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Do lower yielding farmers benefit from Bt corn? Evidence from instrumental variable quantile regressions

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ABSTRACT

There have been serious questions about whether lower-yielding farmers in developing countries, who are typically poor smallholders, benefit from genetically-modified crops like *Bacillus thuringensis* (Bt) corn. This article examines this issue by estimating the heterogeneous impacts of Bt corn adoption at different points of the yield distribution using farm-level survey data from the Philippines. A recently developed estimation technique called instrumental variable quantile regression (IVQR) is used to assess the heterogeneous yield effects of Bt corn adoption and at the same time address potential selection bias that usually plague impact assessment of agricultural technologies. We find that the positive yield impact of Bt corn in the Philippines tend to be more strongly felt by farmers at the lower end of the yield distribution. This result suggests that Bt corn could be a "pro-poor" technology since most of the lower-yielding farmers in the Philippines are poor smallholders with low incomes.

1. Introduction

Genetically-modified (GM) crops have been recognized as a technology that can potentially provide higher yields and reduce pesticide use for farmers. These are some of the reasons why the cultivation of GM crops has continued to increase worldwide since its first introduction in 1996 (FAO, 2004; James, 2008). In particular, insect-resistant crops that have a gene from the soil bacterium *Bacillus thuringensis* (Bt) is now one of the most widely adopted GM crop variety in the world.

There have been a number of studies that have provided empirical evidence on the yield increasing and pesticide reducing effects of Bt crops (see Smale et al., 2007 and Qaim, 2009 for a comprehensive review of this literature). For example, the yield increasing effects for Bt cotton are observed to be largest for countries that typically underutilize pesticides, such as in Argentina, India, and South Africa (Qaim and de Janvry, 2005; Qaim, 2003; Shankar and Thirtle, 2005). While in countries where pesticide use is typically high, such as China and the United States (US), the pesticide-reducing effect of Bt cotton is much more dominant than the yield effect (Huang et al., 2002; Falck-Zepeda et al., 2000). Although there have been fewer studies that examine the impacts of Bt corn (rather than Bt cotton), the existing literature also show similar yield-increasing and insecticide-reducing effects for Bt corn, albeit with a smaller magnitude (Brookes and Barfoot, 2005; Gouse et al., 2006; Fernandez-Cornejo and Li, 2005; Yorobe and Quicoy, 2006; Qaim, 2009).

Based on these previous studies, it seems that (on the surface) both lower yielding and higher yielding farmers in developing countries equally benefit from using Bt crops. Given that developing county farmers at the lower end of the yield distribution tend to be poorer farmers and those at the upper end are wealthier farmers,[1] these previous studies also seem to imply that the benefits of Bt crops would be felt by all types of farmers regardless of whether they are poor smallholders or larger commercial producers. However, most of these studies only investigate the effect of Bt technology on *mean* yield and *mean* pesticide use.[2] This general result only implies that Bt corn tends to have a statistically significant positive effect on the yields of the "average" (or the mean yielding) farmer. This finding does not give specific information on whether (and how much) Bt affects yields at the lower or upper end of the

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[1] The data used in this study also support this stylized fact since farmers at the lower end of the yield distribution have lower income than the farmers in the upper end of the yield distribution (see Appendix Table A.1).

[2] One study that is somewhat of an exception is Qaim and De Janvry (2005) where they separately examine the effect of Bt cotton for small-scale producers (i.e., farms with less than 90 hectares) and large-scale producers (i.e., farms with more than 90 hectares). They found that the yield and pesticide use effects of Bt are largely felt by the small-scale producers in Argentina. Note, however, that this study does not specifically investigate the impact of Bt. on farmers at different points of the yield distribution.

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yield distribution. It is possible that Bt corn has a heterogeneous impact on yields at different points of the distribution.

In general, policy makers in developing countries would be more interested in supporting increased adoption of Bt crops if there is empirical evidence that the lower yielding farmers (who are typically poor smallholders) specifically benefit from Bt crops. Knowing the effects of Bt technology at different points of the yield distribution gives a more complete picture of the economic impacts of Bt crops. For example, if Bt crops only have a statistically significant effect at the higher end of the yield distribution, while there is no (or there is a negative) Bt impact for lower yielding smallholder farmers, then promoting Bt crops would not be a good policy option to improve the welfare of poor smallholders and improve farm productivity. On the other hand, if Bt crops have a significant yield effect in the lower tail of the cross-sectional yield distribution, then advocating the use of Bt crops to poor farmers may be a viable approach to increase poor smallholders' income, improve agricultural productivity, and enhance overall welfare.

One way to capture the effects of Bt crops at different points of the yield distribution is to use quantile regression techniques introduced by Koenker and Bassett (1978). The main difference between quantile regression and other regression approaches like ordinary least squares (OLS) is that it allows for estimating various quantile functions at various percentiles of the outcome distribution (i.e., the dependent variable distribution) instead of just one function at the mean. This technique has been used in various studies in applied economics to study effects of regressors at different points of a particular outcome distribution, mostly in studying wage distribution or trade effects (see Bishop et al., 2005; Falaris, 2008; Yasar et al., 2006 for example).

