area planted with cotton in Australia is substantially higher in Australia than in China. For example, the amplitudes of the cycles shown there are much greater for Australia than China. While in China's case, annual percentage changes range from −27% to 19%, in Australia's case they range from −57% to 67%. The frequency of cycles appears to be slightly higher in China's case so on average their duration tends to be less.

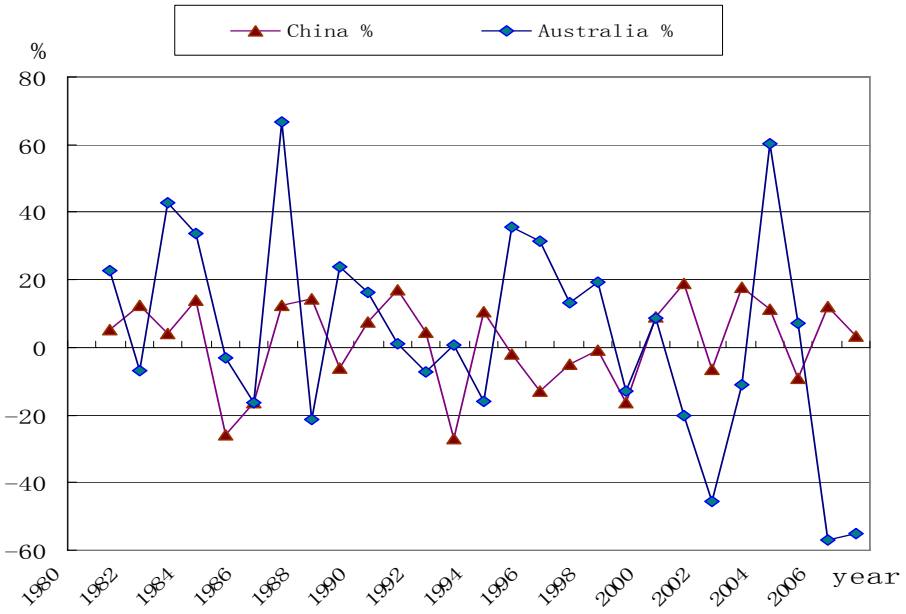

Figure 11 Annual growth rate of planted area of cotton in China and Australia

5.4. *Overall stability and year-to-year variation of cotton yield*

From Figure 3, an upward trend in cotton yield both in Australia and in China can be seen, but there are fluctuations in yield in both countries. Therefore, we shall analyze the yield variable in a similar way to the total supply and planted area of cotton in China and Australia as done above. The results are set out in Table 8,

Table 8 Statistical values for the annual yield of cotton, 1986-2007

Values	China	Australia
Average（kg/ha）	917.963	1531.556
Standard Deviation（kg/ha）	198.2251	289.9025
Coefficient of Variation	0.21594	0.189286
Average Absolute Annual Percentage Change	9.283512	12.30011

From Table 8, it is seen that while the standard deviation of yield is higher for Australia than China, their coefficients of variation are similar in that of Australia being slightly lower than that for China. For China, the coefficient of variation of yield is higher than the coefficient of variation of its planted area whereas the reverse is so for Australia. For Australia, the coefficient of variation planted area (0.5) is much higher than the coefficient of variation of yield (0.19).

Annual percentage variations in yields are graphed in Figure 12. Inspection suggests that these variations are greater for Australia than China, and as can be seen from Table 8, the average absolute annual percentage change of yield in Australia in the period 1980-2007 is greater than in China. On the whole, the amplitude of the cycles shown in Figure 12 are greater in Australia than in China.

