IS THE ECONOMIC BENEFIT OF BT COTTON DYING AWAY IN CHINA?

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Abstract

Both national statistics and empirical studies had showed that economic benefit of Bt cotton is dying away 15 years later after Bt cotton was commercialized in China. The adoption of Bt cotton had been considered as the main reason that cotton sown area declined in recent years. However, this study shows that the adoption of Bt cotton has no negative impact on cotton sown area. On the other hand, the increase of labor cost and decrease of cotton price might be the real reason behind the reduction of cotton sown area in recent years in China.

Introduction

Bt cotton has significantly reduced insecticide use and increased the profit of cotton production at the farm level in both developed and developing countries (Pray, et al., 2001; Raney, 2006; Qaim and Zilberman, 2003). Empirical studies in China showed that Bt cotton farmers reduced pesticide use by more than 70% (Huang, et al., 2002a and 2003). The reduction of the chemical pesticides use meant that Bt cotton had also contributed to a cleaner environment and helped to improve farmer's health (Pray et al., 2002; Huang et al., 2002; Hossain et al., 2004). Because of its high profitability and other benefits, Bt cotton has been wide adopted in China.

One of the most important successes that Bt cotton had led is the recovery of the cotton sown area in China (Hsu and Gale, 2001; Huang et al., 2002b). Due to the outbreak of cotton bollworm, many farmers gave up cotton planting in China in early 1990s (Huang et al., 2003). According to the national statistics, China's total cotton sown area decreased from 6.84 million ha in 1992 to 3.72 million ha in 2000 (National Bureau of Statistics of China (NBSC), 2011). In other words, the cotton sown area decreased by near half in less than ten years. However, after the introduction of Bt cotton, the economic benefit that Bt cotton had generated made cotton production more profitable than that of other crops. As a result, some farmers began to plant cotton again. Consequently, the national cotton sown area bounced back to 5.69 million ha in 2004 when most of the cotton in Yellow River valley and Yangtse River valley was Bt cotton (NSBC, 2011).

However, the increase of cotton sown area did not continue. In fact, this figure began to decrease since 2004 and had kept decreasing continuously, except for 2007 and 2008 when cotton price has soared rocketly. In current years, the national cotton sown area is always less than 5 million ha (NSBC, 2011).

Some policy makers and researchers believed that the decreases of cotton sown area had been led by the fact that economic benefit of Bt cotton was dying away. Transgenic technology is a two-edged sword. On the one hand, biotechnology represents the cutting edge of successful efforts to increase agricultural productivity. On the other hand, there have been continual worries about the sustainability of biotechnology (Huang et al., 2007; Ma, 2003). There are at least two general challenges facing Bt cotton growers and policy makers. First, there have been worries about the potential vulnerability of Bt crops to resistance adaptation by pests (Gould, 1998). Second, a new concern that there will be an outbreak of secondary insect populations in the Bt cotton fields has surfaced (Lu et al., 2010; Meng et al., 2005; Wang et al., 2006). As the development of the pest's resistance and/or outbreak of the secondary pest, the economic benefits of Bt cotton will be offset (Wang et al., 2006 and 2008). Some researchers had expected that the total pesticide use would be gradually restored to the level before the adoption of Bt cotton (for example, Pemsl and Waibel, 2007).

However, other studies showed that economic benefit of Bt cotton continued. For example, Huang et al. (2007) and Wang et al. (2009) showed that the occasional rise in pesticide use did not continue in the following years. Moreover, they showed that increase in pesticide use for the control of secondary insects was far smaller than the reduction in total pesticide use due to Bt cotton adoption. In addition, their studies showed that the rise and fall of secondary pest was largely related to local temperature and rainfall (Wang et al., 2009; Huang et al., 2010).

However, the debate is far from over. Statistics from the Price Division of the National Development and Reform Commission confirmed that cotton pesticide cost had increased dramatically in recent years. According to their statistics, even though Bt cotton adoption led to the reduction of pesticide cost at the end of 1990s and early 2000s, pesticide cost began to rebound since the middle of 2000s. Currently, the pesticide cost was almost as high as that before Bt cotton was commercialized.

Are the economic benefits that Bt cotton had generated sustainable? Will Bt cotton's comparative advantage gradually decrease and eventually disappear? The objective of this study is to understand the sustainability of the economic benefits that Bt cotton had generated. To be more specific, in this study, I want to empirically answer whether the economic benefit of Bt cotton is dying away, and has caused the current decrease of cotton sown area in China.

The rest of the paper is as follows. In the next section, I am going to first describe the data sources, and then descriptively show the unconditional relationship between Bt cotton adoption and cotton sown area. I then set up and run econometric models to isolate the impact of Bt cotton adoption on cotton sown area in the third section. Estimation results are shown and discussed in the fourth section. Final section concludes the paper.

