Production Risk, Farmer Welfare and Bt Corn in the Philippines

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Outline

- Introduction and Significance
- Conceptual Framework
  - Risk Premiums & Certainty Equivalents
  - Stochastic Production Functions
    - Di Falco and Chavas (2006, 2009)
    - Extended Saha et al. (1997)
- Data and Estimation
- Results
- Conclusions and Future Work

Introduction & Significance

- Bt (*Bacillus thuringensis*) crops (e.g. cotton and corn) are now one of the most widely adopted genetically-modified (GM) crops in the world
- Single trait Bt crops controls lepidopteran pests (corn borer, cotton bollworm)
- Evidence of yield increasing and insecticide reducing effects
- Mixed evidence for risk effects
  - Risk increasing & decreasing (Shankar et al., 2007; Crost and Shankar, 2008)

Introduction & Significance

- Gaps in the literature:
  - No study on risk effects of Bt corn in a developing country context
    - Previous studies: Bt cotton in developed and developing countries; Bt corn in a US context
  - No study on downside risk effects (or skewness effect) of Bt corn
    - Previous studies: mean-variance only
    - $\uparrow$ skewness - $\downarrow$downside risk
    - Farmers with decreasing absolute risk aversion (DARA) preferences are averse to downside risk

Objective

- To determine the production risk effects of Bt corn in the Philippines
  - Effect on mean, variance, and skewness of yields
    - Stochastic production function approaches using a non-damage abatement and a damage abatement specification
  - Evaluate welfare implications of these effects using risk premium and certainty equivalent (CE) measures

Conceptual Framework

- Welfare measures based on expected utility theory:

Stochastic Production Function

$$EU(\pi) = EU[p \cdot g(x,v) - c(x)] = U[E(\pi) - R]$$

- Risk Premium (R) – willingness-to-pay for a scheme (i.e., insurance) that would eliminate the risk exposure (from v) by replacing the random net income (π) with its expected value E (π)

Conceptual Framework

- Certainty Equivalent (CE)

$$CE = E(\pi) - R = E\left[p \cdot g(x,v)\right] - c(x) - R.$$

  - Sure amount of net income that the farmer would be willing to receive that would give the same utility as the expected value of random income
  - *R* typically greater than zero to reflect risk aversion

Conceptual Framework

- We would know if farmers are "better-off" with Bt corn depending on its effect on *R* and *CE*
- From the literature, it can be shown that *R* can be approximated as follows:

$$R_a = \frac{1}{2} r_2 M_2 + \frac{1}{6} r_3 M_3$$

Where:

$$M_i = E[\pi - E(\pi)]^i$$

$$r_2 = -\left(\partial^2 U / \partial \pi^2\right) / \left(\partial U / \partial \pi\right) > 0$$

$$r_3 = -\left(\partial^3 U / \partial \pi^3\right) / \left(\partial U / \partial \pi\right) < 0$$

Conceptual Framework

- Assuming *p* is fixed and *c*(*x*) is deterministic, then effects of Bt on *R* and *CE* will depend on the moments of stochastic production function

$$\pi = p \cdot g(x,v) - c(x)$$

- Thus, key to understanding the effect of Bt on farmer welfare is to empirically estimate the effect of Bt on the moments of the stochastic production function

Conceptual Framework

- Stochastic production function estimation
- Two specifications:
  1. Di Falco and Chavas (2006, 2009)
     - Expanded Just-Pope production function (Just and Pope, 1978, 1979)
  2. Extended Saha et al. (1997)
     - Damage abatement specification that we expanded to allow for skewness effects

Conceptual Framework

- Di Falco and Chavas (2006, 2009):

$$g(x,v) = f_1(x,\beta_1) + \left[f_2(x,\beta_2) - \left[\frac{f_3(x,\beta_3)}{k}\right]^{\frac{2}{3}} \right]^{\frac{1}{2}} e_2(v) + \left[\frac{f_3(x,\beta_3)}{k}\right]^{\frac{1}{3}} e_3(v)$$

