Field Trials as an Extension Technique: The Case of Swaziland

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One potentially serious problem in evaluating the effectiveness of extension programs is that participants are not picked at random. Self-selection can be a problem, and it can be compounded if extension officials concentrate on the most progressive farms. This study explores the relationships between adoption of maize high-yielding varieties (HYVs) and participation in field trials intended to foster HYV usage, drawing on data from Swaziland. Results indicate that it is impossible to say if field trials had any effect on adoption. Participating farms used more HYVs, but this could have been due to self-selection or the government's selection process.

Field trials are a potentially powerful communication tool. In the adoption and diffusion of any new innovation within agriculture, some farmers have to take the lead and show others that the innovation is profitable. By subsidizing inputs or providing technical assistance, field trials can potentially encourage some farmers to become early adopters. Other farmers can then observe and learn from those participating in the field trials.

One potentially serious problem with field trials and other extension techniques is that participants are generally not picked at random (Birkhaeuser, Evenson, and Feder). Self-selection can clearly be a problem: those most willing to participate may be the most progressive and the most likely to adopt the new innovation anyway. A related problem is that public authorities may concentrate their efforts on the most progressive farmers. For understandable reasons, public officials usually want their projects to succeed, and this can lead them to pick "winners," people who would have been early adopters anyway.

When participants in field trials or other extension programs are not picked at random, it becomes difficult to evaluate the effectiveness of these programs. Simple participant-nonparticipant or before-and-after comparisons will not do. Simple regression techniques in which extension is treated as exogenous will also be flawed, yielding estimates of extension impact on farm performance that are biased upward. More subtle empirical techniques have to be used to separate the impact of the extension program from other forces.

The objective of this paper is to explore the usefulness of field trials as an extension technique within the context of the kingdom of Swaziland, a country in southern Africa. Field trials were conducted during 1987–88 to demonstrate new maize production techniques. The principal new techniques were high-yielding maize varieties (HYVs) and fertilizer. Farms in the field trials received subsidized HYV seeds, fertilizer, and agricultural chemicals in exchange for completely adhering to a prespecified set of production practices. The field trials were part of a larger Cropping Systems project designed to aid small Swazi Nation Land (SNL) farmers, who were neglected in favor of large commercial farms during the British colonial period (see the project's 1987–88 *Annual Report*). A related objective of this article is to explore the determinants of the field trial selection process. What induced Swazi agricultural officials to choose some farms and not others?

Swaziland is one of the smallest countries in Africa, with an area of 17,000 square kilometers and 750,000 people.[1] Per capita income in 1988 was about $800, while life expectancy was 56 years. The country is landlocked, surrounded by Mozambique in the east and South Africa on all other sides. Swaziland is divided into five agrocli-

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[1] The descriptive material for Swaziland comes from a variety of sources, including Davies, O'Meara, and Dlamini; Stokes et al.; East African Technical Services; and Booth.

matic regions: Highveld, Middleveld, Cool Middleveld, Lowveld, and the Lebombo Plateau. The Highveld is characterized by a mountainous landscape; only 10% of the land is suitable for crops. Many crops are grown in the Middleveld, Cool Middleveld, and Lebombo, including maize, fruits, cotton, tobacco, and rice. The Lowveld is well suited for tobacco, cotton, sugar cane, and other large-scale commercial crops.

Private holdings, referred to as title deed land (TDL), comprise 40% of total cropland. TDL consists mostly of large commercial estates devoted to sugar cane, cotton, pineapple, citrus, pulpwood, tobacco, and other export crops. Swazi Nation Land (SNL) comprises the remaining 60% of cropland. SNL, which is held in trust by the king for the Swazi nation, is allocated to farm families by local chiefs. Area is allocated primarily on the basis of family size. Once a homestead is allocated land, it has use rights but not ownership rights.

SNL farms devote most of their land to maize, Swaziland's staple food. Nearly all maize is produced under rain-fed conditions. Aside from land preparation and plowing, women do the bulk of maize production work. Maize is typically planted in October–December and harvested in April–June. Marketed surpluses of maize and other crops from SNL farms are generally very small or zero. SNL farms obtain nearly all their cash income from off-farm work. About 80% of rural homesteads have at least one family member working off the farm, and about 75% of those working off the farm are men.

