Web Appendix for

Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya

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Appendix 1: Rate of Return to Fertilizer

This appendix is an extension to the profitability analysis presented in Duflo, Kremer, and Robinson (2008) [henceforth: DKR 2008]. That paper presented a point estimate for the rate of return for fertilizer, based on the assumptions that the return to fertilizer was realized when farmers home-consumed the extra maize after previous stocks had run out, and there was no difference in labor use on plots on which fertilizer was used (based on the fact that farmers were asked to farm as usual on all plots). In this appendix, we calculate a range of estimates of the return to top-dressing fertilizer, assuming maize is sold at the immediate post-harvest price, and under different assumptions about the extra labor involved in using fertilizer.

We start by briefly describing the intervention used for the profitability analysis. More detail is in the original DKR 2008 paper. We then explain each of the changes to the DKR estimates.

Background on Agricultural Trials

We conducted a set of agricultural trials over 6 seasons in Busia District, Western Kenya, beginning in July 2000, in conjunction with ICS (the same NGO which was involved in the SAFI programs). In each season, farmers were randomly selected for project participation from a list of parents of school-aged children in the area. Those that were selected for treatment were visited by a field officer, at which point the field officer drew off several small test plots on a small piece of the farmer's land (each plot was either 30 m^2 or 60 m^2, depending on the season). This visit happened after land preparation.

One or more of the plots were then randomly selected to serve as treatment plots. In all seasons, at least one plot used top dressing fertilizer, (Calcium Ammonium Nitrate), which is the focus of our calculations here, and another plot served as control, on which farmers were asked to farm exactly as they would normally.

There were some differences across the 6 seasons. First, the number of plots varied between 2 and 4 across the years. Second, the quantity of top dressing fertilizer given for the plots varied (between ¼, ½, and 1 teaspoon of fertilizer per planting hole). Third, in two of the seasons, a plot was drawn on which farmers used the “full package” of inputs recommended by the Ministry of Agriculture: hybrid seeds, fertilizer at planting (Di-Ammonium Phosphate), and fertilizer at top dressing. Fourth, in two of the seasons, farmers simultaneously kept plots with varying quantities of top dressing fertilizer.

In each trial, ICS provided farmers the inputs for free, and field workers showed farmers how to plant with correct spacing (on both treatment and control plots), and how to apply the fertilizer (and seeds, on the plots which received the full package). In addition, field officers monitored farmers a few times during the season, participated in planting, top dressing application, and harvest, and measured the yield from each plot. Apart from these minimal interactions, farmers were left to farm as normal, and asked to farm on their control plot exactly as they normally would.

This appendix introduces the following changes over DKR, 2008.

1) Labor Costs

DKR 2008 will understate fertilizer profitability to the extent that it is optimal to increase labor usage when fertilizer is applied, but farmers did not fully adjust (they were instructed to farm “as usual” on both plots). However, DKR 2008 will overstate returns on fertilizer if farmers used more labor but the labor increase was not measured (in particular, we would expect that farmers spend time applying fertilizer, and harvest and post-harvest activities may take more time with a bigger harvest). In this appendix, we therefore adjust the estimate to take labor inputs into account.

The major labor-using activities involved in growing maize are (1) land preparation, (2) planting, (3) weeding and general plot maintenance, (4) applying fertilizer, (5) harvesting, and (6) post-harvest activities (drying and shelling the maize). As the plots were drawn only after the land had been prepared, and the plot on which the top dressing should be applied was only revealed to the farmers at the time of fertilizer application (after planting), there is, by definition, no difference in labor usage in land preparation and planting time across top dressing and non-top dressing plots in our experiment.

We collected data on weeding time and saw no difference in treatment and comparison plots, consistent with the instructions provided to farmers. First, we asked 30 farmers about the number of hours spent weeding each plot, and we find no difference in reported labor time. In that trial, farmers kept 3 30 m^2 plots (full package, top dressing, and control) and no farmer reported differential weeding time on any of the plots. We also asked ICS field officers to record how "weedy" the various plots appeared (mostly, somewhat, or not at all free of weeds), for a sample of 97 farmers. Again, we find no difference: for 99% of farmers, the field officers' perceptions of the weediness of the plots, was exactly the same for the 2 plots.

However, we unfortunately did not collect explicit measures of labor usage on the various plots for tasks other than weeding, even though a field officer was present during the trials. One might also think that farmers would have been reluctant to report differential weeding labor across plots and might think the field officers visual impressions unreliable.