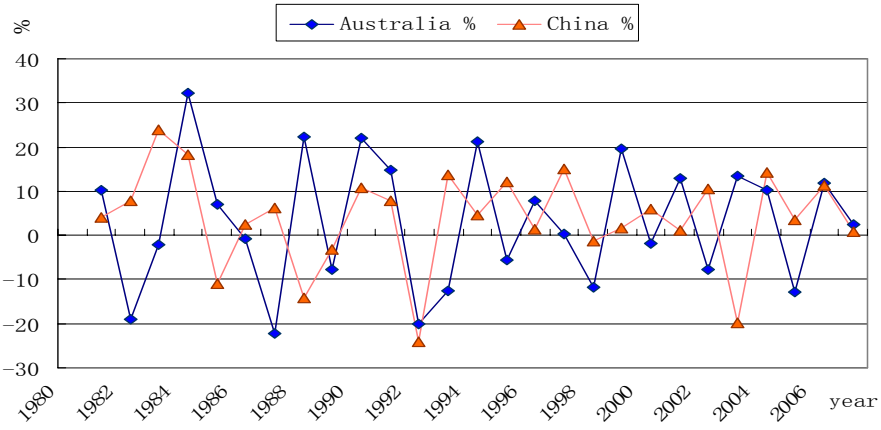

Figure 12 Annual growth rate of cotton yield in China and Australia 1980-2007

An interesting feature of the relationship shown in Figure 12 is that in both China and Australia, the variations are converging towards zero with the passage of time. This indicates that there is increasing control of yields from cotton. This is probably a result of scientific and technological advances in the cultivation of cotton and these have also resulted in rising yields. Changing location of cotton growing areas has also had an influence.

With the scientific progress and technological improvements, in cotton production, the ability of responding to natural disasters and controlling cotton diseases and insect pests has been strengthened. Cotton yield has increased gradually and steadily. In Australia, changes in soil, water, insect, weed and disease management and cultivar development have been dramatic and together have produced a yield increase of 180% with better fibre quality in the 25 years since 1980. The change from a system heavily reliant on persistent pesticides and on exploitive soil and water practices to integrated crop management has substantially improved sustainability in Australia (Constable, 2004). In China，better selection of cotton varieties and cultivation methods for its varied ecological zones have helped to increase China's cotton-yields and dampen fluctuations in these. Geographical changes in the location of China's cotton production has also played a role, as stated above. Furthermore, the research on development and application of transgenic pest-resistant cotton varieties has resulted in a steady improvement in cotton yield in China（Du, 2005; Lu,2006）and in Australia. This has also helped to reduce fluctuations in yields.

6. Discussion

It has been found that China's total production of cotton in the period 1980-2007 has persistently trended upwards mainly due to a rise in its yields from growing cotton. On the other hand, Australia's production of cotton rose during this period until 2000 but then declined sharply even though it yields from cotton continued to rise. This change was due to the reduction in the area previously planted with cotton in Australia.

A major factor in the decline in Australian cotton production has been the decline in Australia's availability of water as a result of reduced rainfall. Australian production of cotton is largely dependent on local rainfall whereas China's cotton growers have access to relatively reliable supplies of water for irrigating cotton in most areas, except the Yellow River region. Even when Australian cotton growers do not depend on local catchment dams on their properties for irrigation water, access to other water sources, for example, in rivers and streams, is limited. Because of low rainfall since 2000 (probably due to climate change) many Australian cotton growers have substituted summer grain crops, such as sorghum, for cotton. The substituted crops are more drought resistant than cotton and require a lower level of investment. Furthermore, grain prices have been quite favourable for grain crops compared to cotton prices in recent years, and may have encouraged some farmers to switch to grain crops in place of cotton.

The decline in Australian cotton production is not due to declining yields or a failure of cotton yields to continue to rise, as is evident from Figure 3. In fact, with some fluctuation, absolute annual increases in Australian cotton yields have continued steadily and the prediction of Carpio (2002) that growth in Australian yields was about to decline have not been realized. Those areas that have been planted with cotton in Australia continue to display rising yields (on average) with the passage of time.

In China, the area planted with cotton only rose slightly throughout the period 1980-2007 but its production of cotton increased substantially due to rises in its yield from cotton (Ke, 2004). Water availability is said to be the main constraint for the further expansion of Australian's cotton production (Morris & Stogdon, 1995). Carpio

& Ramirez (2002), using a 1979-99 model, found that cotton acreage in Australia was affected by changes in the returns from competing crops, but the magnitude of their competing crops' effect seems to have diminished during the last two decades. Availability of water for growing cotton is now the main constraint on production of cotton in Australia.

