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Fifteen Years of Bt Cotton in China: The Economic Impact and its Dynamics

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Summary. — Even though the economic benefit of Bt cotton adoption in the short-run has been well documented, the dynamics of this benefit remain unclear. In particular, the possibility of pest resistance build-up and secondary pest outbreaks has caused concern regarding the sustainability of this economic benefit in the long run. Hence, this study analyzes the economic impact of Bt cotton and its dynamics in China. Using nationally representative long panel data for 1997–2012, we show that this economic benefit continues 15 years after the commercialization of Bt cotton.

Key words — economic benefit, Bt cotton, sustainability, China

1. INTRODUCTION

The short-run economic benefit of *Bacillus thuringiensis* (Bt) cotton has been well documented (e.g., Carpenter, 2010; Qaim, 2003; Stone, 2011; Wossink & Denaux, 2006). Empirical studies in China showed that the expenditure on pesticide decreased by more than two-thirds after Bt cotton adoption (Huang, Hu, Pray, Qiao, & Rozelle, 2003; Huang, Hu, Rozelle, Qiao, & Pray, 2002; Pray, Ma, Huang, & Qiao, 2001). Furthermore, the reduction of chemical pesticide use not only increased the yield and net profit of cotton farmers, but also contributed to a cleaner environment and improved the health of farmers (Hossain, Pray, Lu, Huang, & Hu, 2004; Kouser & Qaim, 2011). Because of its high profitability, Bt cotton was almost exclusively adopted in the North China Plain only a few years after its commercialization in 1997 (James, 2013).

On the other hand, concerns regarding the long-run effect of Bt technology continue. In fact, the debate on the advantages and disadvantages of this technology began even before the commercialization of Bt crops. It was expected that the widespread adoption of Bt crops would lead to pests' developing resistance to Bt toxin and/or secondary pest outbreaks. As a result, the total pesticide use would be gradually restored to the level before the adoption of Bt cotton, and the short-run economic benefit of Bt cotton would be completely offset in the long run (e.g., Pemsl & Waibel, 2007; Wang, Just, & Pinstrup-Anderson, 2008). In recent years, this negative attitude toward Bt cotton has often seemed to dominate the public debate in the news and media (Cleveland & Soleri, 2005; Kathage & Qaim, 2012). For example, in China, Bt technology had even been described as a "weapon" that developed countries used to attack developing countries (Jiang & Li, 2010).

These concerns have important impact on agricultural production practices. To mitigate the development of pest's resistance, farmers were required to plant refuges of non-Bt cotton in almost all the countries where Bt cotton is planted, as suggested by the entomologists and ecologists (Bates, Zhao, Roush, & Shelton, 2005; Gould, 1998; Tabashnik *et al.*, 2003). Because pests adapted to one toxin may still be susceptible for another toxin, cotton varieties with stacked Bt genes are more efficient in pest control (Gould, 1998). Due to the worry that the economic benefit of varieties with a single Bt gene would die away, some farmers had switched to varieties with stacked Bt genes (James, 2013).

Whether the short-run effect of Bt cotton adoption is sustainable remains a question for two notable reasons. First, most of the previous studies analyze data collected in the first few years after the commercialization of Bt cotton in a country. However, an increase in pesticide use owing to pest resistance build-up and/or secondary pest outbreaks may not appear in the short run (Qiao, Wilen, & Rozelle, 2008). Therefore, these studies may not provide satisfactory answers on the long-term impact or the sustainability of the economic benefit of Bt cotton. [1]

Second, all previous studies were based on a small sample of household survey data. Even though there are more than ten million cotton farmers, these surveys usually include only data on a few hundred of them (e.g., Huang *et al.*, 2003; Kathage & Qaim, 2012). Moreover, although all the sampled households are from the major cotton-producing regions, the estimation results based on the data set might be biased.

In this study, we address this shortcoming by using nationally representative panel data over 15 years. We choose China as the focus of our study for two reasons. First, prior to 2006, China was the largest country to plant Bt cotton, and subsequently became the second largest country (James, 2013). [2] More importantly, Bt cotton was commercialized in China early in 1997. In other words, Bt cotton has presently been commercialized for over 15 years. Furthermore, nationally representative data on the detailed information of input and output of cotton production have been surveyed, recorded, and published annually.

Second, the sustainability of the effect of Bt cotton adoption is still a hot topic in China. In fact, there has been widespread opposition from the public regarding Bt cotton adoption, particularly after a secondary pest outbreak in some Bt cotton fields in the early 2000s. Scientists and researchers who supported genetically modified (GM) crops were labeled "traitors" (Economist, 2013). Faced by increasing criticism against GM technology, the Chinese government delayed the

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commercialization process of other Bt crops (Jiang & Li, 2010). For example, even though GM rice technology has been mature for years, the Chinese government has no plan or schedule for its commercialization.

The remainder of this paper is organized as follows. The next section discusses the data used in this study. A descriptive analysis of the economic benefit of Bt cotton and its dynamics is presented by showing the quantities of pesticide cost, seed cost, labor use, and cotton yield and their dynamics since Bt cotton adoption. To isolate the impact of Bt technology and its dynamics, econometric models are set up in the third section, and the estimation results are discussed in the fourth section. The final section concludes the paper.