Data and cotton sown area in China

All the data used in this study are from NBSC. To be more specific, the panel data has two sources: China Statistical Yearbook (*Zhongguo Tongji Nianjian – in Chinese pinyin*), and Statistics of Cost and Benefit of Main Crops (SCBMC) (*Quanguo Nongye Shengchan Ziliao Huibian – in Chinese pinyin*). For example, cotton sown areas by province, price indexes, total power of large agricultural machines are from the China Statistical Yearbook (varies years), and the pesticide cost, prices are from the SCBMC (varies years).

China's major cotton producing areas can be divided into three regions: the Yellow River valley, the Yangtze River valley, and the Northwest (Hsu and Gale, 2001). The Northwest region includes primarily the Xinjiang Uighur autonomous region, which has been the largest cotton production province in China since the middle 1990s. Production of Xinjiang is about one third of total cotton production in China in 2010 (NBSC, 2011). The top three provinces in Yellow River valley are Hebei, Shandong and Henan provinces, while Jiangsu, Anhui and Hubei are the top three provinces in Yangtze River valley. These six provinces are also the 2nd to 7th largest cotton production provinces in China. Total cotton sown area of these six provinces was 2.60 million ha, or 53% of the national sown area (NBSC, 2012).

Climate in Xinjiang is dry and hot which has kept pests and diseases problems to a minimum (Hsu and Gale, 2001). In early 2000s, Bt cotton was also introduced to Xinjiang. However, since the Bt varieties introduced at that time were from either Yellow River valley or Yangtze River valley, some of them were not suitable for production in Xinjiang. As a result, the Bt varieties did not outperform local non-Bt varieties. Partly due to this reason, spread of Bt cotton in Xinjiang was relatively slow. In addition, the production organization and management system in Xinjiang are different from other regions of Mainland China (Paggi et al., 2010). For this reason, the following discussion of this paper focuses on the six provinces in Yellow River and Yangtze River valleys.

Due to the warm and dry climate conditions, infection of cotton bollworm in Yellow River valley is the most serious (Wu et al., 2005). Nationally, the Ministry of Agriculture's pest prevention teams estimated that cotton yields in Hebei province have been reduced by near 40% due to pest infestations (mainly cotton bollworm) in 1992 (Huang et al., 2003). For this reason, Bt cotton was first planted in Yellow River valley in 1997. The great success that Bt cotton had generated made it spread quickly in Yellow River valley and Yangtze River valley at the end of 1990s. As shown in Table 1, all the cotton in Yellow River valley and Yangtze River valley were Bt cotton only a few years later after it was commercialized in 1997.

As the spread of Bt cotton in China, pesticide cost decreased dramatically and cotton sown area increased significantly. According to the statistics of SCBMC, the pesticide cost was 146 USD/ha (in 2012 price, similarly hereinafter) in 1995, two years before the commercialization of Bt cotton. This figure dropped to 92 USD/ha in 2004 as the wide spread of Bt cotton in Yellow River valley and Yangtze River valley. During the same time, the cotton sown area began to increase and bounced back to 5.69 million in 2004 and near 6 million in 2007 (Figure 1).

However, this great success did not continue. After 2004, spread of Bt cotton became slow, and the pesticide cost began to increase. By 2011, pesticide cost had risen to US$ 137/ha, only a few dollars less than the level before Bt cotton was commercialized. Accordingly, cotton sown area has decreased significantly in recent years (Figure 1).

To make the dynamic more clearer, Figure 2 smoothed the changes of cotton sown area over the last two decades. National total sown area data were used in Panel A, while the six sample provincial sown area data were used in Panel B. Both Panel A and Panel B show that cotton sown area increased significantly as the spread of Bt cotton before 2004 when near 100% cotton in Yellow River and Yangtze River valley was Bt cotton. However, since then, the cotton sown area began to decrease.

The dynamics of cotton sown area over the last two decades, as shown in Figure 1 and Figure 2, seem to show that the economic benefit of Bt cotton is dying away in China. In other words, the economic benefit is just a one-time bonus. As time goes, everything will back to their own tracks. If it is true, we can expect that pesticide cost will keep increasing and cotton sown area will keep decreasing in the future.