  – Based on the specification above, the mean, variance, and skewness represented by:

$$E\left[g(x,v)\right] = f_1(x,\beta_1)$$

$$E\left[\left(g(x,v) - f_1(x,\beta_1)\right)^2\right] = f_2(x,\beta_2)$$

$$E\left[\left(g(x,v) - f_1(x,\beta_1)\right)^3\right] = f_3(x,\beta_3)$$

Conceptual Framework

- Extended Saha et al. (1997):

$$y = f(x,\beta)\,h(z,\alpha,e)\exp(\varepsilon)$$

$$h(z,\alpha,e) = \exp\left[-A(z,\alpha)e\right] \longrightarrow$$ Damage abatement function

  – Under the specification above yields are log-normal:

$$\ln(y) \sim N\left[\left[\ln\left(f(x,\beta)\right) - \mu A(\cdot)\right], B(\cdot)\right]$$

$$\text{where } B(\cdot) \equiv \left[1 + A(\cdot)^2 - 2A(\cdot)\rho\right]$$

Conceptual Framework

- Log-normal distribution of yields imply the following moment conditions:

$$E(y) = f(\cdot)\times\left[\exp\left(\tfrac{B(\cdot)}{2} - \mu A(\cdot)\right)\right]$$

$$V(y) = E\left[y - E(y)\right]^2 = \left(E(y)\right)^2 \times \left[\exp\left(B(\cdot)\right) - 1\right]$$

$$S(y) = E\left[y - E(y)\right]^3 = \left(E(y)\right)^3 \times \left[\exp\left(B(\cdot)\right) + 1\right] \times \left[\exp\left(B(\cdot)\right) - 1\right]^2$$

Data

- Data from two farm-level surveys in 2003/2004 and 2007/2008 crop years
  1. ISAAA survey in Isabela, Camarines Sur, Bukidnon and South Cotabato (407 obs., 101 Bt and 306 non-Bt)
  2. IFPRI survey in Isabela and South Cotabato (466 obs, 254 Bt and 212 non-Bt
- Stratified random sampling of Bt and non-Bt growers
  – Barangays within provinces selected based on density of Bt corn growers

Estimation

- Di Falco and Chavas (2006,2009) model estimated by non-linear least squares
- Extended Saha et al. (1997) model estimated by maximum likelihood
- AIC and BIC specification tests used to determine the best-fitting functional forms

Estimation

- Empirical specification:
  - Yield (y) in tons/ha
  - Input vector (x): seed (kg/ha), insecticide use (li/ha), fertilizer (kg/ha), and labor (man-days/ha)
  - Binary Bt adoption variable
- Selection problem due to non-random selection of Bt farmers
  - Use Propensity Score Matching (PSM) techniques to get a valid “counterfactual”
  - Selection and endogeneity tests on matched sample were undertaken

Results

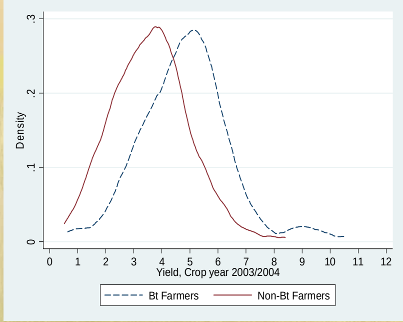
- Descriptive Statistics

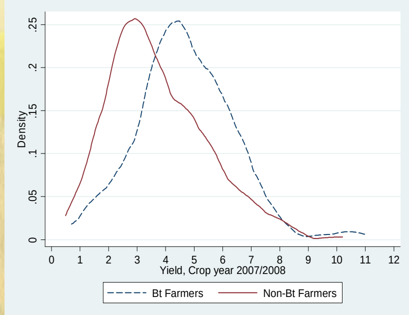
Table 2.1. Summary Statistics for the Full Data Set in 2003/2004 and 2007/2008.

Variable	--- Crop Year 2003/2004 ---				--- Crop Year 2007/2008 ---			
	Bt (n=101)		Non-Bt (n=306)		Bt (n=254)		Non-Bt (n=212)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Yield (tons/ha)	4.85	0.16	3.60	0.08	4.68	0.11	3.73	0.12
Seed (kg/ha)	19.13	0.50	18.43	0.24	18.35	0.24	19.42	0.36
Insecticide (li/ha)	0.26	0.05	0.77	0.10	0.25	0.05	0.99	0.12
Fertilizer (kg/ha)	452.02	17.98	400.65	9.84	475.13	13.00	391.60	10.65
Labor (man-days/ha)	54.19	2.51	56.64	1.92	53.94	1.89	49.80	1.57