2. DATA AND THE IMPACT OF BT COTTON ADOPTION IN CHINA

Data used in this study are primarily obtained from the All China Data Compilation of the Costs and Returns of Main Agricultural Products (*Quanguo Nongchanpin Chengben Shouyi Ziliao Huibian* – in Chinese pinyin) and China Statistical Yearbook (*Zhongguo Tongji Nianjian* – in Chinese pinyin). Specifically, the data regarding expenditure on pesticides, labor use, fertilizer use, seed cost, and other material cost, as well as cotton yield are obtained from the All China Data Compilation of the Costs and Returns of Main Agricultural Products (National Development and Reform Commission, various years).[3] However, the data on national total cotton sown area, provincial cotton sown areas, and price indexes are obtained from the China Statistical Yearbook (National Bureau of Statistics of China (NBSC), various years). Due to lack of national statistics, the percentages of Bt cotton in different provinces are mainly obtained from the Center for Chinese Agricultural Policy (CCAP), Chinese Academy of Sciences.[4]

China has three major cotton-producing regions: the Yellow River valley, the Yangtze River valley, and the Northwest (Hsu & Gale, 2001). The Northwest region includes primarily the Xinjiang Uyghur autonomous region, which has been the largest cotton-producing province in China since the mid-1990s. Another important cotton-producing province in the Northwest region is the Gansu province, which is the twelfth largest cotton-producing province in China (NBSC, 2013).

The Yellow River valley is China's largest cotton-producing region. In this study, five provinces from the Yellow River valley—Shandong, Hebei, Henan, Shaanxi, and Shanxi—are included. In addition, five provinces from the Yangtze River valley—Hubei, Anhui, Hunan, Jiangsu, and Jiangxi—are included. These 10 provinces are also the second to thirteenth largest cotton-producing provinces in China (NBSC, 2013).[5] The total cotton sown area of these 12 provinces included in this study is 4.59 million ha, which is 97.80% of the national total sown area. The basis characteristics of the variables used in this study is shown in Table 1.

As shown in Figure 1, Bt cotton adoption in the major cotton-producing provinces was rapid, but significantly different in many aspects. Because of the warm and dry climate conditions and yield damage caused by cotton bollworm, Bt cotton adoption in the Yellow River valley is significantly higher than that in the other two regions (Wu & Guo, 2005). For example, yield loss caused by cotton bollworm in the Hebei province in 1992 was nearly 40% (Ministry of Agriculture, 1990–1999). Hence, Bt cotton was first commercialized in the Yellow River valley in 1997 (Hsu & Gale, 2001). As this was very successful, Bt cotton adoption then rapidly spreads to the Yangtze River valley. As shown in Figure 1, only Bt cotton was grown in the Yellow River and Yangtze River valleys within a few years after its commercialization. On the other hand, because of their dry and hot climate, the percentage of Bt cotton adoption in Xinjiang and Gansu provinces was relatively small until 2004.

Table 1. *Basic characteristics of variables*

Variable names	Mean	Standard deviation
Yield (kg/mu)	142.69	38.90
Bt cotton adoption (%)	32.05	41.63
Pesticide cost (yuan/mu)	67.66	39.25
Seed cost (yuan/mu)	36.36	18.20
Labor (day/mu)	35.30	12.59
Fertilizer use (yuan/mu)	610.77	574.11
Other cost (yuan/mu)	438.39	121.72

Note: 1 ha = 15 mu; 1 USD = 6.25 Chinese Yuan.

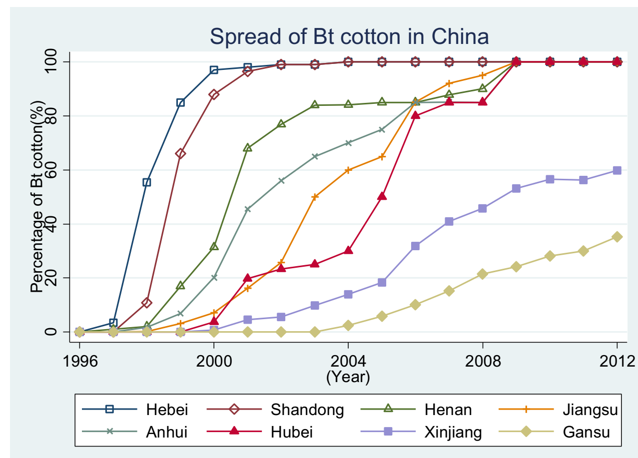

Figure 1. *Spread of Bt cotton in China.*

Figure 2 shows the dynamics of inputs and cotton yield with the widespread adoption of Bt cotton. As shown in Panel A, the pesticide cost decreased significantly after Bt cotton adoption. Similarly, labor use also decreased significantly from 1997 onward (Panel B). Simultaneously, however, both seed cost and yield increased (Panels C and D).

In order to show the changes of inputs and yields before and after the Bt cotton adoption, we compared the inputs and yields of three time periods: 1990–96, 1997–2003, and 2004–12. The first time period comprises the years before Bt cotton adoption. In the second time period, Bt cotton cultivation spread from the Yellow River valley to the Yangtze River valley (early adoption period hereafter). In the third time period, only Bt cotton was grown in the Yellow River and Yangtze River valleys and Bt cotton adoption began to increase significantly in the Northwest region (late adoption period hereafter). In fact, 2004 is also the year when the concern regarding the sustainability of the economic benefit of GM technology became the center of public debate.

Table 2 shows that with the spread of Bt cotton, pesticide use decreased significantly (column 1). Moreover, as observed in column 2, the pesticide cost is 93.71 yuan/mu during 1990–96, which decreased to 74.45 yuan/mu during 1997–2003 and to 60.54 yuan/mu during 2004–12 (row 1 to row 3). After dividing the entire sample into three major regions, we found that the reduction in pesticide use mainly comes from the