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

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We model farmers as facing small fixed costs of purchasing fertilizer, and assume some are stochastically present-biased and not fully sophisticated about this bias. Such farmers may procrastinate, postponing fertilizer purchases until later periods, when they may be too impatient to purchase fertilizer. Consistent with the model, many farmers in Western Kenya fail to take advantage of apparently profitable fertilizer investments, but they do invest in response to small, time-limited discounts on the cost of acquiring fertilizer (free delivery) just after harvest. Calibration suggests that this policy can yield higher welfare than either laissez faire or heavy subsidies.

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"The rest of the world is fed because of the use of good seed and inorganic fertilizer, full stop. This technology has not been used in most of Africa. The only way you can help farmers get access to it is give it away free or subsidize it heavily."
Stephen Carr, former World Bank specialist on Sub-Saharan African agriculture, quoted in Dugger, 2007.

Many agricultural experts see the use of modern inputs, in particular fertilizer, as the key to agricultural productivity. Pointing to the strong relationship between fertilizer use and yields in test plots, they argue that fertilizer generates high returns and that dramatic growth in agricultural yields in Asia and the stagnation of yields in Africa can largely be explained by increased fertilizer use in Asia and continued low use in Africa (Morris, Kelly, Kopicki, and Byerlee, 2007). Based on this logic, Ellis (1992) and Sachs (2004) argue for fertilizer subsidies. Many governments have heavily subsidized fertilizer. In India, for example, fertilizer subsidies amounted to 0.75 percent of GDP in 1999–2000 (Gulati and Narayanan, 2003). In Zambia, fertilizer subsidies consume almost 2 percent of the government's budget (World Bank, 2007).

In contrast, the Chicago tradition associated with Schultz (1964) starts with the presumption that farmers are rational profit maximizers, so subsidies will distort fertilizer use away from optimal levels. Others have argued that fertilizer subsidies create large costs beyond these Harberger triangles. They are typically regressive as wealthier farmers and those with more land often benefit most from subsidies (Donovan, 2004), and loans for fertilizer often go to the politically connected and have low repayment rates. Moreover, while moderate fertilizer use is environmentally appropriate, overuse of fertilizer induced by subsidies can cause environmental damage and eventually reduce the effect of fertilizer (World Bank, 2007, Anand, 2010). Furthermore, fertilizer subsidies may lead to government involvement in fertilizer distribution, politicization, and very costly failures to supply the right kind of fertilizer at the right time.

Partly due to the dominance of the anti-subsidy view among economists and international financial institutions, fertilizer subsidies have been rolled back in recent decades. Recently, however, they have seen a resurgence. For example, after Malawi's removal of fertilizer subsidies was followed by a famine, the country reinstated a two-thirds subsidy on fertilizer. This was followed by an agricultural boom which many, including Jeffrey Sachs, attribute to the restoration of the fertilizer subsidies (Dugger, 2007).

A key assumption in the Chicago tradition case against fertilizer subsidies is that farmers would use the privately optimal quantity of fertilizer without subsidies. To reconcile low fertilizer use with the large increases in yield from fertilizer use found in agricultural research stations, economists often note that conditions on these stations differ from those on real-world farms, and returns may be much lower in real conditions, where farmers cannot use other inputs optimally. There is evidence that fertilizer is complementary with improved seed, irrigation, greater attention to weeding, and other changes in agricultural practice that farmers may have difficulty in implementing. However, in previous work we implemented a series of trials with farmers on their own farms in a region of Western Kenya where fertilizer use is low. Those trials showed that when fertilizer is used in limited quantities, the yield increases it generates make it a profitable investment even without other complementary changes in agricultural practices (Duflo, Kremer, and Robinson, 2008, henceforth DKR). DKR estimated annualized rates of return of 70%. In this paper, we assume crops are sold immediately after harvest rather than, like DKR, using higher prices from before the next harvest. Using earlier, lower prices brings down the absolute return but increases the estimated annualized return. We also consider alternative assumptions regarding potential labor input associated with fertilizer, which yield a range of annualized rates of return between 52% and 85%. While this is in part because fertilizer is cheap, the increase in yield is not negligible. For the average farmer in our sample, who farms 0.93 acres of land, these estimates imply that using fertilizer would increase maize income net of input costs by about $9.59 to $15.68 per season, on a base of about $89.02.

Low investment rates in the face of such high returns are particularly puzzling since fertilizer is well-known and long-used in the area. Moreover, since fertilizer is divisible, standard theory does not predict credit constraints will lead to low investment traps in this context.[1] There could, of course, be fixed costs in learning to use or buying fertilizer (for example, making a trip to the store). Indeed, small fixed costs of this type will play an important role in our model. However, such costs would have to be implausibly large to justify the lack of fertilizer investment in the standard model.[2]

[1] As discussed below, profits are concave rather than convex in fertilizer use per unit of land area. Moreover, since farmers always have the option of applying fertilizer intensely on some land while leaving other pieces of land unfertilized, returns must be non-increasing.

[2] For instance, consider a farmer with an hourly wage of $0.16 (the average wage rate for the area in Suri 2009) for whom round trip travel to town to buy fertilizer takes 30 minutes and who can only initially afford 3.7 kgs of fertilizer at a cost of $1.92 (the average bought through the program described in this paper). Since the returns to

In this paper we argue that just as behavioral biases limit investment in attractive financial investments in pension plans by workers in the United States (e.g., Choi, Laibson and Madrian, 2008), they may limit profitable investments in fertilizer by farmers in developing countries. We set out a simple model of biases in farmer decision-making inspired by models of procrastination from the psychology and economics literature (see O'Donoghue and Rabin, 1999). In the model some farmers are (stochastically) present-biased and at least partially naïve, systematically underestimating the odds that they will be impatient in the future, at least in the case when they are patient today. Going to the store, buying fertilizer, and perhaps deciding what type of fertilizer to use and how much to buy, involve a utility cost. Even if this cost is small, so long as farmers discount future utility, even farmers who plan to use fertilizer will choose to defer incurring the cost until the last moment possible, if they expect they will purchase the fertilizer later. However, farmers who end up being impatient in the last period in which buying is possible will then fail to invest in fertilizer altogether.

Under the model, heavy subsidies could induce fertilizer use by stochastically hyperbolic farmers, but they also could lead to overuse by farmers without time consistency problems. The model implies that if offered just after harvest (when farmers have money) small, time-limited discounts on fertilizer could induce sizeable changes in fertilizer use. In particular, early discounts of the same order of magnitude as the psychic costs associated with fertilizer purchase can induce the same increase in fertilizer use as much larger discounts of the order of magnitude of the out-of-pocket costs of fertilizer later in the season. Moreover, *ex ante* (before the harvest) some farmers would choose to be eligible for the discount early on, so as to have an option to commit to fertilizer use.

In collaboration with International Child Support (Kenya), a non-government organization (NGO), we designed and tested a program based on these predictions. Using a randomized design, we compared the program to alternative interventions, such as standard fertilizer subsidies or reminders to use fertilizer. The results are consistent with the model. Specifically, offering free delivery to farmers early in the season increases fertilizer use by 47 to 70 percent. This effect is greater than that of offering free delivery, even with a 50 percent subsidy on fertilizer, later in the season.