In China, the level of the cotton price (especially the grain-cotton price ratio) is considered to be the main economic influence on its supply of cotton. As the price ratio of cotton to substitute crops (e.g. grain) changes, cotton production costs and returns alter also. According to Ke (2004), China's cotton production displays a high degree of decentralization and is a part of diversified farming. When the grain-cotton price-ratio changes, farmers alter their combination of crops, increasing or decreasing the planted area of cotton depending on relative returns. According to Wang & Li (2006), in Xingjiang (the main cotton-producing region of China) when the cotton price is favorable for Chinese cotton farmers, their planted area of cotton is universally increased and their agricultural inputs into cotton production are also increased; when the cotton price is unfavourable for cotton farmers, their area planted with cotton is not reduced much; instead the farmers try to neutralize the effects of low cotton prices by decreasing their use of chemical fertilizer and cutting down their expenses for pesticides and mechanical irrigation. This indicates that Chinese farmers' responses to variations in relative cotton prices are asymmetric, that is hysterisis occurs in the supply responses. The acreage planted with cotton increases in response to higher relative prices for cotton but declines by a much smaller extent when relative cotton prices fall.

Pan, Mohanty, Ethridge & Fadiga (2005) also found that China's cotton acreage is affected by both cotton and competing crop prices. The research made by Zhong and Hu (2008) by use of the data from 1980 to 2005 indicates that, with other conditions unchanged, if the relative price of cotton to substitute crops increases by one per cent the area planted with cotton in China rises by 0.1395%. In other words, if the relative price of cotton in China goes up by 10%, the area planted with cotton increases by 1.4%. Therefore while there is a positive association between the relative price of cotton and the area planted with cotton in China, the response is comparatively slight. The relationship is highly inelastic. Although Zhong and Hu (2008) do not take

specific account of the asymmetry observed by Wang and Li (2006), the relationship observed by them appears to be one factor contributing to this observed inelasticity of cotton supply in China.

At the present time, the Australian supply of cotton appears to be much more responsive to the supply of water than to the comparative price of cotton relative to drought-resistant summer grain crops, such as sorghum. Asymmetry of supply responses also appear to be present in the production of Australian cotton but seems to have a different basis to that observed by Wang and Li (2006) in China. A combination of favourable rainfall and superior economic returns from cotton resulted in a rapid increase in Australian cotton supplies between 1980 and 2000. This was associated with long-term capital investment in the industry such as the building of huge earthen dams on properties to collect local supplies of water. Decline in Australian cotton supplies occurred mainly after 2000 because of water shortages rather than because of a less favourable price for cotton relative to other crops.

In many geographical areas in which cotton grows in Australia, cotton is said to be still more profitable than other crops if sufficient water is available to provide it with adequate irrigation (Personal communication, Ian Peterson, 'Sandia', Dalby, 24 April, 2009). There is a gap between the profitability of growing cotton and alternative dryland crops and because of this gap, Australian cotton supplies do not appear to be very responsive to changes in the relative prices of cotton and summer grains. Infrastructure for harvesting and storing water expanded rapidly between 1980 and 2000 but now with falling rainfall, excess capacity for harvesting and storing water exists on most properties that have grown cotton. Even with more favourable cotton prices, there would be no or little economic advantage in increasing water capacity because of the lack of water supplies. Reduced water supply may be a permanent phenomenon in Australia due to climate change.

The economic situation facing a typical Australian cotton farmer might be modeled the way illustrated in Figure 13. There $\bar{x}$ represents the size of farm in hectares and assumes that the land is suitable for growing cotton or alternative crops. Suppose that cotton requires a fixed quantity of water per hectare in its growing season and that the farm has a water storage (or availability) capacity that will enable x_2 hectares of

cotton to be cultivated per year if water is available **to full** capacity. The marginal net return from growing cotton is shown by line ABC. The marginal net return from growing alternative dryland crops to cotton are shown by line DEF. If water availability is at full capacity, it is most profitable for the farmer to plant x_2 of cotton and plant the remainder of his property ($\bar{x} - x_2$) with other crops, given that DF is below AC.