Table 1. Bt cotton adoption in China and sample provinces,

	Cotton area (000 ha)		Bt cotton adoption rate (%)										
			China	Yellow River valley					Yellow River valley				Northwest
	Total	Bt cotton		Hebei	Shandong	Henan	Shanxi	Shaanxi	Anhui	Jiangsu	Jiangxi	Hubei	Xinjiang
1997	4491	34	0.8	3.4	0.0	1.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0
1998	4459	261	5.8	55.4	10.9	2.1	22.9	1.4	1.8	0.2	0.0	0.0	0.0
1999	3726	654	17.6	85.0	66.1	17.0	39.8	19.9	6.9	3.1	0.0	0.0	0.0
2000	4041	1216	30.1	97.0	87.9	31.4	66.0	76.4	20.2	7.1	1.0	3.8	0.8
2001	4810	2158	44.9	98.0	96.5	68.0	82.0	80.4	45.5	16.3	9.9	19.8	1.0
2002	4184	2156	51.5	99.0	99.0	76.9	90.0	84.1	56.0	25.7	14.5	23.3	2.0
2003	5111	2996	58.6	99.0	99.0	84.0	94.0	74.0	65.0	50.0	40.0	25.0	4.0
2004	5650	3688	65.3	100.0	100.0	84.1	96.4	80.0	80.0	82.0	85.0	33.0	8.0
2005	5117	3343	65.3	100.0	100.0	90.0	90.0	80.0	80.0	80.0	85.0	70.0	10.0
2006	5360	3519	65.7	100.0	100.0	85.0	94.6	80.0	80.0	80.0	90.0	70.0	10.0
2007	5547	3830	69.0	100.0	100.0	87.8	96.7	83.7	85.1	92.0	91.1	84.7	11.7
2008	5754	4183	72.7	100.0	100.0	96.8	100.0	100.0	93.5	100.0	100.0	93.5	18.0
2009	4949	3746	75.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	27.0
2010	4849	3758	77.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	32.4
2011	5040	4012	79.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	38.9
2012	4863	3934	80.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	42.8

Data source: 1997 to 2007 are from Wang, Z. 2008. “Study on the Sustainability of Genetically Modified Crops Production in China: A Case of Bt Cotton, PhD dissertation, the Graduate University of Chinese Academy of Sciences, Beijing China. Share of Bt of 2008-2012 are author’s estimation.

Figure 1. Cotton sown area in China.

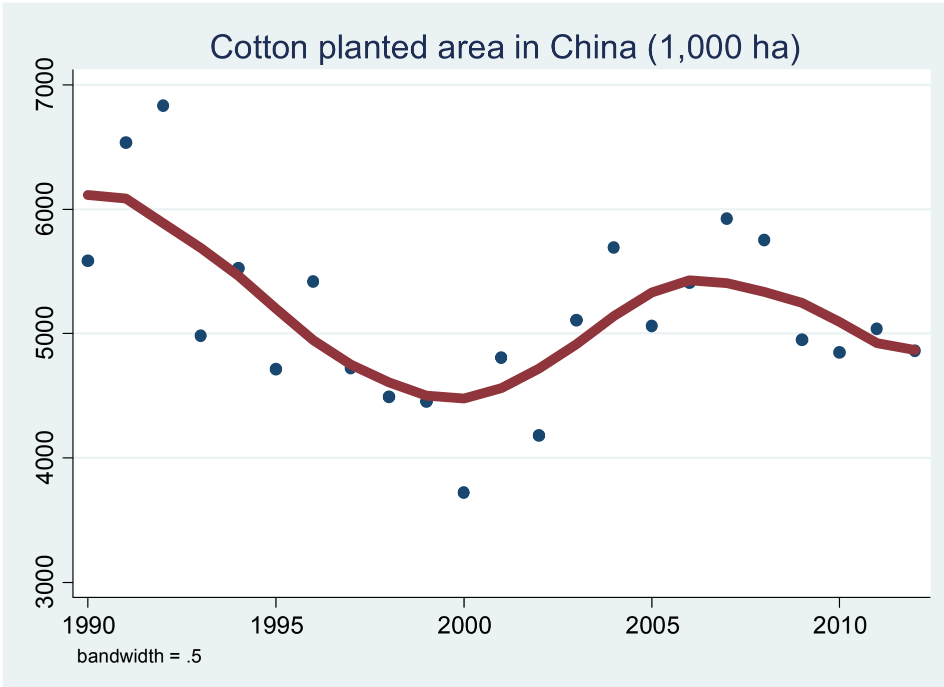
Econometric Models

However, the unconditional comparison above might yield bias. Hence, we buildup and run econometric models in the following to isolate the impact of Bt cotton adoption on cotton sown area. In mathematics, the estimation equation can be written as follows.