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half a teaspoon of top dressing fertilizer are 15.0-27.2% over a season (52-85% on an annualized basis), netting out the lost wages for time spent shopping for fertilizer would leave the farmer with a 48-81% annualized rate of

Following an approach similar to O'Donoghue and Rabin (2006), we use the model to analyze the impact of different policies depending on the distribution of patient, impatient, and stochastically present-biased farmers. Calibrations based on our empirical results suggest that 69 percent of farmers are stochastically present-biased, 14 percent are always patient, and 17 percent are always impatient. This yields a prediction that roughly 60 percent of farmers should never use fertilizer in the three seasons we follow them (in the absence of any of our experimental interventions). Empirically, 57 percent of comparison farmers do not use fertilizer in any of the three seasons for which we have data. The calibrated model matches other moments in the data, in particular the proportion of farmers who take up fertilizer when given the choice of which date they would like to be offered free fertilizer delivery.

The calibration suggests that a "paternalistic libertarian" (Thaler and Sunstein, 2008) approach of small, time-limited discounts could yield higher welfare than either laissez faire policies or heavy subsidies, by helping stochastically hyperbolic farmers commit themselves to invest in fertilizer while avoiding large distortions in fertilizer use among time-consistent farmers, and the fiscal costs of heavy subsidies.

The rest of the paper is structured as follows: Section 2 presents background information on agriculture and fertilizer in Western Kenya. Section 3 presents the model and derives testable predictions. Sections 4 lays out the program used to test the model; Section 5 reports results, and Section 6 calibrates the model and then uses the calibrated model to compare welfare under laissez faire, heavy subsidies, and small time-limited subsidies. Section 7 examines alternative hypotheses, and Section 8 concludes with a discussion of the potential for realistically scaling up small, time-limited subsidies in a way that would not involve excessive administrative costs.

2. Background on Fertilizer use in Western Kenya

Our study area is a relatively poor, low-soil fertility area in Western Kenya where most farmers grow maize, the staple food, predominantly for subsistence. Most farmers buy and sell maize on the market and store it at home. There are two agricultural seasons each year, the "long rains" from March/April to July/August, and the less productive "short rains" from July/August until December/January.

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return. This is an extremely low bound as it's very unlikely that farmers would not need to come to town for other reasons at some point during the season, at which point they could have bought fertilizer.

Based on evidence from experimental model farms (see Kenya Agricultural Research Institute, 1994), the Kenyan Ministry of Agriculture recommends that farmers use hybrid seeds, Di-Ammonium Phosphate (DAP) fertilizer at planting, and Calcium Ammonium Nitrate (CAN) fertilizer at top dressing, when the maize plant is knee-high, approximately one to two months after planting. Fertilizer is available in small quantities at market centers and occasionally in local shops outside of market centers. Our rough estimate is that the typical farmer would need to walk for 30 minutes to reach the nearest market center. Although there is a market for reselling fertilizer, it is not very liquid and resale involves substantial transaction costs.[3]

Experiments on actual farmer plots suggest low, even negative returns to the combination of hybrid seeds and fertilizer at planting and top dressing, (DKR, 2008), although it is plausible that returns might be higher if farmers changed other farming practices. Similarly, the use of a full teaspoon of fertilizer per plant as top dressing is not profitable, because farmers realize large losses when rains fail or are delayed and seeds do not germinate. However, a more conservative strategy of using only one half teaspoon of fertilizer per plant as top dressing, after it is clear that seeds have germinated, yields a high return and eliminates much of the downside risk. The average farmer in our sample plants just under one acre of maize. As discussed in detail in Appendix Table 2, Panel B, using one half teaspoon of fertilizer per plant increases yield by about $25.22 per acre and costs $19.83 per acre. Without accounting for the extra labor associated with fertilizer use, the rate of return is 106 percent on an annualized basis.

Since we do not have estimates of labor input, we use Suri's (2009) estimates from Tegemeo's survey of Kenyan farmers which gives the time spent on various agricultural activities for farmers who use fertilizer, and farmers who do not. Labor is then valued at the agricultural wage rate in Western Province. These returns adjusted for labor costs are likely a lower bound for two reasons: first, most labor is family labor, which is unlikely to be valued at the market wage rate; second, time spent on farming by regular fertilizer users may be higher than the extra time spent by farmers in our experiments (who were instructed to farm as usual on both plots). With this adjustment for labor costs, the rate of return to fertilizer turns out to be between 52% and 85% depending on whether we use the data on farmers

[3] Discussions with people familiar with the area suggest reselling fertilizer typically involves a discount of approximately 20 percent of the cost of fertilizer in addition to the search costs of finding a buyer.

using only top dressing fertilizer (the high estimate) or data on farmers using any kind of fertilizer (the low estimate).

We also calculate the incremental yield associated with the second half teaspoon of fertilizer for a subset of farmers who used both quantities on test plots in the same season (Appendix Table 2, Panel D). Among those farmers, the extra maize from using 1 teaspoon is valued at only $11.61 per acre at a cost of $20.46. Accounting for labor costs, this corresponds to a negative gross return over a season of approximately -52.5 percent at full price, but about a 41 percent gross seasonal return under a two-thirds subsidy. On an annualized basis, the returns under a 2/3 subsidy are well over 100% per year, well above the rate of return to the first unit of fertilizer at full prices.

Using fertilizer can have a substantial overall effect in increasing total income. From Appendix Table 2, we estimate that the average farmer harvests maize worth about $95.72 per acre per season. Using top dressing fertilizer on an acre would cost $19.83. At annualized net returns of 52-85% per year, this corresponds to an increase in agricultural income of $10.31-$16.86, or 10.8%-17.6% of annual income. Since the average farmer in the sample over which we estimated these returns has 0.93 acres of land, we estimate that using fertilizer would increase agricultural income net of costs by about $9.59 to $15.68, on a base of about $89.02. Thus, while using fertilizer would not immediately allow such farmers to exit from poverty, these are still sizeable income gains.

Despite the potential returns to applying limited quantities of fertilizer as top dressing, only 40 percent of farmers in our sample report ever having used fertilizer and only 29 percent report using it in at least one of the two growing seasons before the program. When asked why they do not use fertilizer, farmers rarely say fertilizer is unprofitable, unsuitable for their soil, or too risky: instead, they overwhelmingly reply that they want to use fertilizer but do not have the money to purchase it. Of farmers interviewed before the small-scale agricultural trials we conducted, only 9 percent said that fertilizer was unprofitable while 79 percent reported not having enough money. At first this seems difficult to take at face value: fertilizer can be bought in small quantities (as small as one kilogram) and with annualized returns of at least 52 percent, purchasing a small amount and investing the proceeds would eventually yield sufficient money to generate sufficient funds to fertilize an entire plot. Even poor farmers could presumably reallocate some of the proceeds of their harvest from consumption to fertilizer investment per acre.