Results

- Kernel density estimates of yield distribution

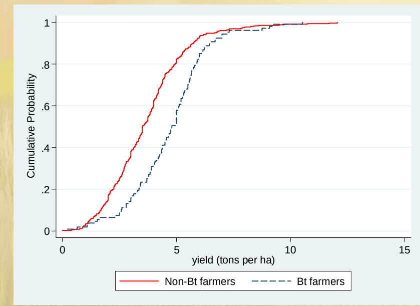




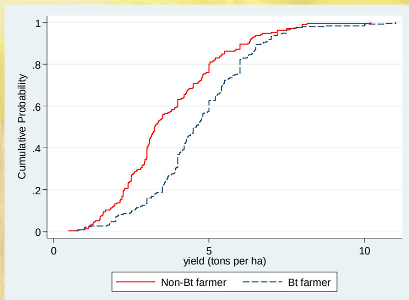
Results

- Stochastic Dominance Techniques
  - Non-parametric technique for comparing risky alternatives; direct comparison of distributions
  - First-degree stochastic dominance: CDF of Bt to the right of non-Bt, then Bt preferred
    - If CDFs cross, cannot rank; use second degree
  - Second-degree stochastic dominance: area under CDF of Bt is less than non-Bt, then Bt preferred

Results



2003/2004



2007/2008

- Bt corn technology second-order stochastically dominates non-Bt technology

Results

- Limitation of stochastic dominance – do not control for other observables factors that affects outcomes (e.g., inputs)
- Stochastic production function approach allow for control of inputs
- PSM used to address selection issues and control for other non-input variables that affects outcome
  - Matched data for 2003/2004: 91 Bt and non-Bt obs
  - Matched data for 2007/2008: 147 Bt and non-Bt obs

Results

- PSM First-stage Logit Results

Table 2. First Stage Logit Results for the PSM Approach.

Crop Year/Variable	Parameter Estimate	P-value
A. Crop Year 2003/2004 (Bt: n= 101; Non-Bt: n=303)		
Farming experience	-0.016	0.223
Education	0.170	0.000
Planted corn area	0.041	0.280
Training	0.366	0.186
Electricity	0.593	0.209
Borrow	-0.142	0.637
Topography	0.765	0.028
Extension	0.346	0.227
Bukidnon	1.194	0.140
Socsargen	2.142	0.006
Isabela	3.915	0.000
Intercept	-6.129	0.000
Log-Likelihood		-174.110
Pseudo-R-squared		0.217

Table 2. First Stage Logit Results for the PSM Approach.

Crop Year/Variable	Parameter Estimate	P-value
B. Crop Year 2007/2009 (Bt: n= 254; Non-Bt: n=212)		
Farming experience	0.013	0.135
Education	0.008	0.591
Household size	-0.041	0.534
Distance to seed supplier	0.028	0.049
Training	0.776	0.002
Government seed source	2.664	0.000
Company seed source	0.214	0.442
Cooperative seed source	0.304	0.430
Borrow	0.059	0.821
Isabela	1.557	0.000
Intercept	-1.562	0.004
Log-Likelihood		-276.485
Pseudo-R-squared		0.120

Results

- Unmatched vs. Matched Data

Table 2.4. PSM Results: Equality of Means for the Unmatched and Matched Data.

Observable Variables	Unmatched Data			Matched Data		
	Bt	Non-Bt	p-value of difference	Bt	Non-Bt	p-value of difference
A. Crop Year 2003/2004						
Farming experience	15.05	16.68	0.20	14.97	14.08	0.53
Education	9.81	7.95	<0.01	9.71	9.77	0.91
Planted corn area	2.42	1.93	0.18	2.40	2.17	0.69
Training	0.48	0.42	0.29	0.47	0.45	0.77
Electricity	0.93	0.83	0.02	0.92	0.90	0.60
Borrow	0.56	0.48	0.15	0.56	0.52	0.55
Topography	0.65	0.59	0.28	0.64	0.67	0.64
Extension	0.61	0.64	0.56	0.61	0.60	0.88
Bukidnon	0.13	0.35	<0.01	0.14	0.11	0.51
Socsargen	0.37	0.31	0.26	0.38	0.46	0.30
Isabela	0.48	0.17	<0.01	0.45	0.43	0.77
B. Crop Year 2007/2008						
Farming experience	17.88	16.00	0.09	16.07	17.47	0.30
Education	7.62	8.21	0.38	8.09	8.12	0.96
Household size	4.43	4.62	0.21	4.66	4.59	0.71
Distance to seed supplier	7.59	3.58	<0.01	3.67	4.31	0.35
Training	0.36	0.33	0.41	0.31	0.35	0.39
Government seed source	0.06	0.01	0.02	0.01	0.02	0.31
Company seed source	0.62	0.69	0.10	0.65	0.67	0.71
Cooperative seed source	0.12	0.09	0.33	0.12	0.12	1.00
Borrow	0.74	0.67	0.09	0.72	0.69	0.61
Isabela	0.73	0.44	<0.01	0.63	0.61	0.72