The Model

This section lays out a simple model of the interactions between field trials and the adoption of new production techniques. The large and growing literature on the adoption of agricultural innovations in developing countries is reviewed by Feder, Just, and Zilberman. Key variables affecting adoption that have been identified in the literature include farm size, risk and uncertainty, human capital, labor availability (for labor-using innovations), credit availability and cost, prices and availability of other inputs, and land tenure. Within this context, a field trial might have two effects on adoption. First, the subsidized seeds, fertilizers, and chemicals might encourage adoption. Second, information provided to a participating farm by agricultural officials might reduce the farm's subjective risk of trying an unproven technique.

The literature on the determinants of participation in field trials or other extension programs is very sparse (Birkhaeuser et al.). Clearly, though, the participation decision is a joint one between the government and the farmer. Government officials (that is, extension officers) choose the farms eligible to participate in field trials. Once eligible, a farm needs to agree to participate. As Birkhaeuser et al. emphasize, a farm's propensity to adopt new techniques might affect either part of the participation decision. More productive farmers might be more inclined to seek out extension information. Similarly, extension officers might seek out farmers who would be good performers even without any extension contacts.

Farms either participate in the field trials or they do not. This suggests a probit specification when modeling the determinants of field trial participation. With this specification, the probability of participating in a field trial depends on a theoretical (but not actually measured) index that in turn depends on exogenous variables. The probability of participation increases as the index increases. On the other hand, the level of adoption of new techniques may range from zero to a very high level. This suggests a tobit model for adoption. With this specification, adoption is a function of an unmeasured, theoretical index that in turn is a function of exogenous variables. For a nonadopting farmer, the probability of adoption increases as the index increases. For an adopting farmer, the level of adoption is an increasing function of the index. Given the potentially simultaneous nature of the participation and adoption decisions, we permit the participation index to influence the adoption index and vice versa.

Let z_{1t} denote the participation index and let z_{2t} denote the adoption index. We assume that

$$(1) \qquad z_{1t} = \alpha_1 z_{2t} + \beta_1' x_{1t},$$

$$(2) \qquad z_{2t} = \alpha_2 z_{1t} + \beta_2' x_{2t}.$$

Equation (1) expresses the field trial participation index as a function of the adoption index and a vector x_{1t} of exogenous variables. Equation (2) expresses the adoption index as a function of the participation index and a vector x_{2t} of exogenous variables. α_1 and α_2 are coefficients, while β_1 and β_2 are coefficient vectors.

Let $y_{1t} = 1$ if the farm actually participates in the field trials, with $y_{1t} = 0$ if the farm does not participate. We assume that

$$(3) \qquad y_{1t} = \begin{cases} 0, & z_{1t} + e_{1t} \le 0, \\ 1, & z_{1t} + e_{1t} > 0. \end{cases}$$

Since we assume a probit specification for field trial participation, e_{1t} is a normally distributed ran-

Table 1. Summary Statistics

Variable	Subsample: Not Asked to Be in Field Trial	Asked but Said No	Asked and Said Yes	Whole Sample
Maize HYVs (kg seed/ha)	17	11	20	18
	(14)	(9)	(13)	(13)
Total area (ha)	1.4	2.3	2.3	1.9
	(1.2)	(1.7)	(1.7)	(1.6)
Cattle owned	6.9	19	11	9.7
	(6.5)	(21)	(9.4)	(11)
Head male & on farm	0.40	0.38	0.41	0.40
(no = 0, yes = 1)	(0.49)	(0.51)	(0.50)	(0.49)
Head education (years)	5.3	4.2	5.1	5.1
	(4.0)	(4.2)	(4.5)	(4.2)
Distance to market (km)	88	106	77	85
	(36)	(22)	(36)	(36)
Average rain/year (mm)	885	910	871	882
	(212)	(125)	(163)	(185)
Regional dummies:				
Highveld	0.36	0.08	0.33	0.32
	(0.48)	(0.28)	(0.48)	(0.47)
Middleveld	0.34	0.08	0.63	0.43
	(0.48)	(0.28)	(0.49)	(0.50)
Sample size	67	13	56	136