One way to reconcile farmers' claims that they do not have money to buy fertilizer with the fact that even poor farmers have resources available at the time of harvest is to note that farmers may initially intend to save in order to purchase fertilizer later but then fail to follow through on those plans. Table 1 suggests that farmers almost never buy fertilizer early in the season. It shows results from a survey of 139 farmers we conducted in the same area in November-December 2009 in which we asked farmers about whether they used fertilizer in the past 3 seasons, and if so, when they bought it. Depending on the season, 96-98% of those who used fertilizer had bought it just before applying it. Overall, depending on the season, only between 0.4% and 2% of farmers had bought fertilizer well in advance.

There is some anecdotal evidence that farmers do not follow through with their plans to buy fertilizer: 97.7 percent of farmers who participated in the demonstration plot program reported that they planned to use fertilizer in the following season. However, only 36.4 percent of them actually followed through on their plans and used fertilizer in the season in which they said they would. Thus, it appears that even those who are initially planning to use fertilizer often have no money to invest in fertilizer at the time it needs to be applied, for planting or top dressing, several months later.

3. Model

Below we propose a model of procrastination similar to those advanced to explain the failure of many workers in developed countries to take advantage of profitable financial investments (O'Donoghue and Rabin, 1999) and derive testable predictions. In the model, some farmers are present-biased, with a rate of time preference that is realized stochastically each period. When they are very present-biased, farmers consume all they have. When they are moderately present-biased, farmers make plans to use fertilizer. But early in the season, patient farmers overestimate the probability that they will be patient again, and thus they postpone the purchase of fertilizer until later, and save in cash instead. Later, if they turn out to be impatient, they consume all of their savings instead of investing in fertilizer, resulting in a lower usage of fertilizer than the farmer in the early period would have wanted. While the model makes a number of specific assumptions on parameters and functional forms, and is certainly not the only possible model that captures the main insights we have in mind, it has the advantage of leading to a number of simple quantitative predictions, which have motivated our experimental design. In section 7, we present predictions of alternative models and discuss the extent to which they can be ruled out by the data.

3.1 Assumptions

Preferences and Beliefs

In our model, all farmers are present biased. For simplicity, there is no discounting between future periods (i.e. $\delta = 1$), but consumption in any future period, viewed from today, is discounted at rate $\beta_k < 1$.

Suppose that some fraction of farmers γ, are always relatively *patient*. They discount the future at rate β_H.

A proportion ϕ is *(stochastically) present-biased*, and systematically understate the extent of this present bias. In particular suppose that in period k, these farmers discount every future period at a stochastic rate β_k (for simplicity we assume that there is no discounting between future periods). In each period k, with some probability p, the farmer is fairly patient ($\beta_k = \beta_H$), and with probability $(1-p)$, the farmer is quite impatient ($\beta_k = \beta_L$). Furthermore, while these farmers do recognize that there is a chance that they will be impatient in the future, they overestimate the probability that they will be patient. Specifically, the probability that a patient farmer believes that she will still be patient in the future is $\tilde{p} > p$.

There are several ways to interpret this stochastic rate of discount. One interpretation is that farmers are literally partially naïve about their hyperbolic discounting, as in the original O'Donoghue and Rabin (1999) framework. Eliaz and Spiegler (2006) and Asheim (2008) analyze models where partial naivete is modeled in this way. An alternative interpretation, along the lines of Banerjee and Mullainathan (2008a), is that a consumption opportunity occasionally arises (e.g., a party) that is tempting to the farmer in that period, but which is not valued by the farmer in other periods.[4]

A final proportion ψ are *always impatient* so that $\beta_k = \beta_L$ in all periods. All farmers are one of these three types so $\gamma + \phi + \psi = 1$.

[4] Another way to introduce a stochastic element in preferences would be to assume that the rate of discount is fixed (for example, there are hyperbolic and time consistent farmers) and that it is the cost of purchasing fertilizer (as we describe below) is stochastic. One could also introduce naivete in this model by assuming that farmers overestimate the probability that the cost will be lower in the future. This model would have a similar flavor, but somewhat different implications. In particular it would predict that some farmers, for whom the cost is low, buy fertilizer in period 1. In practice, we see almost no purchase in period 1. We thank Rachel Glennerster and a referee who both made this suggestion.

Finally, for simplicity, we assume per-period utility in any period is simply consumption in that period, less a small utility cost associated with shopping for fertilizer and the time cost associated with deciding what quantity of fertilizer to buy, which will be described below.

Timing and Production

There are four periods. *Period 0* is immediately prior to the harvest. The farmer does not plan to save, consume or purchase fertilizer in this period, but we will later consider a situation in which the farmer can pre-commit to different patterns of fertilizer pricing in this period. We will initially abstract from *period 0* but later allow the farmer to make a choice of a price schedule for fertilizer in *period 0*.

In *period 1*, the farmer harvests maize, receives income $x > 2$, and can allocate income between consumption, purchase of fertilizer for the next season, and a short-run investment that yields liquid returns by the time fertilizer needs to be applied. Some farmers, such as those who have shops where they can use more working capital, will have high return investments that yield liquid returns over a short period, whereas others will have lower return investment opportunities. We therefore assume the net return *R* is high ($\overline{R}$) for a proportion λ of farmers, and low ($\underline{R} > 0$) for the rest. Farmers know their rate of return with certainty.[5] Finally, we assume that $\beta_L(1 + \overline{R}) < 1$ and $\beta_H(1 + \underline{R}) > 1$: impatient farmers do not save in short-run alternative investments, even if the return is high, and patient farmers do, even if the return is low.

Farmers can choose to use zero, one or two units of fertilizer. We assume discreteness of fertilizer investment to keep the analysis tractable and to parallel our previous empirical work, which examined the returns to zero, half or one teaspoon of fertilizer per plant. However, the discreteness does not drive our results.

Let p_{f1} denote the price of fertilizer in period 1. Purchasing any fertilizer also entails a small utility cost f (encompassing the time cost of going to the shop to buy the fertilizer, as well as deciding what type to use and how much to buy). This cost is independent of the amount of fertilizer purchased. Note that while fertilizer is a divisible technology, the assumption that there is some fixed cost of shopping for fertilizer is consistent with our

[5] We assume that there is no correlation between behavioral types and returns.

finding that few farmers use very small amounts of fertilizer—they tend to either use no fertilizer or fertilize a significant fraction of their crop.[6]

At the beginning of *period 2*, which can be thought of as the time of planting for the next season, those who have invested in period 1 receive $1+R$ for each unit invested. Farmers receive no additional income during this period: farmers can only consume by using their savings and, if they have sufficient wealth, purchase either one or two units of fertilizer at price p_{f2} per unit incurring *cost f* if they do so. We assume that borrowing is not possible, which is consistent with the fact that farmers report not having access to money to buy fertilizer when they need it, and with low levels of formal borrowing in this part of Kenya (i.e. Dupas and Robinson, 2009).

The cost of producing fertilizer is assumed to be one, so that under competition and laissez-faire, $p_{f1}=p_{f2}=1$. We will also consider the impact of heavy government subsidies of the type adopted by Malawi, under which $p_{f1}=p_{f2}=\frac{1}{3}$, as well as a small, time-limited subsidy in which $p_{f1}<1$ and $p_{f2}=1$.