Results

- Di Falco and Chavas (2006, 2009) parameter estimates:

Table 2.5. Parameter estimates for the Di Falco and Chavas (2006, 2009) stochastic production function: Bt corn.

Equation/Variable	Crop Year 2003/2004		Crop Year 2007/2008	
	Estimate	p-value	Estimate	p-value
A. Mean function				
Constant	1.830	0.03	0.694	0.01
Seed	0.114	0.31	-0.097	0.34
Insecticide	0.016	0.04	-0.006	0.39
Fertilizer	0.156	0.02	0.220	<0.01
Labor	-0.112	0.04	0.186	<0.01
Bt	0.216	<0.01	0.080	0.08
B. Variance function				
Constant	7.531	0.78	0.230	0.53
Seed	-0.841	0.49	0.193	0.62
Insecticide	-0.045	0.17	0.016	0.46
Fertilizer	-0.033	0.89	0.367	0.15
Labor	0.323	0.44	-0.110	0.46
Bt	-0.070	0.80	-0.210	0.20
C. Skewness function				
Constant	-6.211	0.39	-0.094	0.97
Seed	0.191	0.65	0.096	0.51
Insecticide	0.067	0.87	-0.363	0.46
Fertilizer	0.012	0.18	-0.003	0.51
Labor	-0.017	0.83	0.020	0.44
Bt	-0.558	0.83	-1.104	0.38

Results

- Extended Saha et al. (1997) parameter estimates:

Table 2.6. Parameter estimates for the extended Saha et al. (1997) stochastic production function: Bt corn.

Parameter	Crop Year 2003/2004		Crop Year 2007/2008	
	Estimate	p-value	Estimate	p-value
Constant	13.140	0.08	1.416	0.83
Seed	0.118	0.42	-0.089	0.45
Fertilizer	0.104	0.04	0.296	<0.01
Labor	-0.130	0.08	0.234	<0.01
Insecticide	-0.013	0.30	0.007	0.40
Bt	-0.132	0.21	-0.066	0.36
ρ	0.919	<0.01	0.922	<0.01
μ	1.637	0.25	1.475	0.32

Results

- Marginal Effects of Bt

Table 2.7. Estimated mean, variance, and skewness effects of Bt corn

	Mean effect $(E(y)\|_{Bt}-E(y)\|_{Non\text{-}Bt})$	Variance effect $(V(y)\|_{Bt}-V(y)\|_{Non\text{-}Bt})$	Skewness effect $(S(y)\|_{Bt}-S(y)\|_{Non\text{-}Bt})$
A. Parameters from Di Falco and Chavas (2006,2009)			
Bt (2003/2004)	1.009	-0.131	-0.558
	(<0.01)	(0.80)	(0.83)
Bt (2007/2008)	0.346	-0.466	-1.104
	(0.08)	(0.19)	(0.38)
B. Parameters from extended Saha et al. (1997)			
Bt (2003/2004)	0.958	1.417	5.364
	(<0.01)	(0.02)	(0.05)
Bt (2007/2008)	0.397	0.446	1.360
	(0.07)	(0.15)	(0.20)

Note: Values in parentheses are the p-values

Results

- Risk Premium and Certainty Equivalent Estimates:

Table 2.8.Welfare effects of Bt corn: variance effect on risk premium, skewness effect on risk premium, total risk premium (*R*), and certainty equivalent (CE)