In this section we therefore extend our analysis to include estimates of differential labor costs in applying fertilizer, weeding, harvesting, and post-harvest activities.[1] For labor times for fertilizer application, weeding, harvesting, and post-harvest activities, we rely on summary statistics provided in Suri (2009). These statistics are based on a dataset collected by the Tegemeo Agricultural Monitoring and Policy Analysis Project. The dataset is a panel made up of a sample of households' representative of rural, maize-producing areas in Kenya.

The dataset includes information of yields and labor hours (including paid and family labor). Averages hours for each activity (taken from Suri, 2009, Appendix Table 3) are reproduced in Appendix Table 1. The table presents averages for 3 groups of farmers: (1) those that do not use any fertilizer; (2) those who use either planting or top dressing fertilizer; and (3) those that use top dressing fertilizer only. We calculate the rate of return using labor usage among both farmers who use top dressing fertilizer only, compared to other farmers, and among those who use top dressing fertilizer only. Top dressing only is more similar to our experiment, but the sample of farmers who use top dressing fertilizer only is small, and may not be very representative. The labor cost estimates for farmers using other kinds of fertilizer are higher, which lowers our lower bound on profitability. Note that differences in labor input between farmers who use and do not use fertilizer will pick up not only treatment but also selection effects, and that the latter are likely positive, because farmers who use fertilizer are probably also more likely to follow other recommended agricultural practices.

To estimate the extra time needed for harvesting and post-harvesting, we calculate the difference in total time spent in these activities between farmers who use fertilizer and farmers who do not. We then divide this estimate by the difference in yield between the two groups of farmers to get an estimate of the labor hours required in harvesting and post-

[1] We focus here on differences between the control plot and the plots which used top dressing fertilizer (we do not discuss the "full package" plot).

harvesting per extra goro-goro of maize.[2] Note that Suri's data is consistent with the hypothesis that labor time spent in harvest and post-harvest activities is proportional to yield since the ratio of labor time on these activities to yield is similar between farmers who use and do not use fertilizer. We call this quantity $\Delta L_{h,ph}$.

We also construct the difference in labor time (in hours) spent weeding, applying fertilizer, and in other plot maintenance per acre, and treat this as a fixed cost, incurred early in the season (at the same time fertilizer is purchased). We call this quantity $\Delta L_{w,fa,o}$. As mentioned above, we present all results for differences in average labor use for two sets of farmers: those that use any type of fertilizer, and those that use top dressing fertilizer only. We value labor at 61.99 Ksh ($0.89) over a 5.63 hour day, which is the average casual labor rate reported in Suri (2009) for Western Kenya. Using the agricultural wage rate is clearly an overestimate of the actual opportunity costs of these farmers, as they do not hire workers, and working on other people's farms requires them to incur transport and search costs. Moreover, Busia is one of the poorest districts in Western Kenya, so it seems likely that the agricultural wage in Busia is less than the average wage in Western Kenya.

2) Pricing Maize

The price of maize is highly cyclical in Western Kenya. There are 2 growing seasons, the "long rains season" and the "short rains season". The long rains season is longer and is a much more important growing season, with much higher yields (farmers sometimes do not even cultivate in the short rains). In 2003-04 (the time period used for all profitability calculations), the immediate post-harvest price was 24.7 Ksh (US $0.353) after the shorter growing season and 26.7 Ksh (US $0.381) after the longer season. The price rises to a peak of

[2] Yield is measured in the (dried and shelled) number of goro-goros, a volume measure equivalent to just over 2 kgs (2.17 kgs in our data).

43.1 Ksh (US $0.612) when there is a shortage of maize just before the long rains harvest, but does not increase significantly before the short rains harvest.

In DKR 2008, we valued maize assuming that the farmer would sell or consume the extra maize before the next season (the reasoning was that few farmers sell their maize at the market and instead consume it themselves and that the marginal extra harvest would be consumed when the rest of their maize ran out during the hungry season), and we also rounded the prices. Thus, we valued the long rains maize at 25 Ksh, and the short rain maize at 40 Ksh, and we assumed that a farmer had to wait 7 months between investing in fertilizer and realizing profit. We were conservative in assuming that this was the case in both seasons. However, in response to a referee comment we now value the maize at its lower, immediate post-harvest price in all cases.

3) Assumed Time to Realize Returns

As noted above, DKR 2008 assumed farmers had to wait 7 months between applying top-dressing fertilizer and realizing returns. In this paper, we value maize at the immediate post-harvest price, and thus assume the investment is realized at this time.