Note: Means are opposite the variable names, while standard deviations are in parentheses.

dom error with zero mean and unit variance. Let $y_{2t} \geq 0$ denote the actual level of adoption of the new techniques. We assume that

$$(4) \qquad y_{2t} = \begin{cases} 0, & z_{2t} + e_{2t} \leq 0, \\ z_{2t} + e_{2t}, & z_{2t} + e_{2t} > 0. \end{cases}$$

Since we assume a tobit specification for adoption, e_{2t} is a normally distributed random error with zero mean and variance σ^2. We assume that e_{1t} and e_{2t} are independent of each other.[2] Equations (1)–(4) constitute a simultaneous probit-tobit model (see Maddala).

Attention here centers on α_1 and α_2. If $\alpha_1 > 0$, then farmers who are more likely to adopt new techniques are also more likely to be in the field trials (the "picking winners" case). If $\alpha_1 < 0$, which is possible, then field trials help offset other factors working against adoption of new techniques. If $\alpha_1 = 0$, there is no effect. If $\alpha_2 > 0$, then field trials have an independent, positive influence on adoption. If $\alpha_2 = 0$, there is no effect. In this case, any association between field trials and adoption is due to the impact of the latter on the former. We would not expect to find $\alpha_2 < 0$, since in this case field trials actually reduce adoption.

[2] The likelihood function proved to be very ill-conditioned when a nonzero correlation coefficient was permitted between e_{1t} and e_{2t}, and the model could not be estimated.

Data and Variables

A field survey of 200 maize-growing Swazi Nation Land farmers was conducted in 1988. All the farmers were in the Highveld, Middleveld, or Cool Middleveld regions. Incomplete questionnaires and extreme outliers reduced the sample size to 136. Summary statistics are shown in Table 1.

When the Cropping Systems project started in 1982, Swaziland was beginning to define so-called Rural Development Areas (RDAs). The 1987–88 field trials were limited to RDAs covered in a baseline survey performed at the beginning of the project. Within these RDAs, field-based extension personnel had the job of picking farms for the field trials. The extension officers were largely left to their own discretion. From what we have been told, they favored farms that, on the basis of prior formal and informal surveys, were willing to participate in the field trials and had good farming skills. However, those involved with the project insist that the selection process was not entirely arbitrary, either. Of the 200 farms in our original sample, half had been asked to be in the field trials and half had not. The latter half came partly from

RDAs in the baseline survey and partly from other RDAs.

As Table 1 indicates, 56 of the 69 farmers in the sample of 136 who were asked to participate in the field trials said yes. Judging from their use of high-yielding maize varieties, the 13 nonparticipants are distinct from both the participants and those not asked to participate. They should not be lumped together with either of these other two groups, and yet there are too few of them to create a third group. In earlier analyses, we tried a sequential response model (Maddala), in which being asked to participate in a field trial and actually participating were two distinct endogenous variables. In this model, a farm's decision whether to participate was conditional on the government's decision whether to ask the farm to be in the field trials. Because there were only 13 observations distinguishing these two endogenous variables, however, we were not able to estimate the sequential response model.[3] Consequently, the 13 farms were dropped from the sample, reducing the sample size to 123. For our purposes, then, being asked to participate in a field trial and actually participating are synonymous.

Farmers were surveyed regarding the characteristics of their family, their farm characteristics, their use of cash inputs, their sources of agricultural information, agricultural credit, and off-farm income. In particular, they were asked about their use of maize HYVs, basal fertilizer (fertilizer banded below the seed at planting time), top-dressing fertilizer, and other new techniques. We focus on HYVs because they are the key to this package of new techniques. About 89% of farmers in the sample used HYVs during 1987–88. About the same percentage also used basal fertilizer. However, only about 21% used top-dressing fertilizer.

HYVs are measured as the log of 1 plus kilograms of HYV seeds per hectare of maize. Log transformations here and on other variables mitigate against outliers. A linear version of the model was also tried, with results qualitatively similar to those shown below.