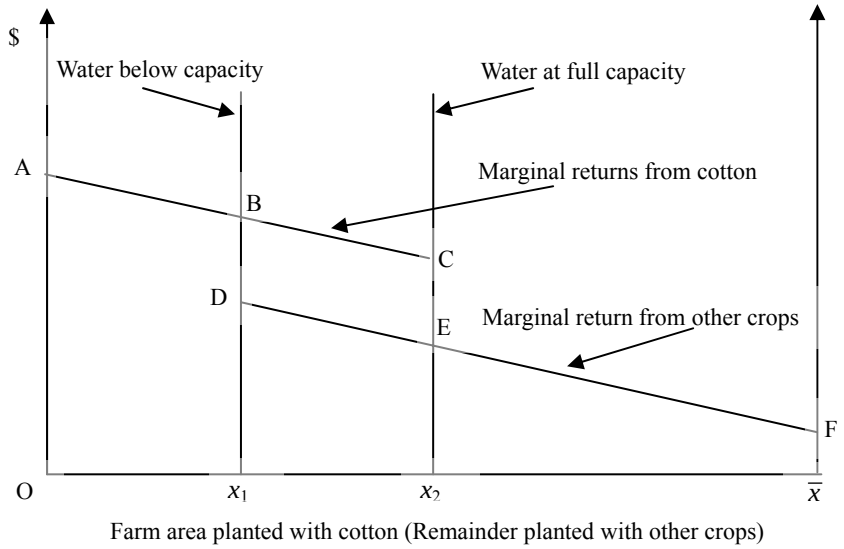

Figure 13 Illustration to show that Australian cotton supplies depend most on water availability and may not be very responsive to variations in comparative returns from alternative crops.

If, as shown in Figure 13, the supply of water diminishes so that only x_1 hectares of cotton can be irrigated, the area planted with cotton declines to x_1, farm profit declines and the area $x_2 - x_1$ (that would have been used for cotton) is now planted with other crops. The switch in cropping is purely a result of water availability. Given that a gap exists between the marginal returns for cotton and other crops, the mixture of crops is relatively insensitive to changes in the comparative price of cotton and alternative crops. Sensitivity to relative prices would only occur should the two marginal return curves shown in Figure 13 intersect in the range where there is sufficient water to irrigate cotton. For example, this would happen if the lower line should intersect the line AC in the segment AB when water is just sufficient to irrigate x_1 hectares of cotton. Given this theory, one expects very little response in the supply of Australian cotton to altered price-ratios of cotton compared to alternative crops. The primary

supply response in Australian cotton is to changes in the availability of water and the supply function has been influenced by the historical evolution of the industry, for example, the provision of water infrastructure in its rapid period of growth. This has created, to some extent, a degree of path dependence which means that the nature of Australian cotton supplies cannot be assessed independently of the nature of the historical evolution of the industry is in Australia.

7. Concluding Comments

China is the world's major producer of cotton and plays a pivotal global role in the cotton textile industry. Australia is also a significant global supplier of cotton. Since 1980 the volume of supplies of cotton in China and Australia have followed different trends. The level of China's production of cotton has continued to expand but Australian production after expanding rapidly to reach a maximum in 2000, declined sharply. The decline in Australian production of cotton can be attributed primarily to reduced availability of water in the cotton-growing areas of Australia since 2000 due to reduced rainfall. This may be a result of climate changes. The fall in Australian production of cotton has occurred because the acreage planted with cotton has declined in line with the reduction in the quantity of water available for irrigation of cotton. The decline is not due to a fall in yield which in fact has continued to increase significantly.

Variations in the area planted with cotton have been shown to be the main prime influence on changes in Australian cotton supplies whereas in China, changes in cotton yields are the principal influence on the supply of cotton. The supply of Australian cotton is much more variable than that of China. This is a consequence of greater variability in the area planted with cotton in Australia because Australia's supply of water for irrigating cotton fluctuates more than China's. It was interesting to note that variability in yields of cotton have declined both in China and in Australia. This indicates that greater control of cotton yields has been achieved due (in some measures) to improved crop management and technological progress.

Research results on the responses of the area planted with cotton in China were reported and discussed. It was found that the elasticity of the area planted with cotton in relation to variations in the cotton-grain price ratio is low, and that an asymmetric

supply response relationship may exist in China. Taking into account the current situation of the Australian cotton industry a theoretical model was developed to show that supplies of Australian cotton are likely to display little responsiveness to alterations in cotton-grain price ratios but are highly responsive to variations in the availability of water. Lack of supply responsiveness of cotton to changes in price ratios for cotton and alternative crops occurs because a gap or discontinuity exists between marginal returns from cotton and that for alternative crops in most areas where cotton is grown in Australia. Only if very large increase in the price of alternative crops relative to the price of cotton occurred, would Australian cotton supplies fall, other things held constant.

