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Drivers of Heterogeneity in Yield Gains from GM Maize in the Philippines: Evidence from Panel Data

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Introduction and Motivations

- In developing countries, human capital is typically key to promote both adoption (1) and realization of benefits of new, potentially more complex agricultural technology (2).
- However, genetically modified (GM) seed traits contribute to modest mean yield gains in developed countries such as the United States (3), though much larger yield effects are found in developing countries where pesticide use is low or sporadic (4).
- With novel GM traits in maize providing insecticidal *Bacillus thuringiensis* (Bt) toxin expression and glyphosate herbicide tolerance, the 'new technology' is actually *simplifying* rather than more complex.
- Thus, **GM maize traits may act as a substitute for human capital, leading to greater yield gains among producers with less knowledge about pest management.** We test this hypothesis with panel data, using a damage abatement production function specification and controlling for potential endogeneity.

Survey Context

- We draw on data from two waves of yellow maize producer surveys conducted by IFPRI in the 2006/2007 and 2010/2011 growing seasons.
- The two surveys provide a panel of 235 producers in the South Cotabato province of the southern island Mindanao and Isabela province on the northern island of Luzon.
- These zones represent the vast majority of the country's maize growing regions and hot-zones of early GM maize adoption.
- All farmers grow hybrid conventional or hybrid GM maize, allowing for an isolation of effects of inserted traits.
- Farmers are mostly smallholders with main plots between 0.1-5.0 hectares.
- In the Philippines, there is a 250% increase in GM planted acres between waves.

Sample Farmers (n=256)	2007		2011	
Variable	mean	median	mean	median
Yield (main plot, kg/ha)	3,999	3,750	5,941	5,600
Yield GM seed (main plot, kg/ha)	4,427	4,286	6,035	5,714
Yield Hybrid Seed (main plot, kg/ha)	3,445	3,080	5,390	4,900
Hybrid seed planters (main plot, %)	0.44	-	0.15	-
GM seed planters (main plot, %)	0.56	-	0.85	-
Insecticide applied (kg/ha)	0.44	-	0.18	-
Insecticide Use (%)	0.37	-	0.09	-
Herbicide applied (kg/ha)	1.03	0.50	2.87	2.00
Main maize plot size (ha)	1.31	1.00	1.26	1.00
Years Farming Maize (#)	16.36	15.00	19.80	18.00
Years of Education (#)	7.60	6.00	7.60	6.00
Received Extension Information (1-y,0-n)	0.51	1.00	0.39	-

Econometric Approach

- We use a first-differenced logistic damage-abatement production function specification, most suitable for trait properties of Bt and herbicide tolerance (5).
- Years of education, farming experience, and extension pest training are plausible and tested proxies for pest control knowledge, based on recent empirical findings (6). The key variables are interaction terms between an indicator for GM maize planting and knowledge proxies. We include plot size to compare to previous work on GM yield heterogeneity in 'small' vs. 'large' farms (4).
- To account for additional sources of endogeneity such as time-varying pest pressure and non-static GM maize seed availability, we also test an instrumental variables (IV) approach with the control function (CF) method. We use seed cost as an instrument for GM adoption, with the probit regression residual included in the non-linear yield model along with exogenous controls $\boldsymbol{X}_{it}$.
- The CF method, rather than a simple IV approach, is necessary as IVs cannot be used as interaction terms.

Step 1: GM adoption (Probit)

$$GM_{it} = f(SP_{it}, \boldsymbol{X}_{it})$$

where GM_{it} is a binary indicator for GM variety adoption, SP_{it} is the price of seed and **X** is a vector of controls and other inputs.

Step 2: FD Yield Regression (NL-LS)

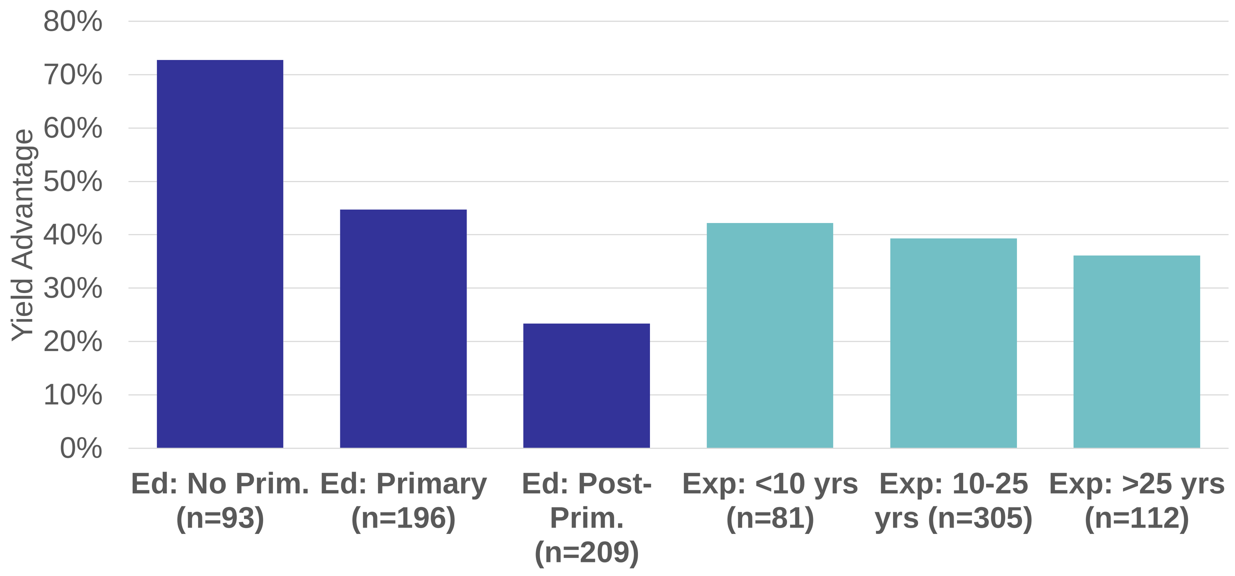
$$\Delta lnY_i = \Delta ln\boldsymbol{X}_{1i}\beta + \Delta resGMhat_i\zeta - ln(1 + \exp(-\Delta\boldsymbol{X}_{2i}\varphi - \Delta GM_i\lambda - \Delta(GM_i * \boldsymbol{K}_i)\xi)$$