In *period 3*, farmers receive income $Y(z)$, where *z* is the amount of fertilizer used. Define the incremental yield to fertilizer as $y(1)=Y(1)-Y(0)$ and $y(2)=Y(2)-Y(1)$.

We assume that the cost of reselling fertilizer is sufficiently large to discourage even impatient farmers from doing so. Maize on the other hand is completely liquid and can be converted to cash at any time. Empirically, maize is much more liquid than fertilizer and can be easily traded at local markets.

Assumptions on Parameters

We assume:

$$\beta_H y(1) > 1 + f \tag{1}$$

$$\frac{1}{1+\overline{R}} + \beta_L f > \beta_L y(1) > \frac{1}{3} + f \tag{2}$$

$$\frac{1}{3} < \beta_H y(2) < 1 \tag{3}$$

$$\frac{1}{3(1+\overline{R})} > \beta_L y(2) \tag{4}$$

[6] For instance, among farmers who were not offered free delivery or subsidized fertilizer, between 20 percent and 30 percent use top dressing fertilizer in a given season, but over 75 percent of those who do use fertilizer use it on their entire plot.

$$\underline{R} < f < \overline{R} \tag{5}$$

The first condition ensures that a patient farmer prefers using one unit of fertilizer to zero units of fertilizer, even if it has to be purchased right away. The second implies that an impatient farmer will prefer to consume now rather than to save in order to invest in fertilizer if the price is not heavily subsidized, even if it is possible to delay the decision and shopping costs of purchasing fertilizer to a future period, and even if the rate of return to the period 1 investment is high. The second condition also ensures that impatient farmers will buy fertilizer if it is heavily subsidized at two-thirds the cost of fertilizer, whatever the return to their period 1 investment opportunity. The third condition implies that the second unit of fertilizer is not profitable at the full market price (and that therefore no farmers will want to use more than one unit at full price), and also implies that patient farmers will prefer to use two units at a heavy subsidy of two-thirds of the cost of fertilizer (note that the third condition does not include the shopping cost f because the cost is incurred if the farmer uses any fertilizer and does not depend on the quantity used). The fourth condition implies that impatient farmers will not use a second unit of fertilizer even with a heavy subsidy of two-thirds the cost of fertilizer. The last condition (combined with the assumption that $\beta_H(1+\underline{R}) > 1$) implies that patient farmers with low returns would prefer to buy fertilizer today rather than save and but fertilizer later, if they were offered the opportunity to save the utility cost by buying today. However, patients farmers with low returns would prefer to save and buy fertilizer later.

These conditions match our empirical evidence on the rates of return to fertilizer (see Appendix) since we find that the return to the first unit of fertilizer is high, and that the incremental return to the second unit is negative at market prices. The assumptions are also consistent with evidence that the incremental return to the second unit at a two-thirds subsidy is higher than the return to the first unit at market prices, which suggests that patient farmers (who use fertilizer without a subsidy) would be likely to use two units at subsidized prices.

In subsections 3.2, 3.3, and 3.4 we consider farmer behavior under laissez-faire, in which $p_{f1} = p_{f2} = 1$; traditional heavy subsidies of the type adopted in Malawi in which $p_{f1} = p_{f2} = \frac{1}{3}$; and time-limited discounts under which $p_{f1} < 1$ and $p_{f2} = 1$.

3.2 Farmer Behavior Under Laissez-faire ($p_{f1} = p_{f2} = 1$)

Under laissez-faire, by assumptions (1) and (3), the proportion γ of farmers who are always patient in every period will always use exactly one unit of fertilizer. All will save at rate *R* in period 1 and buy fertilizer in period 2. By assumption (2), the proportion ψ of farmers who are always impatient will never use fertilizer. By our other assumptions, they will not avail themselves of the investment opportunity, whatever the return.

Now consider the problem of a stochastically present-biased farmer deciding whether (and when) to buy fertilizer. To solve the model, we work backwards, beginning with the problem of a farmer in period 2, who must choose between consuming one unit, or investing it in fertilizer. Assumption (1) implies that a farmer who has sufficient wealth and is patient in period 2 will use fertilizer. Assumption (2) implies that a farmer who is impatient in period 2 will not use fertilizer.

Now consider the problem of a farmer in period 1. First, observe that a farmer who is impatient in period 1 will consume *x*, and will not save: seen from period 1, the gain from investing in one unit of fertilizer is at best $\beta_L y(1) - \beta_L f$ (if the farmer ends up being patient and buys fertilizer), which, by assumption (2), is smaller than $\frac{1}{1+\overline{R}}$ (the loss in consumption in period 1 from saving to purchase fertilizer in period 2, for a farmer with a high return saving opportunity). This farmer will also not save since we assume that $\beta_L(1+\overline{R}) < 1$.

Now consider a farmer who is patient in period 1. Investing in fertilizer today dominates consuming everything today: the farmer's utility if she purchases one unit of fertilizer and consumes the rest is $x - 1 - f + \beta_H y(1)$, while her utility is x if she consumes everything today. By assumption (1), utility from buying fertilizer is higher than from not buying.

Now, in period 1, should a patient farmer buy the fertilizer right away, or plan to wait to do it in period 2? If a farmer who is patient today has a sufficiently high subjective probability of being patient again (and therefore a high probability of buying fertilizer in period 2), then it is best for her to wait, and thus realize the return on the period 1 investment and postpone paying the utility cost of buying fertilizer until period 2. To see that postponing may be optimal, note that if the farmer waits, ends up being patient in period 2, and thus purchases fertilizer (which she believes will happen with probability $\tilde{p}$), her utility is

$$x - \frac{1}{1+R} + \beta_H(y(1) - f) \tag{6}$$

If she ends up being impatient (which she believes will happen with probability $1 - \tilde{p}$), her utility is $x - \frac{1}{1+R} + \beta_H$.

Thus, waiting is optimal if:

$$x - \frac{1}{1+R} + \tilde{p}\beta_H(y(1) - f) + (1-\tilde{p})\beta_H > x - 1 - f + \beta_H y(1) \tag{7}$$

Rearranging, we find that the farmer will wait if:

$$f(1-\tilde{p}\beta_H)+\frac{R}{1+R}>\beta_H(y(1)-1)(1-\tilde{p}) \tag{8}$$

When $\tilde{p}=0$, the right hand side is equal to $\beta_H(y(1)-1)$. If we assume that the utility cost of using fertilizer is small enough that $\beta_H(y(1)-1)$ is larger than $f+\frac{R}{1+R}$, then the right hand side of the inequality is larger than the left hand side. Both sides of the inequality decline with $\tilde{p}$, but the right hand side is steeper. For $\tilde{p}=1$, the left hand side is larger than the right hand side (which is equal to zero). Thus, for each *R*, there is a $\tilde{p}^*(R)$ in the interval (0,1) such that for every $\tilde{p}>\tilde{p}^*(R)$, a farmer who is intending to use fertilizer later prefers to invest in the first period investment opportunity, and plans to buy fertilizer in period 2. It is easy to see that $\tilde{p}^*(R)$ is decreasing with *R*: the higher the return to the period 1 investment, the more valuable it is for the farmer to wait.

