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Risk preferences and pesticide use by cotton farmers in China[☆]

Elaine M. Liu [a,*], JiKun Huang [b]

[a] University of Houston, United States
[b] Center for Chinese Agricultural Policy, Chinese Academy of Sciences, China

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ABSTRACT

Despite that insect-resistant Bt cotton has been lauded for its ability to reduce the use of pesticides, studies have shown that Chinese Bt cotton farmers continue to use excessive amounts of pesticides. Using results from a survey and an artefactual field experiment, we find that farmers who are more risk averse use greater quantities of pesticides. We also find that farmers who are more loss averse use lesser quantities of pesticides. This result is consistent with our conceptual framework and suggestive evidence where farmers behave in a loss averse manner in the health domain and place more weight on the importance of health over money in the loss domain.

1. Introduction

Modern agricultural biotechnology has made a great deal of progress over the past two decades in significantly increasing productivity and living standards in developing countries. These advancements have introduced a wide array of genetically modified crops that are insect resistant, virus resistant, drought resistant, and even nutrient enriched. Take genetically modified *Bacillus thuringiensis* (Bt) cotton as an example. Prior to the invention of Bt cotton, farmers were forced to choose between letting cotton bollworms (the primary cotton pest) damage their cotton yields or sacrificing their own health by spraying their crops with a greater quantity of pesticides. Bt cotton was devised specifically to counter bollworm infestations and has been scientifically proven to be effective in pest resistance (Huang et al., 2002b; Qaim and Zilberman, 2003; Qaim et al., 2006). Emboldened by this scientific evidence, policy makers around the world have encouraged the adoption of Bt cotton. However, several studies find that farmers have continued to use excessive amounts of pesticides even after they adopted pest-resistant Bt cotton (Huang et al., 2002a; Pemsl and Waibel, 2005; Yang et al., 2005).[1] These findings present a puzzle as to why farmers would deviate from profit-maximizing behavior to spray *excessive* amounts of pesticides, especially considering the fact that spraying pesticides is detrimental to their health. Liu (forthcoming) has suggests that Chinese cotton farmers were slow to adopt Bt cotton because of their risk preference. It is possible that farmers who are more risk averse could also be using more pesticides after adopting Bt cotton. This paper uses the same dataset as Liu (forthcoming) to investigate whether Chinese cotton farmers' pesticide-use decisions are correlated with their risk preferences.

There is an extensive theoretical literature where farmers' risk preferences play a role in agricultural production decisions (Feder, 1980; Just and Zilberman, 1983). In determining the relationship between agricultural decisions and risk preferences, most of the empirical studies in the literature typically have two approaches when estimating risk aversion. One is to rely on the assumption of objective function and advanced econometric technique to impute the coefficient of risk aversion that will fit the model (Antle, 1988; Chavas and Holt, 1996; Saha et al., 1994). For example, if a farmer deviates from profit-maximizing production input choices, the structural approach would conclude that it is due to individual risk preference and impute the coefficient of risk aversion. As suggested by Just and Lybbert (2009) and Just (2008), the assumption of a

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* Corresponding author.
E-mail address: emliu@uh.edu (E.M. Liu).

[1] Bt cotton is not a fix-all solution as it only targets cotton bollworm. Pesticide is still essential to cotton production post Bt adoption. However, a few papers (Huang et al., 2002a; Pemsl and Waibel, 2005; Yang et al., 2005) find that farmers are using nearly 3 times more pesticide than the optimal profit maximizing level.

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utility function form and arbitrary heuristics could cause bias when estimating individual risk aversion. On the other hand, some studies use wealth as a proxy for risk aversion (Ackerberg and Botticini, 2002; Dubois, 2002; Fukunaga and Huffman, 2009; Laffont and Matoussi, 1995). Bellemare and Brown (2009) comment that it could be problematic when wealth is being used as a proxy for risk aversion, as it could potentially undermine the role of risk preferences in farming decisions. One contribution to the existing literature is that all risk preference parameters used in the analysis are being elicited from artefactual field experiments.[2]

Starting from Binswanger's (1980, 1981) seminal papers, it is not uncommon to elicit risk preference where farmers are the subjects of the experiments. However, there exists a long-standing debate regarding the external validity of game experiments.[3] In this study, we first elicit farmers' risk preference from an experiment, and we extend their game behaviors to the agricultural decisions. The findings from this study bridge the gap between lab experiments and real world behavior. Similar to research by List (2003), Schechter (2007), and Fehr and Goette (2007), the findings from this study suggest that experiment results can predict real world decisions in the case of Chinese cotton farmers' pesticide use.