From our dataset, it takes an average of 3.42 months from the time topdressing fertilizer is applied until the time it can be harvested, shelled, and dried for sale. In our calculations, we conservatively annualize the returns under the assumption that it takes 4 months to realize returns.

Making the prince and timing changes reduces seasonal profits from fertilizer. However, by reducing the time period over which profits are realized, we obtain higher annualized returns for any given seasonal return.

Calculating Profitability

To calculate profitability with labor costs included, valuing maize at the post-harvest price, we divide labor costs into two categories: Costs of harvest and post harvest activities (drying and shelling), are assumed proportional to the yield and to be incurred around the time that the post-harvest price is realized. These costs are thus akin to a reduction in the value of each kg of maize. Costs of applying fertilizer, weeding, and other plot maintenance are conservatively assumed to be incurred at the same time fertilizer is purchased (though in reality, some of these costs are incurred later).

We then use these estimates to calculate the rate of return over the season in our experimental plots according to the following formula[3]

$$r = \frac{(P_m - W * \Delta L_{h,ph})\Delta Y - C_f - W * \Delta L_{w,fa,o}}{P_f + W * \Delta L_{w,fa,o}} \qquad (1)$$

where p_m is the price of maize (US $0.381 after the long rains and $0.353 after the short rains), ΔY is the difference in yields between the treatment and control plots, C_f is the cost of fertilizer, W is the hourly wage rate, and $\Delta L_{w,fa,o}$ is the difference (in hours) in time spent in weeding, fertilizer application, and other plot maintenance between the 2 plots.[4]

The results are presented in Appendix Table 2, for both ½ teaspoon and 1 teaspoon of fertilizer. Panel A reports the yield and labor cost estimates from Suri (2009), as calculated from Appendix Table 1. The first set of costs, ($\Delta L_{w,fa,o}$ in the formula) are those costs which are incurred earlier and which are not proportional to the yield (weeding, fertilizer application, and other plot maintenance). Overall, farmers who do not use fertilizer actually spend slightly more time on these activities than do farmers who use fertilizer, though the difference is small. These estimates are consistent with our data and observations, since we

[3] Note that there is a typo in the version of this formula reported in Duflo, Kremer, and Robinson (2008). We thank Michael Carter and Rachid Laajaj for pointing this out.

[4] In the formula, we do not divide by the cost of labor applied in harvest and post-harvest activities, since these costs are incurred at the time that the maize would be sold (rather than upfront, at the time that the fertilizer is purchased and applied). Thus these costs should be seen as akin to a reduction in the price of maize.

find no differences in reported weeding time or in field officer observations of the weediness of the plots.

The second set of costs ($\Delta L_{h,ph}$ in the equation), are those which are incurred close to the time that maize is sold and which are proportional to yield (harvesting and post-harvesting). These costs are clearly somewhat higher for farmers that use fertilizer, since their yields are higher: depending on the wage rate used, the additional cost is between $0.062 and $0.065 per goro-goro of additional maize. However, these costs are still relatively small compared to the price of maize ($0.353-$0.381 per goro-goro).

Given these figures, we estimate revised rates of return for each wage rate in Panel C (for comparison with DKR (2008), we also present the estimated return without accounting for labor costs). The gross return is between 0.150 and 0.272. To annualize the figures, we calculate the time from top dressing to the time that maize is dried and shelled using data from the experiments.[5] On average, this figure is 3.42 months. However, we conservatively annualize over a 4 month period as some farmers may take somewhat longer to finish drying. The final annualized rates of return are between 52.2 and 84.8%, depending on the assumptions on the time spent on agricultural activities by farmers who used fertilizer.

The Table also reports results for 1 teaspoon of fertilizer. As in DKR (2008), the gross returns are negative.[6]

Finally, we also calculate the incremental return from going from ½ teaspoon to 1 teaspoon of fertilizer per plant in Panel D. In the Panel, we report the incremental return at

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[5] In several of the trials, we either asked farmers to dry and shell their maize after harvest or took some maize to dry and shell ourselves so that we could measure the weight which was lost in the process. From this we have the specific dates at which the maize was ready for sale. From our other records, we have the exact date on which top dressing fertilizer was applied.