For the remainder of the model, we assume that $\tilde{p}>\tilde{p}^*(R)$. Note that since impatient period 1 farmers will not save in any case, it is not necessary that they believe they will be more patient in the future than they are in the present for this procrastination problem to arise. Instead, it is only necessary that patient farmers overestimate the probability that they will continue to be patient in the future. This tendency to believe that future tastes will more closely resemble current tastes than they actually will, termed "projection bias," has found considerable empirical support (see, e.g., Loewenstein, O'Donoghue, and Rabin, 2003, though that paper is not explicitly about discounting). Asheim (2008) and Eliaz and Spiegler (2006) model partial naivete in this way (that one's preferences will tend to stay what they are today.

3.3 Farmer Behavior Under Malawian-Style Heavy Subsidies ($p_{f1}=p_{f2}=\frac{1}{3}$)

In this model, stochastically present-biased farmers use fertilizer less often than they would like to, viewed from the ex ante perspective of period zero (i.e. from before the beginning of the rest of the game). One potential way to address underinvestment in fertilizer by this group would be through heavy, Malawian-style subsidies. However, under heavy subsidies, by assumption (3), farmers who are always patient will buy two units of fertilizer, and by assumptions (2) and (4), farmers who are always impatient, will buy one unit.

To solve for the behavior of the stochastically present-biased farmers in this case, we again work backwards from period 2. Assumption (2) implies that even farmers who are impatient in period 2 will use one unit of fertilizer if $p_{f2} = \frac{1}{3}$, while assumption (4) implies that impatient farmers will not want to use two units of fertilizer. A farmer who is impatient in period 2 will thus purchase exactly one unit if he has the wealth do to it and has not already purchased it earlier. A farmer who is patient in period 2 will buy two units of fertilizer if he has sufficient wealth and has not already done so.

Now consider the case of a stochastically present-biased farmer deciding whether to purchase fertilizer in period 1. First consider a farmer who is patient in period 1. Assumption (3) implies that a patient farmer wants to either purchase two units, or save enough to buy two units. Recall that it is efficient for farmers to purchase all of their fertilizer in a single period since by doing so they only need to pay the shopping cost of fertilizer once.

If a farmer buys two units of fertilizer immediately, her utility is:

$$x - \frac{2}{3} - f + \beta_H(y(2) + y(1)) \tag{9}$$

If the farmer instead plans to use fertilizer and saves at return *R* for future fertilizer use, she will purchase two units of fertilizer if she is patient in period 2. If, however, she is impatient in period 2 she will purchase only 1 unit. Thus, her expected utility from waiting is:

$$x - \frac{2}{3(1+R)} + \beta_H[y(1) - f + \tilde{p}y(2) + (1-\tilde{p})\frac{1}{3}] \tag{10}$$

Thus, she will prefer to save and plan to buy fertilizer later if:

$$\frac{2R}{3(1+R)} + f(1-\beta_H) > \beta_H(y(2) - \frac{1}{3})(1-\tilde{p}) \tag{11}$$

By reasoning similar to the case without a subsidy, there is a threshold $\tilde{p}^{**}(R)$ such that if $\tilde{p} > \tilde{p}^{**}(R)$, farmers who are patient in period 1 will wait until period 2 to purchase (it is also easy to see that the threshold decreases with *R*, so those with higher returns to investment in period 1 will be more likely to defer purchases). Depending on parameter values, $\tilde{p}^{**}(R)$ could be smaller or larger than $\tilde{p}^{*}(R)$. However, if the incremental return of the second unit of fertilizer at the subsidized price is greater or equal to the incremental return on the first unit of fertilizer at an unsubsidized price (i.e., $3y(2) \geq y(1)$), then $\tilde{p}^{**}(R)$ is larger than $\tilde{p}^{*}(R)$. Below we assume that $\tilde{p}$ is above both thresholds. Note that this is the best case scenario for heavy subsidy; if $\tilde{p}$ was lower than $\tilde{p}^{**}(R)$, the stochastically present-biased farmers who are patient in period 1 would all buy two units in period 1, and thus would all end up overusing fertilizer.

Now, consider a stochastically present-biased farmer who happens to be impatient in period 1. Given our assumptions, she wants to use one and only one unit of fertilizer at the heavily subsidized price. If she saves, she will thus save enough to purchase one unit, and she will always follow through on this plan. Therefore, there is no time inconsistency issue for her, and she will postpone buying fertilizer until period 2, and will buy exactly one unit.

Overall, a heavy subsidy will induce 100 percent fertilizer usage, but will cause the always-patient farmers and the stochastically present-biased farmers who happen to be patient in both periods to overuse fertilizer.

3.4 Impact of Time-Limited Discount ($p_{f1} < 1$ and $p_{f2} = 1$)

Consider the impact of a small discount on fertilizer, valid in period 1 only (which corresponds to the case in which $p_{f1} < 1$ and $p_{f2} = 1$). Consider a discount that is not large enough to make purchasing two units of fertilizer profitable, even for a patient farmer (we will see that this is a reasonable assumption since the necessary discount will be small).

A small discount on fertilizer will not change the behavior of farmers who are always impatient. They will still not buy fertilizer in either period. Always patient farmers will buy fertilizer. If we consider a discount close to the utility cost *f*, by assumption (5), those among them who have a high return opportunity will not take advantage of the small discount: they will invest, and buy fertilizer in period 2. But, also by assumption (5), those who have a low return opportunity will buy fertilizer at the discounted price.

Now consider the stochastically present-biased farmers. To make a patient period 1 farmer prefer purchasing fertilizer in period 1 to waiting to purchase fertilizer in period 2, the period 1 price needs to be such that:

$$x - \frac{1}{1+R} + \tilde{p}\beta_H(y(1) - f) + (1-\tilde{p})\beta_H < x - p_{f1} - f + \beta_H y(1) \tag{12}$$

If we define $p^*_{f1}(R)$ as the price that just satisfies this condition for a farmer with return to investment ***R***, then $p^*_{f1}(R)$ is given by:

$$p^*_{f1}(R) = f(\tilde{p}\beta_H - 1) + \beta_H(1-\tilde{p})(y(1) - 1) + \frac{1}{1+R}. \tag{13}$$

Note that when $\tilde{p}$ is close to 1, the price $p^*_{f1}(R)$ differs from 1 by a term proportional to the utility cost *f*, plus the foregone return to investment ($\frac{R}{1+R}$). The intuition is that the only additional costs that a farmer who is patient in period 1 has to immediately bear when choosing between investing one unit in the period 1 investment and buying one unit of fertilizer are the utility cost of purchasing the fertilizer, and the foregone investment opportunity. Since the period 1 farmer always plans to purchase fertilizer (and only must decide when he wants to purchase it), he will forego immediate consumption whether he plans to buy in period 1 or in period 2. Thus, the farmer does not need to be compensated for delaying consumption (other than for the foregone return to the period 1 investment); instead, he just needs to be compensated for incurring the decision and shopping cost f up front, rather than later, as well as for the foregone return to the period 1 investment. If the return to the period 1 investment is low, even a small discount, or a reduction in the utility cost (such as free delivery in period 1) may then be sufficient to induce the farmer to switch to buying fertilizer in period 1, instead of relying on her period 2 self to purchase fertilizer.