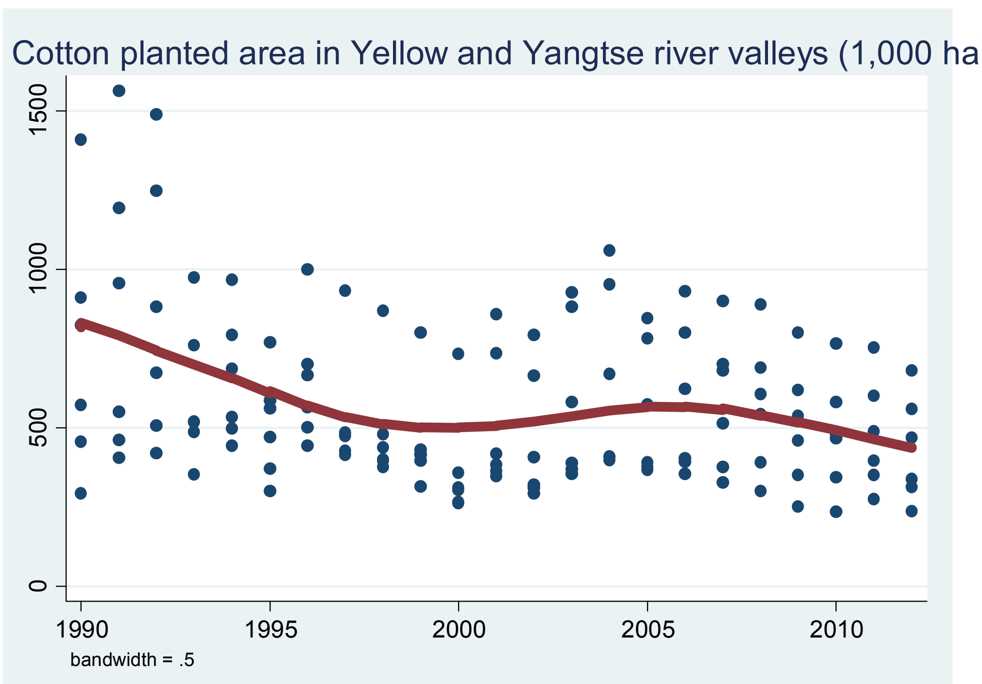
$$Area_{i,t} = \alpha + \beta_1 * Bt_{i,t} + \beta_2 * Bt^2{}_{i,t} + \beta_3 * Labor\cos t_{i,t} + \beta_4 * \Pr ice_{i,t-1} + \beta_5 * \Pr ovince_i + \varepsilon \quad (1)$$

Where β's are the parameters to be estimated; ε is the error term; *i* is the i^th province, *t* is the time. *Province* are province dummy variables. *Area* is the cotton sown area, measured in million ha. *Bt* is the share of Bt cotton in total cotton sown area. To estimate the non-linear relationship between sown area and share of Bt cotton, I also included the square of share of Bt cotton, Bt^2, in the equation.

Laborcost is a variable to measure the impact of labor cost on farmer's crop decision. Cotton is a labor intensive crop in China, which is different from that in developed countries where cotton farming is highly mechanized. Except for the land plowing and pesticide spraying, almost every stage of cotton production is done by hand in Yellow River valley and Yangtze River valley. Consequently, compared to grain crops, cotton is more sensitive to labor cost change. In other words, if the labor cost increases, some farmers might give up cotton production and turn to other labor-saving crop, such as grain, production.



Panel A



Panel B

Figure 2. Smoothed cotton sown area in China

I use couples of variables to capture the impact of labor cost on cotton sown area. First, I use wage rate of agricultural workers to denote the change of the labor cost. As the largest country in the world, it was thought that millions of rural labors are waiting for migration to cities in China (Han et al., 2007). However, China has been suffering a significant labor shortage since 2003(Chen and Hamori, 2009). Wu (2007) revealed that the labor shortage first occurred in the coastal areas and subsequently spread throughout the country. Since then, shortage of migrant labor had been repeatedly reported (Hogg, 2010; Shen, 2010; Hou et al., 2011).

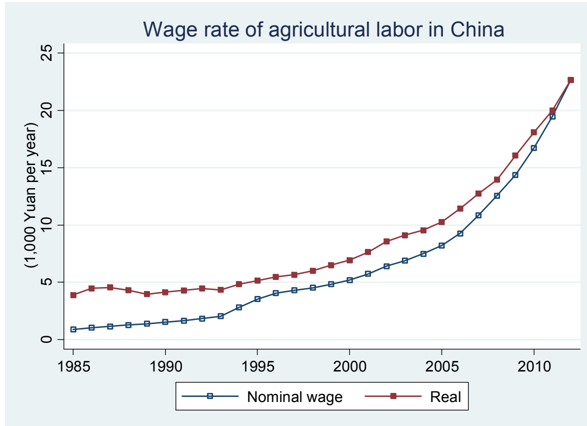
Consistent with these studies, national statistics showed that wage rate of agricultural workers did not increase slowly until early 2000s. As shown in Panel A of Figure 3, increase of wage rate of agricultural workers is less than 100% during 1985-2000. However, it began to grow significantly since the end of 1990s. During the last decade, the wage rate tripled (Panel A of Figure 3). As discussed above, we expect that increase of wage rate has significant negative impact on sown area of cotton, the labor intensive crop.