8. Acknowledgments

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APPENDIX

Table A1: Components and variations of world fibre production (1980-2001)

(10000 Tonnes)

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001
production of chemical fiber	1477	1689	2035	2600	2643	2923	2984	3214	3389	3360
Proportion of chemical fiber (%)	48.1	46.7	48.6	55.2	55.6	58.0	59.7	60.9	62.3	59.4
production of Nature fiber	1590	1927	2153	2108	2115	2120	2017	2062	2048	2292
Proportion of Nature fiber(%)	51.9	53.3	51.4	44.8	44.4	42.0	40.3	39.1	37.7	40.6
Total fiber	3067	3617	4188	4708	4758	5044	5001	5277	5438	5652

Source: China Textile Industrial Association (2003). Development report of China textile industry of 2003/2004. China Textile & Apparel Press, Beijing, China. 346.

TableA2 Production of main fibers in the world (2001-2007)

(1000 Tonnes)

Year	Total fiber	Chemical fiber	Nature fiber			Cotton's share of total fiber (%)	Cotton's share of nature fiber (%)
			cotton	wool	silk		
2001	51057	28166	21480	1317	95	42.07	93.83
2002	50726	30038	19323	1268	97	38.09	93.40
2003	53467	31419	20720	1227	102	38.75	93.97
2004	61692	34153	26204	1220	115	42.48	95.15
2005	61390	34507	25530	1220	133	41.59	94.97
2006	65301	37187	26740	1229	145	40.95	95.11
2007	67733	40702	25690	1195	145	37.93	95.04

Source: Based on Japan Chemical Fiber Association, 2008-01-01. http://www.textileinfo.com /en/news/2008_01/0127_03.html.

Table A3: The volume of Australia's cotton output and export (1980-2007) and the global share of these

(1000 Tonnes)

Year	Production			Export		
	World	Australia	%	World	Australia	%
1980	13799	99	0.73	5719	53	0.93
1981	14989	134	0.90	5610	81	1.45
1982	14443	102	0.71	5556	135	2.43
1983	14431	142	0.99	5516	82	1.49
1984	19314	250	1.30	5923	151	2.55
1985	17450	259	1.49	6114	248	4.06
1986	15320	215	1.41	7262	257	3.54
1987	17734	278	1.57	6555	179	2.74
1988	18338	267	1.46	7290	288	3.96
1989	17357	306	1.77	6828	288	4.22
1990	18975	434	2.29	6437	299	4.65
1991	20749	503	2.43	6151	460	7.48
1992	17930	373	2.09	5547	377	6.80
1993	16922	329	1.95	5805	368	6.34
1994	18800	336	1.79	6131	296	4.83
1995	20439	429	2.10	5958	319	5.36
1996	19621	608	3.10	5844	519	8.89
1997	20093	690	3.44	5819	591	10.16
1998	18746	725	3.87	5122	662	12.93
1999	19153	753	3.94	5916	700	11.84
2000	19400	819	4.16	5705	850	14.90
2001	21491	728	3.39	6347	682	10.75
2002	19809	366	1.85	6632	579	8.74
2003	21067	371	1.77	7229	470	6.51
2004	26441	654	2.48	7624	436	5.72
2005	25383	610	2.41	9708	628	6.47
2006	26561	294	1.11	8077	464	5.75
2007	26245	133	0.52	8370	266	3.18

Source: (1) United States Department of Agriculture(USDA), Foreign Agricultural Service(FAS), 2009;
(2) Australian Bureau of Agricultural and Resource Economics (ABARE) ， 2009

Notes: year: Aug. 1 - July 31.