where the independent variable is log yield, $\boldsymbol{X}_1$ is a vector of yield enhancing inputs such as fertilizer, labor, and seed density as well as plot size, topography, and expected corn borer intensity, $\boldsymbol{X}_2$ is a vector of damage abating inputs insecticide and herbicide, $\boldsymbol{K}$ is a vector of human capital measures including education, experience, and training, and *resGMhat* is the predicted residual from the adoption regression. Both sets of **X** controls are included in the previous adoption regression.

Who gets the greatest yield bump from GM maize?

- Descriptive results point to variation in yield gains from GM varieties, especially across education levels.
- N-L least squares regression results employing the CF confirm remaining endogeneity concerns via significance of the adoption residual.
- **For every year *increase* in formal education, the yield gain from GM maize *decreases* by about 5%.**
- **For every year *increase* in maize farming experience, the yield gain from GM *decreases* by about 1.2%.**
- Neither knowledge through extension training nor plot size appears to affect yield gains from GM adoption.

Unconditional Avg. Yield Advantage of GM vs. Hybrid Varieties by Educ. and Farm Experience (pooled waves)



Dep. Variable Log Yield (kg/ha)	CF without interactions		CF + Ed. & Exp. Interactions		CF + Full Interactions		CF + Only Plot Size Interaction		No CF + Full Interactions	
	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat
CF Residual	-0.425*	(-2.36)	-0.419*	(-2.32)	-0.433*	(-2.36)	-0.434*	(-2.38)		
Low CB Expect. (=1)	0.032	(0.42)	0.009	(0.11)	-0.002	(-0.02)	0.027	(0.35)	0.064	(0.87)
Log Plot Size (ha)	-0.114+	(-1.76)	-0.136*	(-2.11)	-0.176*	(-2.01)	-0.136	(-1.55)	-0.156+	(-1.76)
Flat Plot (=1)	0.159*	(2.25)	0.150*	(2.14)	0.152*	(2.14)	0.160*	(2.26)	0.145*	(2.03)
Log Seed kg/ha	0.322**	(3.50)	0.304**	(3.34)	0.309**	(3.37)	0.325**	(3.51)	0.254**	(2.83)
Log Fertilizer/ha	-0.011	(-0.20)	-0.0007	(-0.01)	0.002	(0.03)	-0.009	(-0.17)	0.014	(0.25)
Log Labor Days/ha	0.147**	(4.19)	0.157**	(4.51)	0.154**	(4.36)	0.145**	(4.11)	0.144**	(4.08)
Insecticide/ha	-0.053	(-1.01)	-0.043	(-0.83)	-0.047	(-0.89)	-0.054	(-1.04)	-0.082	(-1.59)
Herbicide/ha	-0.022+	(-1.73)	-0.023+	(-1.80)	-0.024	(-1.89)	-0.023+	(-1.77)	-0.019	(-1.51)
GM Seed (=1)	**0.312***	**(2.09)**	**0.882****	**(3.50)**	**0.852****	**(3.30)**	**0.285+**	**(1.73)**	**0.574***	**(2.47)**
GM Seed x Yrs. Education			**-0.050***	**(-2.34)**	**-0.052***	**(-2.38)**			**-0.046***	**(-2.13)**
GM Seed x Yrs. Farm Exper.			**-0.012+**	**(-1.87)**	**-0.012+**	**(-1.92)**			**-0.014***	**(-2.24)**
GM Seed x Ext. Train (=1)					**-0.001**	**(-0.14)**			**-0.021**	**(-0.31)**
GMseed x Plot Size (ha)					**0.060**	**(0.69)**	**0.033**	**(0.38)**	**0.033**	**(0.38)**
N	235		235		235		235		235	
Adj. R^2	0.162		0.183		0.178		0.158		0.161	

t statistics in parentheses; + $p<0.10$, * $p < 0.05$, ** $p < 0.01$

Conclusions

- Results indicate that, unlike many 'complexity increasing' new technologies, Bt and herbicide tolerance traits in GM maize simplify farm management and deliver the largest production gains for those with the lowest human capital (and very likely less pest management knowledge).
- Farmers with more education and experience were likely already more adept at controlling pests and weeds, thus the potential for yield increases through Bt and herbicide tolerance traits was lower. These farmers with greater human capital likely benefited most from production cost savings, though we do not directly explore this here.
- Simply separating farmers into 'large' and 'small' land area categories would not provide insight into yield gain heterogeneity in the Filipino context. Modeling directly with the best available proxies for the underlying mechanism of pest management knowledge provides much more sound results.
- **Our results suggest GM maize could potentially raise yields the most for those with the lowest human capital – an important consideration for agricultural development.**
- Further research is needed to directly compare results with farmers growing traditional varieties, in order to anticipate the net effects of increasing complexity through hybrid production and decreasing complexity through traits for Bt and herbicide tolerance.

References and Acknowledgements

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