Alternatively, I use total power of large agricultural tractors to measure the impact of labor cost. In fact, even before the agricultural reform at the end of 1970s, large power agricultural machines were produced and wildly used in agricultural production in China. However, the implementation of Household Responsibility System yields near 200 million small households in China, and the average farm size is usually around 0.5 ha (NBSC, 2011; Fan and Chan-Kang, 2003). And because land quality can differ widely within villages, in consideration of equity in distribution, each household normally has, on average, three or four plots, and some have more than 10 plots (Huang et al., 2012). The typical small households make large agricultural machines unsuitable. As shown in Panel B of Figure 3, development of large agricultural machines was slow before early 2000s.

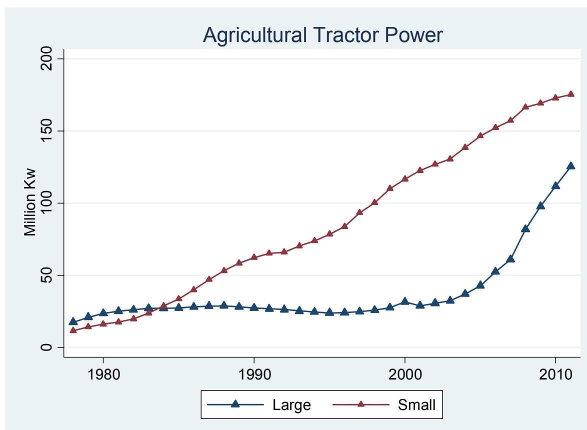
However, as the increase of labor wage in recent years, development of large agricultural machines had been accelerated during the last decades (Panel B of Figure 3). As the economic development, wage rate of agricultural workers also increased rapidly (Meng and Bai, 2007). As a result, agricultural machines were widely used in agricultural operations especially in recent years (Zhang and Shan, 2008). Ministry of Agriculture (2011) data show that the agricultural mechanization has been improved rapidly and the mechanization of farming, seeding and harvesting had reached 54.5% in 2011. For grain crops, for example rice, wheat and corn, agricultural machines were used almost every stage of production, from the plowing and seeding to harvesting (Ministry of Agriculture, 2001).

Price is a variable to measure the impact of cotton price on sown area. Grain crops (corn and wheat in northern China and rice in southern China) are the most important competitors of cotton production (Qiao et al., 2010). The competition between cotton and grain crops is affected by cotton price and grain price. Hence, in this study, I use cotton/grain price ratio to denote the impact of prices on farmer's crop decision. And because farmers adjust their production based on last year prices, lagged value of this ratio is added in the function. As shown in Panel C of Figure 3, this ratio has a clear decreasing trend in recent years. Clearly, this trend should have a negative impact on cotton sown area.

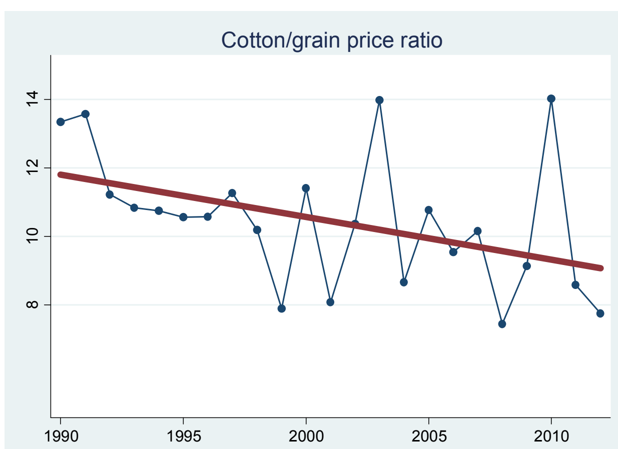
Two scenarios, each with different time periods, are estimated. Even though Bt cotton was commercialized in 1997, it was mostly planted in Hebei province. In the following two years, it began to spread to Shandong and Henan provinces in Yellow River valley. In fact, share of Bt cotton was relatively small in Yangtze River valley even in 2000. Hence, I first run the model using 2000-2012 year data.



Panel A



Panel B



Panel C

Figure 3. Wage rate, power of large agricultural machines, and cotton/grain price ratio