It is useful to compare the impact of a subsidy in period 1 to an unanticipated subsidy in period 2. An unanticipated period 2 subsidy will not affect the period 1 decision. An impatient period 2 farmer with sufficient wealth will decide to use fertilizer if $f - p_{f2} < \beta_L y(1)$. We denote the p_{f2} which just satisfies this inequality as p^*_{f2}. In order to induce fertilizer purchase, the discount now needs to be large enough to compensate an impatient farmer not only for incurring the utility cost f, but also for postponing consumption of p_{f2}. In the case in which $y(1)$ is close to $1 + f$ (so that the return to fertilizer is just positive at a fertilizer price of 1 from an *ex ante* perspective), the discount is approximately the cost of delaying one unit of consumption for one period for an impatient person (in contrast to a period 1 discount, which only must compensate the farmer for incurring the utility cost immediately and for the foregone period 1 investment). Thus, a small discount in period 1 will have as large of an effect on ultimate fertilizer use as a large discount in period 2.

3.5 Choice of Timing of Discount

Finally, let us examine what will happen if the farmer can commit in period 0 to the date at which she gets a small subsidy. Specifically, we consider a subsidy that is large enough to induce patient period 1 farmers to purchase fertilizer immediately but not large enough to induce impatient farmers to buy fertilizer. Suppose there is some fixed discount δ and the farmer can choose either $p_{f1} = 1 - \delta$ or $p_{f2} = 1 - \delta$. The price in the other period remains 1.

Consider first the farmers who are always patient. Because the return to the period 1 investment opportunity is always positive even when it is low, those farmers will always request the subsidy in the second period. In period 1, they will save in anticipation of buying fertilizer in period 2, and will follow through on that plan. Note that if some of the always patient farmers had zero return to cash (or even negative returns) and value getting the fertilizer early (for example because it gives them more flexibility over which period to apply the fertilizer[7]), they may instead request the discount in period 1. However, as we will show below, empirically very few farmers purchase fertilizer early when they are not given an incentive to do so.

Next, consider farmers who are always impatient. They are not planning to save or use fertilizer, so they are in principle indifferent on when the field officer returns with the discounted offer. In cases like this one in which the model suggests that people are indifferent we will assume that people make choices which are consistent with the empirically observed data. In particular, in the calibration below, we will assume these farmers all request the fertilizer in period 2. This makes sense since requesting a visit is costless to the farmer and if there is even a small probability that these farmers either are patient at that time, or have a cash windfall, they could benefit from the discount. This is an assumption for which we have no direct backing, but as we will see below, it appears to be consistent with our data.

Finally, consider the case of stochastically present-biased farmers. If the discount does not reduce the price of fertilizer below $p^*_{f1}(R)$, then farmers will always choose to take the discount in period 2, because the discount is not big enough to induce them to buy immediately in period 1 so the only way that they will buy fertilizer is if they happen to be patient in both periods. In what follows, we consider the case in which $\delta > 1 - p^*_{f1}(R)$.

In this case, if a farmer chooses to receive the discount in period 1, her expected utility is:

$$\beta_k[x + \tilde{p}(y(1) - p_{f1} - f)] \tag{14}$$

If she chooses to receive the discount in period 2, her expected utility is:

$$\beta_k[x + \tilde{p}^2(y(1) - \frac{p_{f1}}{1+R} - f) + \tilde{p}(1-\tilde{p})p_{f2}\frac{R}{1+R}] \tag{15}$$

Note first that current impatience does not affect this decision (since farmers discount all future periods at the same rate in period 0). Second, observe that when *R* is close to zero (and because $\tilde{p} > 0$ from our assumption that $\tilde{p} > p$), the farmer will choose the discount in period 1: since the period 0 farmer does not care whether the period 1 or period 2 farmer pays the

[7] This is unlikely to be the case with fertilizer, since the type of fertilizer used at planting (DAP) is a different chemical than the type used at top dressing (CAN).

utility cost, the only gain to delaying the decision is the return to the period 1 investment opportunity. However, as R increases, the value of delaying the discount to period 2 increases, and if R is high enough, the farmer will choose to receive the discount in period 2. Thus, depending on whether the returns to period 1 opportunity are high or low, the farmers will choose to receive the returns in period 1 or in period 2.

3.6 Summary

To summarize, the model gives rise to the following predictions.

1. In the absence of financial incentives to do so, farmers never buy fertilizer in advance (after harvest): they buy it just before they need it.

2. Some farmers will make plans to use fertilizer but will not subsequently follow through on their plans.

3. Farmers will switch in and out of fertilizer use.

4. A small reduction in the cost of using fertilizer offered in period 1 will increase fertilizer purchase and usage more than a similar but unexpected reduction offered in period 2. The subsidy only needs to be large enough to compensate the farmer for incurring the decision and shopping cost up front, rather than later, as well as for the foregone returns to the period 1 investment. A larger subsidy will be needed in period 2 to induce the same increase in usage as a small subsidy in period 1.

5. When farmers are offered an *ex-ante* choice between a small discount in period 1 or the same discount in period 2, some farmers will choose the discount in period 1. For a positive R, time-consistent farmers would always prefer to receive the discount in period 2. Therefore, if there are farmers who choose the discount in period 1 and follow through by buying fertilizer, this suggests that some farmers are time inconsistent, and have at least some awareness of it.

4. Testing the Model

As noted above, there is some empirical evidence in favor of predictions 1, 2, and 3. First, in November-December 2009, we visited a sample of farmers involved in a pilot for a new program we are currently running (which is briefly described in the conclusion) and asked them if they had used fertilizer over the past 3 seasons. Of those who had purchased fertilizer on their own, we asked them to report the time at which they bought fertilizer. Only 0.4-2% of these farmers (2-4% of those who used fertilizer in a given season) had bought fertilizer early (see Table 1). Second, in a sample of farmers who participated in the demonstration plot program, two-thirds of those who had made plans to use fertilizer do not end up carrying through with these plans (prediction 2). Third, we also find significant switching between using and not using fertilizer (prediction 3): a regression of usage during the main growing season on usage in the main growing season previous year (as well as a full vector of controls) gives an R^2 of only 0.25. Suri (2009) similarly finds considerable switching in and out of fertilizer use in a nationally representative sample.

Of course, we may not want to attach much weight to the declared intentions of farmers and therefore discount the evidence on prediction 2. Similarly, other stories could generate switching in and out of fertilizer use. We therefore focus on predictions 4 and 5 below. These predictions suggest that some simple interventions could have large impacts on fertilizer use. In particular, a time-limited reduction in the cost to acquiring fertilizer could increase fertilizer use. We collaborated with International Child Support (ICS) – Africa, a Dutch NGO that has had a long-lasting presence in Western Kenya, and is well known and respected by farmers, to design and evaluate such a program using a randomized design. Since the model suggests that the cost reduction should be roughly proportional to the fixed cost of acquiring fertilizer, we implemented the reduction by offering free delivery of fertilizer. To test the predictions of the model, we implemented multiple versions of the program, and compared them with alternative interventions, such as a fertilizer subsidy and reminder visits.