[6] Note that in some seasons farmers used 1 teaspoon per plant, in others farmers used ½ teaspoon per plant, and in others farmers kept multiple plots with both ½ teaspoon and 1 teaspoon of fertilizer per plant. To avoid making comparisons across different schools and seasons, we calculate the incremental returns for only those farmers who used both ½ teaspoon and 1 teaspoon during the same season.

the full market price (Columns 1 and 2) and at a 2/3 subsidy (in Columns 3 and 4). The incremental gross returns are highly negative at the full market price (varying from -23.0 to -26.1 percent) but positive at a 2/3 subsidy (varying from 41.1 to 42.5 percent). On an annualized basis, the returns at a 2/3 subsidy are well over 100% per year.

Appendix Table 1. Labor and Yield Information (from Suri, 2009)

	(1) Farmers Who Do Not Use Any Fertilizer	(2) Farmers Who Use Either Planting or Top Dressing Fertilizer	(3) Farmers Who Use Top Dressing Fertilizer Only
A. Labor Usage (Hours)			
Land Prep	126.56	119.31	115.21
Planting	43.43	58.25	74.92
Weeding	184.96	174.18	173.08
Harvest	52.98	68.68	59.26
Postharvest	38.41	69.04	53.46
Fertilizer Application	0.81	3.91	2.50
Other	6.72	3.68	0.07
B. Harvest			
Yield (Goro-Goros)	208.34	321.59	263.11
C. Fertilizer			
Cost (USD)	0.00	14.76	8.20
Observations	953	473	56

Notes: Figures include both family and hired labor.
Data is from the Tegemeo Agricultural Monitoring and Policy Analysis Project, a panel made up of a sample of households representative of rural, maize-producing areas in Kenya.

Appendix Table 2. Adjusted Rate of Return to Top Dressing Fertilizer

	(1) Farmers Who Do Not Use Fert.	(2) Farmers Who Use Any Fert.	(3) Farmers Who Use TD Fert. Only	(4) Difference: Any Fert.	(5) Difference: TD Fert.
A. Estimates of Yield, Labor Time from Suri (2009)					
Yield (goro-goros of dried maize)[1]	208.34	321.59	263.11	113.25	54.76
Cost of Fertilizer	0.00	14.76	8.20	14.76	8.20
Labor Costs [2]					
Activities which are not proportional to yield:					
Weeding, Applying Fertilizer, and "Other" Activities					
Hours	192.49	181.77	175.64	-10.72	-16.84
Labor Cost Ksh[3]	30.43	28.73	27.77	-1.69	-2.66
Activities which are proportional to yield:					
Harvesting and Post-Harvesting Activities					
Hours	91.39	137.72	112.72	46.33	21.34
Labor Cost Ksh	14.45	21.77	17.82	7.32	3.37
Cost per Goro-Goro of Extra Maize[4]	-	0.065	0.062		

	(1) Control Plot	(2) 1/2 Teaspoon Plot	(3) Difference (2)-(1)	(4) 1 Teaspoon Plot	(5) Difference (4)-(1)
B. Agricultural Productivity in Duflo, Kremer and Robinson (2008)					
All Farmers Using 1/2 Teaspoon per Hole on at Least 1 Plot					
Estimated Yield per acre	254.98	322.34	67.36		
Estimated Value at Seasonal Post-Harvest Price[5]	95.72	120.94	25.22		
Estimated Cost of Fertilizer[6]	-	19.83			
All Farmers Using 1 Teaspoon per Hole on at Least 1 Plot					
Estimated Yield per acre	179.93			254.39	74.46
Estimated Value at Seasonal Post-Harvest Price	66.71			94.53	27.82
Estimated Cost of Fertilizer	-			32.82	
Only Farmers who Simultaneously Used 1 Teaspoon and 1/2 Teaspoon per Hole in the same season					
Estimated Yield per acre	207.11	270.25	63.14	300.88	93.77
Estimated Value at Seasonal Post-Harvest Price	76.91	100.35	23.44	111.96	35.05
Estimated Cost of Fertilizer	-	20.60		41.06	

C. Adjusted Rate of Return	(1) 1/2 Teaspoon: Gross	(2) 1/2 Teaspoon: Annualized[7]	(3) 1 Teaspoon: Gross	(4) 1 Teaspoon: Annualized
No Labor Costs	0.272	1.056	-0.152	-0.391
Labor Hours for Farmers Using Any Fertilizer	0.150	0.522	-0.261	-0.596
Labor Hours for Farmers Using Top Dressing Fert.	0.227	0.848	-0.230	-0.543

D. Incremental Return to 2nd 1/2 Teaspoon[8]	(1) Full Price: Gross	(2) Full Price: Annualized	(3) 2/3 Subsidy: Gross	(4) 2/3 Subsidy: Annualized
No Labor Costs	-0.433	-0.817	0.702	3.930
Labor Hours for Farmers Using Any Fertilizer	-0.530	-0.896	0.411	1.812
Labor Hours for Farmers Using Top Dressing Fert.	-0.525	-0.893	0.425	1.895

Notes: All monetary figures in $US. Exchange rate was about 70 Ksh to $1 US during the study period.
All figures are per acre.