Table 2. Cotton sown area and its determinants

	Dependent variable: cotton sown area 2004-2012					Dependent variable: cotton sown area 2000-2012				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Share of Bt cotton	1.9509	0.9727	1.0874	0.3626	0.3254	0.6909	0.3517	0.4362	0.1227	0.1132
	(2.69)***	(1.53)	(1.73)*	(2.77)***	(2.53)**	(2.27)**	(1.07)	(1.37)	(1.67)*	(1.48)
Square of share of Bt cotton	-1.3968	-0.4298	-0.5314			-0.5580	-0.2103	-0.2955		
	(-2.97)***	(-0.98)	(-1.24)			(-2.22)**	(-0.72)	(-1.04)		
Power of large agricultural tract		-2.0461		-2.2604			-0.8545		-1.0719	
		(-4.68)***		(-5.98)***			(-1.58)		(-2.40)**	
Wage rate of agricultural labor			-0.0160		-0.0180			-0.0052		-0.0075
			(-4.65)***		(-5.86)***			(-1.22)		(-2.02)**
Lagged value of ratio of		0.0101	0.0103	0.0097	0.0098		0.0158	0.0160	0.0165	0.0171
cotton price/corn price		(2.04)**	(2.07)**	(1.97)*	(1.97)*		(2.39)**	(2.39)**	(2.52)**	(2.58)**
Constant	-0.0460	0.0771	0.1272	0.2876	0.4020	0.3714	0.2884	0.2907	0.3271	0.3527
	(-0.17)	(0.31)	(0.50)	(2.24)**	(3.24)***	(4.81)***	(3.02)***	(2.92)***	(4.17)***	(4.43)***
Observations	54	54	54	54	54	78	78	78	78	78
R-squared	0.190	0.498	0.495	0.487	0.477	0.068	0.167	0.155	0.161	0.142

Notes: t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Alternatively, 2004-2012 year data are used in the model estimation. Even though worries about the sustainability of Bt cotton began before the commercialization of Bt cotton, most people did not pay much attention until early 2000s. However, there are at least three reasons that make these worries serious problems after 2004. First, as the spread of Bt cotton all over China, field reports which showed that Bt cotton was inferior to non-Bt cotton (in terms of yield, seed cost, etc) were reported (for example Wang, 2009). Second, the wide spread of Bt cotton had effectively controlled the population size of cotton bollworm (Wu et al., 2008). Hence since 2000, the infection of cotton bollworm was not long a very serious problem even in Yellow River valley. As a result, some people began to believe that Bt varieties have no competitive advantage than non-Bt varieties. Third, in some areas, the outbreaks of secondary pest, such as mirids, made people believe there were the evidences that economic benefit that Bt cotton had generated was dying away (Wang et al., 2006 and 2008; Yang et al., 2005). For this reason, I run our model using 2004-2012 year data.

Finally, I specified the equation in the form of a fixed-effects model. The fixed-effects model is used to control the impact of those time-consistent variables (Woodridge, 2007). In other words, the estimation equation that I run is:

$$\Delta Area_{i,t} = \alpha + \gamma_1 * \Delta Bt_{i,t} + \gamma_2 * \Delta Bt_{i,t}^{\,2} + \gamma_3 * \Delta Laborcost_{i,t} + \gamma_4 * \Delta Price_{i,t-1} + \varepsilon_{i,t} \qquad (2)$$

Where Δ*Area*, ΔBt, ΔBt^2 , Δ*Laborcost* and Δ*Price* are changes of these variables separately. The *Province* dummy variables are excluded from the equation since they did not vary over time.

Results

The estimation results are shown in Table 2. In general, most of the regression results are consistent with the descriptive analysis in section II. For example, in both scenarios, the estimated coefficients of the Bt are significant and positive, while the estimated coefficients of the square of Bt are significant and negative (column 1 and column 6). In other words, these estimation results show that there is a quadratic relationship between share of Bt cotton and cotton sown area. Hence, at the early stage of Bt cotton adoption, as the spread of Bt cotton, cotton sown area also increases. However, after share of Bt cotton reached a point, cotton sown area will decrease as the spread of Bt cotton. This is consistent with our discussion in the above section. In this sense, adoption of Bt cotton is, at least, one of the reasons that cotton sown area decreased in recent years.

However, the quadratic relationship changed as impacts of other variables are considered. As discussed above, cotton sown are is affected by many other facts. Hence the estimation results in column 1 and column 6 might be biased. After adding these variables, estimation results are shown in columns 2 and 3, columns 7 and 8 (Table 3). The estimation results show that even though the estimated coefficients of share of Bt cotton are still positive and significant, the estimated coefficients of the square of the share of Bt cotton are not significant. In other words, the quadratic relationship between share of Bt cotton and sown area was changed into linear.

To check whether there is a linear relationship between the share of Bt cotton and cotton sown area, I dropped the square of Bt term and reran the models. As shown in columns 4 and 5, the estimation results show that estimated coefficients of share of Bt are significant and positive. Similar results are shown in other scenarios (columns 9 and 10). In other words, the estimation results (columns 2-5 and columns 7-10) show that, after excluding the impact of other variables, the Bt cotton adoption has significant positive impact on cotton sown area. In other words, as the adoption of Bt cotton, sown area keeps increasing. This finding is contradict to what we found in columns 1 and 6 and the worry that economic benefit of Bt cotton is dying away. To be more specific, estimation results show that adoption of Bt cotton is not the reason that cotton sown area decreased in recent years.