4.1. The SAFI Program

The main program was called the Savings and Fertilizer Initiative (SAFI) program. The program was first piloted with minor variations over several seasons on a very small scale with farmers who participated in the on-farm trials described in DKR (2008). In these pilot programs, we focused on acceptance of the program and willingness to buy from ICS. In 2003 and 2004, the program was implemented on a larger scale, and we followed farmers to determine its impact on fertilizer usage.

Basic SAFI

In its simplest form, the SAFI program was provided at harvest, and offered free delivery of any combination of planting or top dressing fertilizer. The basic SAFI program worked as follows: a field officer visited farmers immediately after harvest, and offered them an opportunity to buy a voucher for fertilizer, at the regular price, but with free delivery. The farmer had to decide during the visit whether or not to participate in the program, and could buy any amount of fertilizer. To ensure that short-term liquidity constraints did not prevent farmers from making a decision on the spot, farmers were offered the option of paying either in cash or in maize (valued at the market price). To avoid distorting farmers' decision-making by offering free maize marketing services, farmers also had the option of selling maize without purchasing fertilizer. Across the various seasons, the majority (63 percent) of those who purchased fertilizer through the program bought with cash, which suggests that maize was not overvalued in the program. Participating farmers chose a delivery date and received a voucher specifying the quantity purchased and the delivery date. Choosing late delivery would provide somewhat stronger commitment to use fertilizer since fertilizer can potentially be re-sold (at some cost) and the vouchers themselves were non-transferable.

The basic SAFI program could have reduced the utility cost of fertilizer use, and thus reduced procrastination, in two ways. First, it can save a trip to town to buy fertilizer, which is typically about a 30 minute trip from the farmers' residences. Suri (2009) argues that distance to a fertilizer provider accounts for her surprising finding that those who would have had the highest return to using fertilizer are some of the least likely to use it. Fertilizer is typically available in major market centers around the time it is needed for application for maize crops. Since most farmers travel to market centers occasionally for shopping or other errands, they could pick up fertilizer when they go to town for other reasons.[8]

Second, and more speculatively, by requiring an immediate decision during the field officer's visit and offering a simple option, the program may have reduced time spent thinking through which type of fertilizer to use, and in what quantity.

SAFI with *ex-ante* choice of timing

To test prediction 4 of the model, in the second season of the experiment, farmers were visited *before* the harvest (period 0 in our model) and offered the opportunity to decide when they wanted to be visited again later to receive a SAFI program: farmers were told that, during this visit, they would have the opportunity to pay for fertilizer and to choose a delivery

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[8] Most farmers who bought fertilizer through the SAFI program did not buy enough that they would have had to pay for transportation. On average, farmers who bought fertilizer through the SAFI program bought 3.7 kilograms of fertilizer (at a total cost of 135 Kenyan shillings, or $1.92), and only 1 percent of farmers bought more than 10 kilograms. It would take the average farmer roughly a half-hour to walk to town, buy fertilizer, and walk back. For a farmer who makes $0.16 per hour (as in Suri 2009), the SAFI program would save her a bit less than 5 percent of the cost of the fertilizer bought by the average farmer. This cost would be substantially smaller if the farmer were going to town anyway and so would not miss any work time.

date. As discussed earlier, in a standard exponential model, farmers would be expected to choose a late visit: those who want to use fertilizer would then invest in period 1, and be prepared for fertilizer purchase in period 2. If farmers were present-biased but completely naïve, they would also have chosen a late delivery date, since they expect to be patient in the future, and would then plan to invest in period 1 and purchase fertilizer in period 2. This would lead to low ultimate adoption. In our model, stochastically present-biased farmers whose period 1 investment opportunity has a high return also choose a late delivery date to avoid forgoing the returns of the investment, but those who have a low return investment opportunity in period 1 will choose an early delivery date, to increase the probability that they eventually use fertilizer.

4.2 Experimental Design

The two versions of the SAFI program were implemented as part of a randomized field experiment, allowing for a test of the model. Farmers were randomly selected from a sample frame consisting of parents of fifth and sixth grade children in sixteen schools in Kenya's Busia district. Though the program was offered to individuals, data was collected on all of the plots farmed by the household, including those not controlled by the farmer who was offered the program. We consider a household as using fertilizer if fertilizer was used on any plot in the household.

The experiment took place over two seasons. In the first season (beginning after the 2003 short rain harvest, in order to facilitate fertilizer purchase for the 2004 long rains season), a sample of farmers was randomly selected to receive the basic SAFI program. The randomization took place at the individual farmer level after stratification by school, class, and participation in two prior agricultural programs (a program to provide farmers with small amounts of fertilizer in the form of "starter kits" they could use on their own farm, and a program to set up demonstration plots on the school property).

In the following season (the 2004 short rains), the program was repeated, but with an enriched design to test the main empirical predictions of the model in Section 3 as well as some predictions of alternative models. All treatment groups were randomized at the individual level after stratification for school, class, previous program participation, and treatment status in the previous season's treatments.

The second season interventions were structured as follows. First, a new set of farmers was randomly selected to receive a basic SAFI visit. Second, another group of farmer was offered SAFI with *ex ante* choice of timing (as described above).

Third, to test the hypothesis that small reductions in the utility cost of fertilizer have a bigger effect if offered in period 1, another group of farmers was visited close to the time fertilizer needs to be applied for top dressing (approximately 2 to 4 months after the previous season's harvest, the equivalent of period 2 in our model), and offered the option to buy fertilizer with free delivery. To calibrate the effect of a discount, a fourth group of farmers was visited during the same period, and offered fertilizer at a 50 percent discount. This allows us to compare the effect of a 50 percent subsidy to the effect of the small discount offered by the SAFI program. In all of these programs, farmers could choose to buy either fertilizer for planting, top dressing, or both. However, one caveat to bear in mind is that in the late visits many farmers had already planted and could only use top dressing fertilizer in that season. If farmers preferred using fertilizer at planting, however, they could have bought planting fertilizer for use in the next season, so a standard model would suggest that these farmers should have taken advantage of the discount for later use.

Finally, in each of the intervention groups as well as in the comparison group, a random subset of farmers was offered the option to sell a set quantity of maize at a favorable price to the field officer before the program took place. The objective of this additional treatment was to test the alternative hypothesis that the SAFI program was just seen by the farmers as a safer way to protect their savings than available alternatives. The purchase of maize put some cash in the hands of the farmers who accepted the offer, which is more liquid than maize, and thus arguably easier to waste. If the main reason why farmers purchased fertilizer under the SAFI program is because of an aversion to holding liquidity, the purchase of maize should have encouraged them to take up SAFI. Under our model, this would make no difference, however.