[1]A goro-goro is a volume measure equivalent to 2.17 kilograms in our data.

[2]Estimates from Suri (2009) include both family and hired labor.

[3]For these calculations, we use a wage rate of 61.99 Ksh ($0.89) per 5.63 hour day, which is the average casual wage rate in Suri (2009) for Western Kenya.

[4]The cost per goro-goro extra maize is calculated by dividing the increase in labor costs by the increase in yield.

[5]During the sample period, the average post-harvest price is 24.7 Ksh ($0.353) in the short rains growing season, and 26.7 Ksh ($0.381) in the long rains growing season.

[6]The cost of fertilizer at top dressing was about 30 Ksh (US $0.43) per kg during the sample period.

[7]From trials in which we dried maize with farmers, the average time from the application of top dressing to the time it can be sold is 3.42 months. We conservatively use 4 months for this calculation. The time from top dressing to shelling/drying does not differ across the long and short growing seasons.

[8]The incremental return is calculated for those farmers that kept 1/2 teaspoon and 1 teaspoon plots during the same season.

Appendix 2: Supplementary Information

This appendix includes supplementary material for "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya."

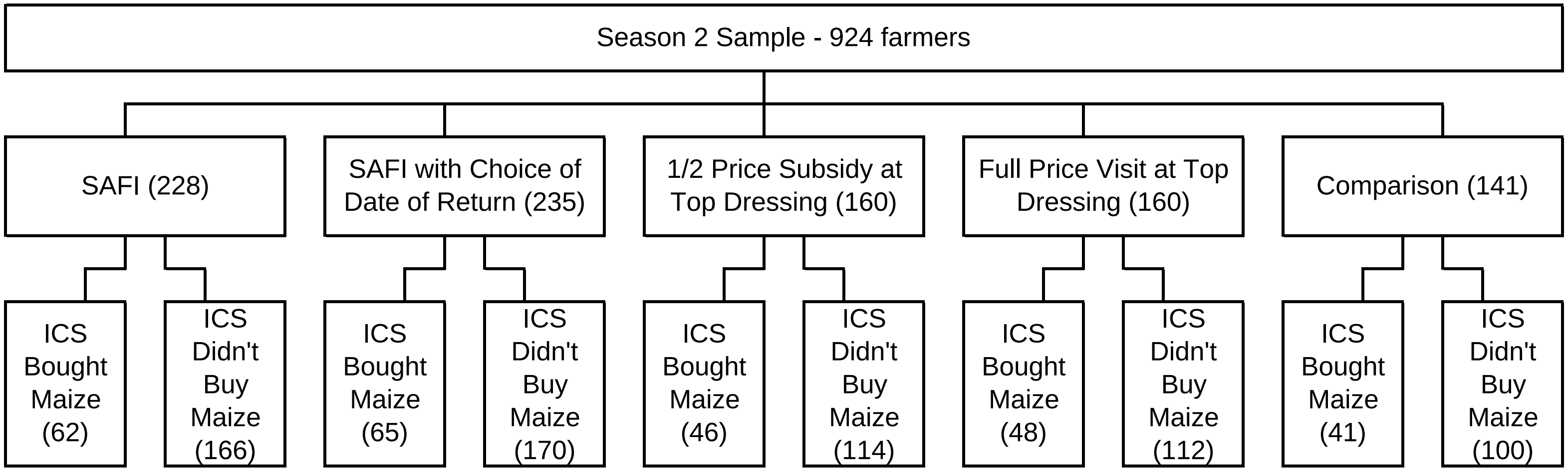
First, Appendix Figure 1 summarizes the experimental design of programs in the second season.

Second, Appendix Table 3 is taken from a survey of a non-random sample of farmers which was conducted in November-December 2009. In that survey, we asked farmers about whether they had purchased fertilizer over the past 3 seasons and, if they had, when they bought the fertilizer. Consistent with our model, we find that very few farmers purchase fertilizer early in the season (in this case, immediately after the prior harvest).