Model/Technology	--- Crop Year 2003/2004 ---				--- Crop Year 2007/2008 ---			
	Variance Part of R	Skewness Part of R	*R*	CE	Variance Part R	Skewness Part of R	*R*	CE
A. Parameters from Di Falco and Chavas (2006,2009)								
Non-Bt	3,914.14	-835.91	3,078.23	13,100	6,733.35	-917.87	5,815.47	11,834
Bt	3,084.29	-406.07	2,678.25	20,124	5,309.71	-97.01	5,212.70	13,490
p-value for equality in CE				(<0.01)				(0.47)
B. Parameters from extended Saha et al. (1997)								
Non-Bt	6,495.81	-3,621.13	2,874.68	14,563	7,907.70	-4,708.96	3,198.74	14,258
Bt	7,956.80	-4,437.46	3,519.34	20,098	8,767.49	-5,271.90	3,495.59	15,533
p-value for equality in CE				(0.04)				(0.55)

Results

- Simulated probability of profit loss for Di Falco and Chavas (2006, 2009) model:

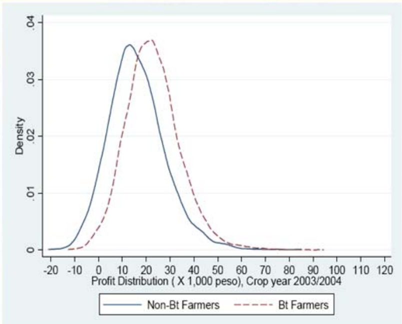


Figure 2.3 A

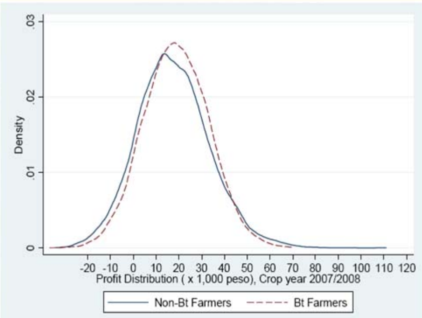


Figure 2.3 B

Results

- Simulated probability of profit loss extended Saha et al. (1997) model

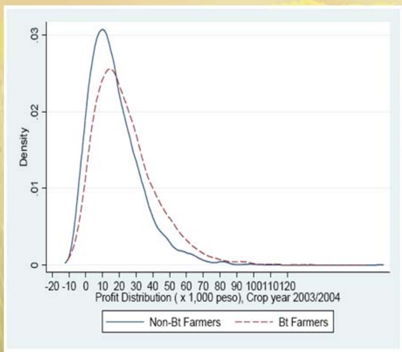


Figure 2.4 A

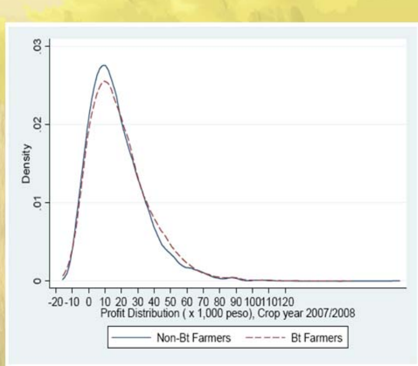


Figure 2.4 B

Conclusions

- Bt corn has a strong statistically significant mean yield increasing effect
- Generally, no statistically significant variance and skewness effects
  - No overwhelming evidence to suggest that Bt corn reduces production risk
  - Consistent with US studies where risk reduction effects only found for “triple-stack” Bt corn that also control for corn rootworm

Conclusions

- Exception: Statistically significant variance and skewness increasing effect for 2003/2004 extended Saha et al. (1997) model
  - Counterfactual includes traditional varieties rather than just hybrids
  - Some evidence of downside risk reduction

Conclusions

- CE welfare measures still suggests Bt corn farmers are better off
  - Dominant mean increasing effects
- Simulated profit distributions provide some evidence on the lower probability of loss for Bt corn
  - Exception: extended Saha et al. (1997) model for 2007/2008 where there is no significant different in probability of loss for Bt and non-Bt farmers

Future work

- Use/collect panel data
  - Pseudo-panel techniques?
- Study multi-trait Bt corn (i.e. triple stacks or more)
- Use of lower partial moment (LPM) techniques (See Antle, 2010)

Thank You!

Questions, comments, and suggestions are welcome!