However, if there are endogeneity or self-selection problems, the coefficient estimates from standard quantile regression techniques may be biased (Melly, 2006; Wehby et al., 2009; Chernozhukov and Hansen, 2004). Moreover, the standard instrumental variable (IV) or two stage least squares (2SLS) approach in ordinary least squares (OLS) regression is not directly applicable in a quantile regression context. Chen and Portnoy (1996) actually developed a quantile regression analogue to the standard 2SLS approach called a two stage quantile regression (2SQR), but Chernozhukov and Hansen (2004) show that 2SQR is not consistent when the quantile treatment effect differs across quantiles, which is the main purpose for using quantile regression. To address this problem, Chernozhukov and Hansen (2004, 2005, 2006) developed an IV technique that is applicable for quantile regressions (called the instrumental variable quantile regression or IVQR) and they have shown that the estimated coefficients in this approach are unbiased.[3] Note that there are only a few studies that have applied IVQR in empirical settings (see Atella et al., 2008; Wehby et al., 2009 for example).

To the best of our knowledge, there has been no study that has investigated the possible heterogeneous effects of Bt crop adoption on different points of the yield distribution, especially in the presence of self-selection (i.e., non-random selection of Bt adopters; see Shankar et al., 2008 and Crost and Shankar, 2008 for the importance of accounting for self-selection). This study aims to fill this gap in the literature and specifically determine the effect of Bt corn adoption at different points of the yield distribution. To achieve this objective, we apply the IVQR approach of Chernozhukov and Hansen (2004, 2005, 2006) to two separate farm level data sets collected from Bt and non-Bt corn farmers in the Philippines during the 2003/2004 and 2007/2008 crop years. As a robustness check, we also use the propensity score matching (PSM) to trim the data (create a subset of corn farmers) in order to control for self-selection issues and then utilize conventional quantile regression techniques with the trimmed data to determine the effects of Bt crop adoption on different point of the yield distribution.

2. Empirical setting and data description

Corn is the second most important crop in the Philippines after rice, with approximately one-third of Filipino farmers (∼1.8 million) depending on corn as their major source of livelihood. Yellow corn, which accounts for about 60% of total corn production (white corn accounts for the rest), is the corn type that is considered in this study. Corn in the Philippines is typically grown rainfed in lowland, upland, and rolling-to-hilly agro-ecological zones of the country. There are two cropping seasons per year – wet season cropping (usually from March/April to August) and dry season cropping (from November to February). Most corn farmers in the Philippines are small, semi-subsistence farmers with average farm size ranging from less than a hectare to about 4 hectares (Mendoza and Rosegrant, 1995; Gerpacio et al., 2004).

The most destructive pest in the major corn-producing regions in the Philippines is the Asian corn borer (*Ostrinia furnacalis Guenee*) (Morallo-Rejesus and Punzalan, 2002). Over the past decade or so, corn borer infestation occurred yearly (i.e., infestation is observed in at least one region yearly) with pest pressure being constant to increasing over time. Farmers report that yield losses from this pest range from 20% to 80%. Although the Asian corn borer is a major pest in the country, insecticide application has been moderate compared to other countries in Asia (e.g., China) (Gerpacio, 2004). Gerpacio et al. (2004) also report that corn farmers in major producing regions only apply insecticides when infestation is high.

With the Asian corn borer as a major insect pest for corn in the country, the agricultural sector was naturally interested in Bt corn technology as a means of control. In December 2002, after extensive field trials, the Philippine Department of Agriculture (DA) provided regulations for the commercial use of GM crops and approved the commercial distribution of Bt corn (specifically Monsanto's *Yieldgard™ 818* and *838*). In the first year of its commercial adoption, 2002, Bt corn was grown in only 1% of the total area planted with corn – on about 230,000 hectares. In 2008, about 12.8% of corn planted was Bt, and in 2009 this increased to 19%, equal to about 500,000 hectares (GMO Compass, 2010). Apart from Monsanto, Pioneer Hi-Bred (since 2003) and Syngenta (since 2005) sell Bt corn seeds in the Philippines.

The data used in this study come from two sources: (1) the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) corn surveys for crop years 2003/2004 in the Philippines and (2) the International Food Policy Research Institute (IFPRI) corn surveys for crop years 2007/2008 in the Philippines. These are two separate cross-section data sets with different samples in 2003/2004 and 2007/2008 (i.e., it is not a panel data set). Data collected in the survey included information on corn farming systems and environment, inputs and outputs, costs and revenues, marketing environment, and other factors related to Bt corn cultivation (i.e., subjective perceptions about the technology). Actual data collection was implemented through face-to-face interviews using pre-tested questionnaires.

The 2003/2004 survey considered four major yellow corn growing provinces: Isabela, Camarines Sur, Bukidnon, and South Cotabato. To arrive at the sample of Bt respondents to be surveyed, three towns and three barangays (i.e., the smallest political unit in the Philippines) within each town were initially chosen in each of the four provinces based on the density of Bt corn adopters in the area. Using a list of Bt corn farmers from local sources (i.e., local

[3] There are other "IV" type approaches applicable to quantile regressions (see, for example, Abadie et al., 2002). One of the advantage of the Chernozhukov and Hansen (2004) approach is that it is applicable to different types of endogenous/self-selected variables (i.e., binary, discrete, continuous). Most of the other approaches only apply to binary endogenous variables (i.e., quantile treatment effects).