Third, Appendix Table 4 presents information on attrition from the experiment. The results suggest relatively low attrition, and minor differences across the various treatment groups.

Finally, Appendix Table 5 checks that the groups for the pilot SAFI groups are balanced along observable characteristics at baseline. Overall, the groups appear to be quite similar prior to the program.

More detail on these programs is included in the main text of the paper.



Within each cell, farmers were randomly selected for a "reminder" visit that occurred just before top dressing.
In total, 88 farmers were sampled for the reminder, and 107 served as reminder comparison farmers

Appendix Figure 1. Experimental Design for School-Based Starter Kit Program for Season 2

Notes: Number of farmers include all farmers who were traced for the baseline questionnaire (prior to the Season 1 treatments). Sampling for all Season 2 treatments is stratified by Season 1 treatments.

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Appendix Table 3. Attrition

	Completed 2004 Background Questionnaire (1)	Completed 2005 Adoption Questionnaire (2)	Completed 2005 Adoption Questionnaire (3)
Starter Kit Farmer	0.009	0.047	0.017
	(0.039)	(0.038)	(0.030)
Demonstration Plot School	-0.261	0.245	0.078
	(0.319)	(0.316)	(0.298)
Starter Kit Farmer * Demonstration Plot School	0.054	0.035	0.009
	(0.050)	(0.050)	(0.039)
SAFI Season 1	0.043	0.050	-0.019
	(0.043)	(0.042)	(0.033)
SAFI Season 2	0.003	0.002	0.051
	(0.054)	(0.054)	(0.043)
SAFI Season 2 with Choice	0.041	0.037	0.031
	(0.054)	(0.053)	(0.043)
Subsidy Season 2	0.082	0.083	0.049
	(0.059)	(0.059)	(0.046)
Full Price Visit Season 2	0.109	0.088	0.039
	(0.060)*	(0.059)	(0.046)
ICS Bought Maize Season 2	0.026	0.000	-0.019
	(0.034)	(0.033)	(0.026)
Sample	Whole Sample	Whole Sample	Only those that completed Background
Mean of Dependent Variable	0.751	0.754	0.906
Observations	1230	1230	924

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%
Regressions control for school and for interactions between the demonstration plot and the various treatments.
As can be seen in Column 3, 90.6% of respondents who completed the 2004 questionnaire also completed the 2005 adoption questionnaire.

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Appendix Table 4. Verifying Randomization for Pilot SAFI Programs

	Household had Ever Used Fertilizer Before (1)	Years Education (2)	Home has Mud Walls (3)	Home has Mud Floors (4)	Home has Thatch Roof (5)	Income in Month Prior to Survey^ (6)	Number of Children (7)	Acres of Land Owned (8)
SAFI Variants								
option 1: take-it-or-leave-it	0.455	7.223	0.780	0.810	0.420	1.829	7.298	3.990
	(0.500)	(3.419)	(0.416)	(0.394)	(0.496)	(2.715)	(2.758)	(3.097)
option 2: return in a few days	0.340	6.040	0.780	0.840	0.460	1.672	7.000	4.391
to collect money	(0.479)	(4.130)	(0.418)	(0.370)	(0.503)	(2.275)	(2.678)	(3.508)
option 3: return in a few months	0.352	4.254	0.833	0.722	0.556	2.359	9.471	3.844
to collect money	(0.481)	(4.013)	(0.383)	(0.461)	(0.511)	(5.814)	(3.281)	(2.663)
p-value, option 1 = option 2	0.470	0.162	0.901	0.565	0.452	0.665	0.834	0.355
p-value, option 1 = option 3	0.847	0.077*	0.350	0.965	0.630	0.332	0.208	0.645
p-value, option 2 = option 3	0.732	0.475	0.400	0.681	0.995	0.220	0.166	0.905
Observations	222	222	168	168	168	169	158	163

Notes: Figures are from the pilot SAFI programs, which were conducted mostly among farmers that participated in demonstration plot trials.
p-values are from a regression which includes school controls.
Means are reported, with standard deviations in parentheses.
The bottom of the table reports p-values of F-tests for pairwise testing of means across SAFI options.
^Income is measured in 1,000 Kenyan shillings. Exchange rate was roughly 70 shillings to $1 US during the sample period.
* significant at 10%; ** significant at 5%; *** significant at 1%