Exogenous variables in the field trial equation (1) include the log of the farm's total area, the log of 1 plus the number of cattle owned by the farm, a dummy equal to 1 if the farm household head is male and lives on the farm but zero otherwise, the log of 1 plus the number of years of education for the household head, and dummies for the Highveld and Middleveld regions. For Swazi farmers, area and cattle are the two principal measures of social status and may have a bearing on decisions made by local extension personnel. Some critics of the Cropping Systems project claimed that, for cultural reasons, field trials workshops were geared toward men rather than women. If true, the workshop information may not have reached farms headed by females and may not have been used if the head was male but living off the farm.[4] The null hypothesis is that project areas are chosen so as to encompass farms with more land, more cattle, or male household heads living on the farm. The effect of education on field trial participation is uncertain. On the one hand, the more educated may feel less need to rely on the government for information (Birkhaeuser et al.). On the other hand, extension officials might be more likely to seek out the well educated for the field trials. The regional dummies capture differences across regions in other relevant socioeconomic factors.

Exogenous variables in the technology-adoption equation (2) include the log of the farm's total area, the log of 1 plus the number of years of education for the household head, the log of the distance to Swaziland's central output market,[5] the log of average rainfall at the nearest reporting station over the past 30 years, and dummies for the Highveld and Middleveld regions. In accordance with prior research, HYV use per hectare is expected to be a decreasing function of farm size and an increasing function of education (Feder et al.). Farmers who are farther away from output and input markets are expected to user smaller amounts of HYVs since transportation costs for fertilizer and any additional marketed surplus of maize are greater. The yield advantage of HYVs over traditional varieties is reduced under moisture stress, so that rainfall is expected to have a positive impact on adoption. The regional dummies capture any other systematic differences across regions in socioeconomic or agroclimatic factors.

Many other variables could be included in the field trial equation or the technology-adoption equation. Some were tried in estimation but then excluded because of their lack of statistical signif-

[3] The Hessian for this model was not negative definite at the apparent maximum of the likelihood function.

[4] Technically, a female cannot head a Swazi homestead, since the local chief will refuse to allocate any land. However, females circumvent this by designating a son or other male relative as the titular head.

[5] Distance is a weighted sum of road lengths and is measured in kilometers (km) of main (tar) road. Each km of secondary road is counted as 2 km of main road, while each km of motorable track is counted as 4 km of main road. Swaziland's central output market is located in Manzini, the site of the Swazi Milling Company. There are many informal local markets, but it was impossible to get good information on them.

icance, their questionable relevance, and the small sample size. Others were excluded because of either the nature of Swaziland or the survey. For example, one might expect HYV adoption to be a function of fertilizer and maize prices. However, owing to the small size of the country, government policy, and Swazi custom, prices FOB of the store in any given year are predetermined and uniform throughout Swaziland.[6] CIF prices vary because of transportation costs, which are captured by the distance-to-market variable. One might also expect HYV adoption to be a function of field trial participation in prior years as well as the current year. However, the farmers in our sample were not asked about prior participation.

Results and Discussion

The simultaneous probit-tobit model is estimated by maximum likelihood, and the results are shown in Table 2. For comparison, the single-equation tobit estimate of the HYV equation is also shown. For this estimate, the field trial dummy variable (y_{1t}) is substituted for its index (z_{1t}) in the HYV equation. The fit of the field trial equation is fair and the fit of the HYV equation is poor. However, household models rarely achieve a very good fit to the data.

The single-equation model for HYVs makes it clear that field trials and HYVs are associated. However, judging from the simultaneous-equation results, it is not possible to determine the direction of causation. Either farmers more likely to use HYVs are more likely to be chosen for field trials, or field trials are succeeding in boosting use of HYVs, or both are true. We cannot conclude that field trials were ineffective, but we cannot conclude that they succeeded either. As a further check on causality, we estimated two restricted versions of the simultaneous model: one with $\alpha_1 = 0$, and the other with $\alpha_2 = 0$. The results, which are omitted to save space, indicate that neither model fits the data any poorer than the unrestricted model in Table 2. Since neither restriction can be rejected, causality might once again be running in either direction. The bottom line is that we cannot say that field trials had any effect at all on HYV adoption, much less the magnitude of that effect.