In fact, it is not hard to understand the estimation results. As shown in rows 3, 4 and 5, estimated coefficients of power of large agricultural machines, wage rate of agricultural workers are significant and negative, while estimated coefficients of cotton/grain price ratio are significant and positive. In other words, the estimation results show that as the increase of labor cost (i.e. increase of wage rate of agricultural workers, and/or power of large agricultural machines) in the past decade, some farmers give up cotton production and turn to other crops. On the other hand, as the decrease of the cotton/grain price ratio in recent years, planting grain becomes more profitable that planting cotton. As a result, cotton sown area decreases as the decrease of cotton/corn price ratio. In other words, the reasons that cotton sown area decreased in recent years are the increase of labor cost and the decreases of cotton/grain price ratio, but not the adoption of Bt cotton.

Conclusions

Both national statistics and empirical studies had showed that economic benefit of Bt cotton is dying away 15 years later after Bt cotton was commercialized in China. The adoption of Bt cotton had been considered as the main reason that cotton sown area declined in recent years. However, this study shows that the adoption of Bt cotton has no negative impact on cotton sown area. On the other hand, the increase of labor cost and decrease of cotton price might be the real reason behind the reduction of cotton sown area in recent years in China.

This result has important implications in practices. For example, even though Bt rice was read to commercialized in China for years, Chinese government did not release it until today. In fact, we have no idea when it is going to be released and whether it will be released. One of the most important concern behind this is the worry about the sustainability of the benefit that Bt cotton, the only Bt crop that was widely spread in fields. Results of this study help to clear some misunderstandings of the Bt crop and will contribute to the policies related to genetically modified crops.

Acknowledgments

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References

Chen, G., S. Hamori, 2009. Solution to the dilemma of the migrant labor Shortage and the rural labor surplus in China. China & World Economy 17(4), 53-71.

Fan, S. and C. Chan-Kang. 2003. Is small beautiful? Farm size, productivity and poverty in Asian agriculture. Plenary paper prepared for the 25th International Conference of Agricultural Economists, July 17, 2003, Durban, South Africa.

Gould, F., 1998. Sustainability of transgenic insecticidal cultivars: integrating pest genetics and ecology. Annual Review of Entomology, 43, 701-722.

Han, J., C. Chui and A. Fan, 2007. Rural surplus labor: Findings from village survey, in Cai Fang and Yang Du, eds, Green Book of Population and Labor, Beijing: Social Sciences Academic Press, pp. 113–27 (in Chinese).

Hogg, C., 2010. China's Pearl River manufacturing hub 'lacks workers', BBC News, Shanghai, Monday, 22 February 2010. Available at: http://news.bbc.co.uk/2/hi/8527621.stm.

Hou, D., Y. Jiang, Y. Cao, J. Chen, Jian, 2011. A survey of labor shortage in one county of Sichuan province: pushing rural labors out in the past and keeping them stay today. Xinhuanet, March 2, 2011. Available at: http://news.xinhuanet.com/politics/2011-03/02/c_121137964.htm.

Hossain F., C. Pray, Y. Lu, et al., 2004. Genetically modified cotton and farmers' health in China. Int J Environ Health Res, 10: 296–303

Huang, J., R. Hu，S. Rozelle，F. Qiao， C. Pray．2002a．Transgenic varieties and productivity of smallholder cotton farmers in China. Australian Journal of Agricultural and Resource Economics 46(3):367—387

Huang, J., S. Rozelle, C. Pray, and Q. Wang, 2002b. Plant biotechnology in China, Science, 295:674-676.

Huang, J.，H. Lin，R. Hu，S. Rozelle, C. Pray, 2007. Analysis of the impact of Bt cotton adoption on secondary pest. Journal of Agrotechnical Economics (in Chinese), 1:4-12.

Huang, J., J. Mi, H. Lin, Z. Wang, R. Chen, R. Hu, S. Rozelle, C. Pray, 2010. A decade of Bt cotton in Chinese fields: Assessing the direct effects and indirect externalities of Bt cotton adoption in China, Science China Life Sciences, 53 (8): 981-991.

Huang, J., X. Wang, and H. Qiu, 2012. Small-scale farmers in China in the face of modernisation and globalization. IIED/HIVOS.

Hsu, H., Gale, F., 2001. Regional shifts in China's cotton production and use, Economic Research Service, USDA, November.

Lu Y, Wu K, Jiang Y, Xia B, Li P, Feng H, Wyckhuys KA, Guo Y. 2010. Mirid Bug Outbreaks in Multiple Crops Correlated with Wide-Scale Adoption of Bt Cotton in China, Science, Vol. 328: 1151-1154.

Ma, J. B. Gao, F. Wan, J, Guo, 2003. Ecological risk of Bt transgenic cotton and its management strategy. Chinese Journal of Applied Ecology (in Chinese), 14(3):443-446.