Before eliciting the risk preference using the experiment, we first need to decide on the form of the utility function. The common approach to characterize individual risk preference is to use expected utility (EU), in which risk aversion is the sole parameter for determining the curvature of the utility function. On the other hand, in prospect theory (PT) (Kahneman and Tversky, 1979), the shape of the utility function is jointly determined by risk aversion, loss aversion (which measures one's sensitivity to loss compared to gain), and nonlinear probability weighting (i.e., the individual tendency of overweighting small [large] probabilities and underweighting large [small] probabilities). As suggested in earlier agricultural economics research, if farmers follow safety-first principles by setting a target income and minimizing the probability of severe yield loss below that income (Moscardi and de Janvry, 1977; Young, 1979), then it is likely that farmers' risk preferences will be best captured by prospect theory instead of neoclassical utility theory.[4] Ex ante, EU or PT could act as a potential theory for explaining the cotton farmers' decision making processes; however, it is not clear which theory is more appropriate. Therefore, we use an experimental design modeled after that of Tanaka, Camerer, and Nguyen (TCN) (Tanaka et al., 2010). The major advantage of TCN's design is that it allows the experiment's results to determine whether EU or PT better fits the farmers' decision making processes. It allows us to elicit three risk preference parameters—coefficient of risk aversion, loss aversion, and nonlinear probability weighting—without rejecting outright the use of EU theory. Our survey covers 320 cotton farmers from 16 villages across eight counties in four provinces in China in 2006. We collect information on household characteristics, individual characteristics, and detailed plot information for the 2006 harvest and planting season. We relate the farmers' elicited risk preferences to their pesticide use while controlling for farm and individual characteristics.

Before interpreting our results, in order to understand how each of the risk preference parameters would affect optimal pesticide use, we set up a conceptual framework in which farmers' utility is a function of income as well as their health. By using more pesticide, farmers would prevent loss of income but would have to sacrifice their health due to the danger of pesticide poisoning. Therefore, depending on one's coefficient of risk aversion, loss aversion and one's reference points for health and income, the optimal pesticide use would differ.

Our main finding is that controlling for village fixed effects, farmers who are more risk averse use greater quantities of pesticides. If the average farmer from our sample became risk neutral, he would spray approximately 13% less pesticides—a reduction in pesticide use equivalent to the effect of 6 additional years of education).[5] Combining with the finding from Liu's (Forthcoming) paper on Bt cotton adoption, we can conclude that more risk averse farmers not only adopt Bt cotton later, but they also continue to use higher level of pesticide post adoption. Therefore, wealth accumulation associated with this technological advancement is negatively correlated with farmers' risk aversion. We also find that farmers who are more loss averse use lesser quantities of pesticides. It may seem surprising at first glance, but it is consistent with our conceptual framework and suggestive evidence where farmers behave in a loss averse manner in the health domain and yet place more weight on the importance of their health over the importance of money in the loss domain.

We find that more educated farmers seem to better understand the advantages of using Bt cotton since it requires less pesticides than regular cotton. For every additional year of education, farmers reduce pesticide use by 0.56 kg per hectare (~2%). Several other hypotheses have been put forth by others to explain the overuse of pesticide, including the deterioration of the bollworm-resistant quality of Bt cotton seeds, the existence of counterfeit Bt cotton seed, the incorrect information supplied by extension agents and the rise of secondary pests. In our study, with our regression specifications, controlling for village fixed effects, we find no evidence supporting these alternative hypotheses.[6]

This paper proceeds as follows. Section 2 provides background on Bt cotton. Section 3 describes the experiment and dataset and provides some summary statistics on farmers' characteristics and describes the experimental design. Section 4 provides background on pesticide use and the conceptual framework. Section 5 describes the econometric framework and regression results for pesticide use. Section 6 concludes.

2. Background

China is one of the largest cotton producers in the world. Unlike commercial cotton farmers in the United States, Chinese cotton farmers are generally subsistence farmers who are more risk averse, less tolerant of pest infestations, and place the highest priority on resolving severe pest problems (Bentley and Thiele, 1999; Pray et al., 2002). During the early 1990s, many Chinese cotton farmers experienced failures in controlling bollworm damage to their crops due to frequent outbreaks of increasingly pesticide-resistant bollworm infestations. In an attempt to ameliorate the bollworm problem, the provincial governments in certain regions of China began commercializing Bt cotton seeds in 1997.[7] Bt cotton seeds are planted in a similar fashion to traditional cotton seeds, but Bt cotton seed carries the Bt toxin which targets the cotton bollworm. Using data collected in 2001, Huang et al. (2002b) found that Bt cotton adoption leads to a significant decrease in pesticide use. Bt cotton farmers reduce their total pesticide expenditure by 82%. Chinese

[2] We adopt the terminology artefactual field experiment from Harrison and List (2004). Artefactual field experiments are conventional lab experiments but are done with nonstandard subjects. Hereafter, we will refer to it as the experiment.

[3] See Samuelson (2005) for discussion.

[4] The applications of these two concepts, "safety-first rule" and "loss aversion," can be found in behavioral finance studies (see Camerer and Kunreuther, 1989; Campbell and Kräussl, 2007; Polkovnichenko, 2005).

[5] The average farmer in the sample is risk averse with a coefficient of risk aversion equal to 0.48.

[6] It is still possible that these hypotheses can explain cross-village variations of pesticide use. For the purpose of our paper, investigating the role of risk preferences, it is essential to control for village fixed effects for the following reasons. First, a village can play a role in determining one's risk preferences (e.g. a particular village may have more poor quality, less arable land), hence people in the village are more risk averse. Second, if we do not have village-fixed effect, we need a lot more information about the village characteristics that could possibly affect pest severity, which is missing from our survey.

[7] It was a rolling decision. In some provinces Bt cotton was approved in 1998.