Table 2. Maximum-Likelihood Results

	Simultaneous-Equation Model		Single-Equation Model
Variable	Field Trials	HYVs	HYVs
HYVs	0.44		
	(0.7)		
Field trials		0.41	0.65*
		(0.8)	(2.6)
Area	0.71*	−0.36	−0.20
	(3.0)	(0.8)	(1.2)
Cattle	0.18		
	(1.2)		
Head male & on farm	−0.25		
	(1.0)		
Head education	−0.04	0.04	0.04
	(0.3)	(0.3)	(0.4)
Distance to market		−0.37	−0.43*
		(1.3)	(1.9)
Rain		0.10	0.36
		(0.2)	(0.7)
Highveld	1.41*	−0.76	−0.47
	(2.9)	(1.0)	(1.4)
Middleveld	1.55*	−0.72	−0.42
	(3.1)	(0.8)	(1.1)
Intercept	−2.94*	4.23	2.01
	(1.8)	(1.5)	(0.6)
Predicted vs. actual r^2	.28	.05	.09

Note: Absolute values of asymptotic t-ratios are in parentheses. An * denotes significance at the 10% level.

The results show that farms with more land are more likely to be in field trials, presumably reflecting their greater social status. Swazi agricultural personnel claim that large farms were not deliberately targeted. However, they acknowledge that small farms, who were perceived as reluctant to innovate, were excluded in favor of medium-sized farms. To capture possible nonlinearities between farm size and propensity to participate in field trials, we tried including the square of farm size in the field trial equation. It was not statistically significant.

Contrary to the critics of the Cropping Systems project, field trial participation is not positively influenced by having a male household head on the farm. In estimating a single-equation probit model for field trials, homesteads were also broken into four groups, depending on whether the head was female/male and on/off the farm. The results indicated that, relative to the male/on-farm group, all three other groups were more likely to be in a field trial. Unfortunately, the simultaneous model could not be estimated with this four-group classifica-

[6] In the Lebombo Plateau, there is widespread smuggling into neighboring Mozambique, where the maize price is about 50% greater. However, in the more mountainous regions included in our sample, the terrain and the distance to Mozambique preclude smuggling. No smuggling reportedly occurs into South Africa, since the maize price there is about the same or less than in Swaziland.

tion.[7] Participation is not significantly affected one way or another by the household head's education.

HYV usage is a nonincreasing function of farm size, although the effect is statistically significant only in the single-equation HYV model. The sign of the education variable is positive, as expected, but the coefficient estimate is not statistically significant. Similarly, the signs of the distance-to-market and rainfall variables are as expected, but neither is statistically significant in the simultaneous-equation model.

Conclusions

The main objective of this article was to explore the impact of field trials on the adoption of high-yielding varieties of maize in Swaziland, a small country in southern Africa. We constructed a simultaneous-equation model of the adoption process, reflecting the fact that HYV usage may influence field trial participation as well as vice versa. Very few other studies on the impact of extension programs have attempted to account for this simultaneous relationship between extension efforts and economic outcomes (Birkhaeuser et al.). Our principal conclusion is that it is impossible to say that field trials had any effect on HYV adoption. Farms in the field trials used slightly more HYVs, but this might have been due to self-selection or the way in which the government selected field trials areas.

As a caveat, the Cropping Systems project had many other components aside from the field trials analyzed here. For example, a training and visit (T&V) extension system was instituted, and about 40% of the farmers in our sample had contact with extension agents. Information was also disseminated through radio and newspapers (reaching 64% and 18% of the farms in our sample, respectively). We excluded these other project components from the study to keep it econometrically feasible (since they would also need to be endogenous), although we recognize that our results may be biased as a result. In addition, while the project's field trials were underway, field trials were also being conducted by seed and pesticide companies. The farmers in our sample were not asked whether or not they participated in these other field trials.

The principal recommendation to emerge from this article is that policymakers need to take a closer look at the ways in which field trials are designed and conducted. A greater effort needs to be made to ensure that farms of all types can participate in the field trials so that participants approximate a random sample of all farms. Self-selection will always be a problem, but other sources of nonrandomness can be controlled.

[7] The Hessian was not negative definite at the apparent maximum of the likelihood function.

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