Men, X., F. Ge, C. Edwards, E. Yardim, 2005. The influence of pesticide application on Helicoverpa armigera Hübner and sucking pests in transgenic Bt cotton and non-transgenic cotton in China. Crop Protection, 24, 319-324.

Meng, X., and N. Bai (2007), "How much have the wages of unskilled workers in China increased? Data from seven factories in Guangdong" in Garnaut, Ross and Ligang Song (eds) China: Linking markets for growth, Asia-Pacific Press, Canberra and Social Sciences Academic Press, Beijing.

Department of Agriculture, 2011. Agricultural mechanization has been improved rapidly and the mechanization of farming, seeding and harvesting had reached 54.5% in 2001. Available at: http://www.gov.cn/gzdt/2011-12/21/content_2025583.htm.

National Bureau of Statistics of China, varies years. Cost and Benefit of Agriculture Production in China, China Statistics Press, China: Beijing.

National Bureau of Statistics of China, varies years. China Statistics Yearbook, China Statistics.

National Bureau of Statistics of China, 2011b. China Rural Statistical Yearbook, 1985–2011. China Statistical Press, Beijing.

Peggi, M., F. Qiao, Y. Guo, 2010. Cotton production in Xinjiang, China, Selected Paper, Beltwide Cotton Conference, National Cotton Council of America, January 4 – 7, 2010, New Orleans, Louisiana.

Pemsl, D., H. Waibel, 2007. Assessing the profitability of different crop protection strategies in cotton: Case study results from Shandong Province, China Agricultural Systems, 95(1-3): 28-36.

Pray, C., Ma, D., Huang, J. and Qiao, F. (2001). Impact of Bt cotton in China. World Development 29: 813–825.

Price Division of the National Development and Reform Commission, varies years. All China Data Compilation of the Costs and Returns of Main Agricultural Products (in Chinese), China Statistics Press. Beijing, China.

Qaim, M., Zilberman, D., 2003. Yield effects of genetically modified crops in developing countries. Science, 299(5608): 900 - 902.

Qiao, F., L. Zhan, M. Paggi, 2010. The Impact of Global Financial Crisis On Chinese Cotton Production, Selected Paper, Beltwide Cotton Conference, National Cotton Council of America, January 4 – 7, 2010, New Orleans, Louisiana.

Raney, T., 2006. Economic Impact of Transgenic Crops in Developing Countries. Current Opinion in Biotechnology, 17:1–5.

Shen, H., 2010. The mystery of China's labor shortage, The Wall Street Journal, February 22, 2010. Available at: http://blogs.wsj.com/chinarealtime/2010/02/22/the-mystery-of-chinas-labor-shortage/tab/article/.

Wang, H., 2009. Worry about yield loss led by Bt cotton adoption. 21 Century Economic report. September 30, 2009. Available at: http://www.21cbh.com/HTML/2009-9-30/148758.html.

Wang, S., D. Just, and P. Pinstrup-Andersen, 2006. Tarnishing Silver Bullets: Bt Technology Adoption, Bounded Rationality and the Outbreak of Secondary Pest Infestations in China. Selected Paper. American Agricultural Economics Association 2006 Annual meeting, July 23-26, Long Beach, CA.

Wang, S., D. Just, and P. Pinstrup-Andersen, 2008. Bt-cotton and secondary pests. International Journal of Biotechnology, 10:113-121.

Wang, Z., H. Lin, J. Huang, R. Hu, S. Rozelle, C. Pray, 2009. Bt cotton in China: Are secondary insect infestations offsetting the benefits in farmer fields. Agr Sci China, 8: 101–105.

Wooldridge, J.M., 2007. Introductory Econometrics- A Modern Approach. Beijing: Tsinghua University Press.

Wu, K. and Y. Guo. 2005. The evolution of cotton pest management practices in China. Annu. Rev. Entomol. 50, 31-52.

Wu, K., Y. Lu, H. Feng, Y. Jiang and J. Zhao, 2008. Suppression of Cotton Bollworm in Multiple Crops in China in Areas with Bt Toxin–Containing Cotton, Science 321(5896):1676-1678.

Wu, Y., 2007. Labor shortage continues and spreads, in Cai Fang and Yang Du, eds, Green Book of Population and Labor, Beijing: Social Sciences Academic Press, pp. 63–94 (in Chinese).

Yang, P., M. Iles, S. Yan, F. Jolliffe, 2005. Farmers' knowledge, perceptions and practices in transgenic Bt cotton in small producer systems in Northern China, Crop Protection 24:229–239.

Zhang, H., B. Shan, 2008. Historical records of heavy metal accumulation in sediments and the relationship with agricultural intensification in the Yangtze–Huaihe region, China, Science of The Total Environment, 399(1-3): 113–120