Table A4: The value of China's cotton production and import, 1980-2007 and the global share of these

(1000 Tonnes)

Year	Production			Import		
	World	China	%	World	China	%
1980	13799	2700	19.57	5934	773	13.03
1981	14989	2962	19.77	5596	479	8.56
1982	14443	3593	24.88	5677	237	4.18
1983	14431	4638	32.14	5892	145	2.47
1984	19314	6249	32.36	6016	19	0.32
1985	17450	4137	23.71	6310	1	0.02
1986	15320	3549	23.17	7206	4	0.06
1987	17734	4246	23.95	6648	19	0.29
1988	18338	4159	22.68	7312	316	4.33
1989	17357	3789	21.83	7121	408	5.73
1990	18975	4507	23.76	6658	481	7.23
1991	20749	5683	27.39	6319	355	5.62
1992	17930	4507	25.14	5891	53	0.9
1993	16922	3745	22.14	6086	176	2.9
1994	18800	4333	23.05	6595	884	13.41
1995	20439	4769	23.34	5879	634	10.79
1996	19621	4203	21.43	6223	761	12.23
1997	20093	4595	22.87	5646	376	6.66
1998	18746	4507	24.05	5330	73	1.37
1999	19153	3833	20.02	6092	26	0.43
2000	19400	4420	22.79	5711	51	0.9
2001	21491	5313	24.73	6381	98	1.54
2002	19809	5487	27.7	6573	681	10.37
2003	21067	5182	24.6	7406	1923	25.97
2004	26441	6598	24.96	7283	1391	19.1
2005	25383	6184	24.37	9686	4199	43.36
2006	26561	7730	29.11	8150	2306	28.3
2007	26245	8056	30.7	8283	2511	30.32

Source: (1) United States Department of Agriculture, Foreign Agricultural Service, 2009;
(2) The National Cotton Council, 2009.

Notes: year: Aug. 1 - July 31.

Table A5: Variations in planted area, yield and production of cotton in China, in Australia and in the world, 1980-2007

Year	World			China			Australia		
	Area	Yield	Production	Area	Yield	Production	Area	Yield	Production
1980	32,369	426	13799	4,920	549	2700	84	1,183	99
1981	32,938	455	14989	5,185	571	2962	103	1,300	137
1982	31,394	460	14443	5,828	616	3593	96	1,052	103
1983	30,920	467	14431	6,077	763	4638	137	1,030	144
1984	33,741	572	19314	6,923	903	6249	183	1,361	254
1985	31,581	553	17450	5,140	805	4137	177	1,458	263
1986	29,347	522	15320	4,306	824	3549	148	1,446	219
1987	30,871	574	17734	4,844	876	4246	247	1,124	283
1988	33,831	542	18338	5,535	751	4159	194	1,376	272
1989	31,696	548	17357	5,203	728	3789	240	1,271	311
1990	33,151	572	18975	5,588	807	4507	279	1,552	442
1991	34,786	596	20749	6,539	869	5683	282	1,780	512
1992	32,667	549	17930	6,835	659	4507	262	1,424	380
1993	30,743	550	16922	5,000	749	3745	264	1,246	336
1994	32,278	582	18800	5,530	784	4333	222	1,509	342
1995	35,947	569	20439	5,422	879	4769	301	1,425	437
1996	33,769	581	19621	4,722	890	4203	396	1,535	620
1997	33,800	594	20093	4,491	1,023	4595	448	1,539	703
1998	32,894	570	18746	4,459	1,011	4507	534	1,357	738
1999	32,356	592	19153	3,726	1,028	3833	464	1,623	767
2000	32,016	606	19400	4,058	1,089	4420	527	1,553	819
2001	33,728	637	21491	4,820	1,102	5313	404	1,800	741
2002	30,752	644	19809	4,500	1,219	5487	220	1,663	373
2003	32,310	652	21067	5,300	978	5182	196	1,888	378
2004	35,709	740	26441	5,900	1,118	6598	314	2,080	666
2005	34,737	731	25383	5,350	1,156	6184	336	1,814	621
2006	34,706	765	26561	6,000	1,288	7730	145	2,027	300
2007	33,199	791	26245	6,200	1,299	8056	63	2,120	133

Source: (1) United States Department of Agriculture, Foreign Agricultural Service, 2009; and
(2) Australian Bureau of Agricultural and Resource Economics (ABARE) ， 2009

Notes: (1) Year: Aug 1 - July 31.
(2) Area (Area Harvested)— 1000 ha; Production ----Kt; Yield---- kg/ha.

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