Appendix Figure 1 summarizes the experimental design for this second season, and Table 2 summarizes the predictions of the model:

Table 2. Predictions of Model

	Period 0 (1)	Period 1 (2)	Period 2 (3)	Units Fertilizer Used (4)
A. Laissez Faire				
Always Impatient	-	Consume y	Consume 0, do not purchase fertilizer	0
Always Patient	-	Consume $y - \frac{1}{1+R}$	Consume 0, purchase and use 1 unit of fertilizer	1
Hyperbolic				
- If patient in both periods 1 and 2	-	Consume $y - \frac{1}{1+R}$	Consume 0, purchase and use 1 unit of fertilizer	1
- If patient in period 1 & impatient in period 2	-	Consume $y - \frac{1}{1+R}$	Consume 1, do not purchase fertilizer	0
- If impatient in period 1	-	Consume y	Consume 0, do not purchase fertilizer	0
B. SAFI				
Always Impatient	-	Consume y	Consume 0, do not purchase fertilizer	0
Always Patient	-	Consume $y - \frac{1}{1+R}$	Consume 0, purchase and use 1 unit of fertilizer	1
Hyperbolic				
- If patient in both periods 1 and 2	-	Consume $y - 1$, purchase fertilizer	Consume 0, use 1 unit of fertilizer	1
- If patient in period 1 & impatient in period 2	-	Consume $y - 1$, purchase fertilizer	Consume 0, use 1 unit of fertilizer	1
- If impatient in period 1	-	Consume y	Consume 0, do not purchase fertilizer.	0
C. 2/3 Subsidy				
Always Impatient	-	Consume $y - \frac{1}{3(1+R)}$	Consume 0, purchase and use 1 unit of fertilizer	1
Always Patient	-	Consume $y - \frac{2}{3(1+R)}$	Consume 0, purchase and use 2 units of fertilizer	2
Hyperbolic				
- If patient in both periods 1 and 2	-	Consume $y - \frac{2}{3(1+R)}$	Consume 0, purchase and use 2 units of fertilizer	2
- If patient in period 1 & impatient in period 2	-	Consume $y - \frac{2}{3(1+R)}$	Consume $\frac{1}{3}$, purchase and use 1 unit of fertilizer	1
- If impatient in period 1	-	Consume $y - \frac{1}{3(1+R)}$	Consume 0, purchase and use 1 unit of fertilizer	1
D. SAFI with ex ante Timing Choice				
Always Impatient	Request SAFI in period 2	Consume y	Consume 0, do not purchase fertilizer	0
Always Patient	Request SAFI in period 2	Consume $y - \frac{1}{1+R}$	Consume 0, purchase and use 1 unit of fertilizer	1
Hyperbolic (if low return)				
- If patient in both periods 1 and 2		Consume $y - 1$, purchase fertilizer	Consume 0, use 1 unit of fertilizer	1
- If patient in period 1 and impatient in period 2	Request SAFI in period 1	Consume $y - 1$, purchase fertilizer	Consume 0, use 1 unit of fertilizer	1
- If impatient in period 1		Consume y	Consume 0, do not purchase fertilizer.	0
Hyperbolic (if high return)				
- If patient in both periods 1 and 2		Consume $y - \frac{1}{1+R}$	Consume 0, purchase and use 1 unit of fertilizer	1
- If patient in period 1 and impatient in period 2	Request SAFI in period 2	Consume $y - \frac{1}{1+R}$	Consume 1, do not purchase fertilizer.	1
- If impatient in period 1		Consume y	Consume 0, do not purchase fertilizer.	0

4.3 Data and Pre-Intervention Summary Statistics

The main outcome of interest is fertilizer use (irrespective of where farmers bought the fertilizer from), with fertilizer purchase through the program as an intermediate outcome. It is important to focus on use, rather than only fertilizer purchase through the program: some farmers who were planning to use fertilizer anyway will buy fertilizer under SAFI, so the effect on purchase is not equivalent to the effect on use. And for some of our tests (for example the impact of a late subsidy), the impact on purchase may seem low because some farmers have made their fertilizer purchase decisions already, and do not need fertilizer anyway. This will not affect the data on usage.

We have administrative data from ICS on fertilizer purchase under the program. Data on fertilizer use was collected at baseline (before the 2003 short rains harvest) for that season and for the previous season. We later visited farmers to collect fertilizer usage data for the three seasons following the first SAFI program (i.e., both seasons in 2004 and one season in 2005). Attrition was low and similar across treatment groups (see Appendix Table 3). The baseline data also includes demographic information and some wealth characteristics of the sampled households. In households where different members farm different plots (which is typically the case in polygamous households), we asked each member individually about fertilizer use on her own plot, and we asked the head of the household (the husband) about fertilizer use on each plot. The data is aggregated at the household level.

Table 3 shows descriptive statistics. In season one, of those that could be tracked for a followup usage survey (see Appendix Table 3 for attrition results), 204 farmers were eligible to participate in the basic SAFI program, and 673 farmers constituted a comparison group. In season two, 179 farmers were eligible to participate in the basic SAFI program; 208 were eligible for the SAFI with *ex ante* choice of timing; 135 were offered fertilizer at the normal retail price with free delivery at top dressing time; and 135 were offered fertilizer at half price with free delivery at top dressing time. An additional 102 farmers served as a comparison group.

There were some relatively minor pre-treatment differences between groups in each season. In season one 43 percent of both SAFI and comparison groups had previously ever used fertilizer. However, there were some pre-treatment differences in other observables: comparison group farmers had 0.6 more years of education (a difference significant at the 10 percent level), and were about 5 percentage points less likely to live in a home with mud floors, mud walls, or a thatch roof (and two of these differences are significant at the 10 percent level).[9]

In season two, the comparison group was more likely to have used fertilizer prior to the program (Table 3, panel B). The point estimate for previous fertilizer usage is 53 percent for the comparison group, but only between 37 percent and 44 percent for the various treatment groups. Turning to the bottom of the Table, these differences are significant at the 5 percent level for the 2 SAFI groups and the subsidy group. In addition, the comparison group appears better educated, though those differences are not statistically significant.

These pre-treatment differences are in general relatively minor and would, if anything, bias our estimated effects downwards. We present results with and without controls for variables with significant differences prior to treatment—in all cases, the inclusion of these controls does not substantially affect our results.

5. Results

5.1 The SAFI Program

The SAFI program was popular with farmers. In season one, 31 percent of the farmers who were offered SAFI bought fertilizer through the program (Table 3, Panel A). In season two, 39 percent of those offered the basic version of SAFI bought fertilizer through the program (Table 3, Panel B), as did 41 percent of those offered SAFI with *ex ante* choice of timing. The fraction of farmers who purchase fertilizer is of course not equal to the impact of the program on use: some program farmers who were going to use fertilizer anyway presumably bought fertilizer through SAFI, to take advantage of the free delivery. In addition, some farmers may not have used fertilizer purchased through SAFI on their maize crop: they could have kept it, sold it, or used it on other crops. In the 2005 adoption questionnaire 76.6 percent of the farmers who purchased fertilizer under SAFI reported using it on their own plot, 7.3 percent on the plot of their wife or husband, and 8.1 percent reported saving the fertilizer for use in another season. The remainder reported that they had used the fertilizer on a different crop (4.8 percent) or that the fertilizer had been spoiled (1.6 percent).

[9] Online Appendix Table 3 suggests that attrition patterns were similar across groups. Regressions of indicators for appearance in the pre-treatment background and post-treatment fertilizer adoption questionnaires on being sampled for treatment yield no significant differences between groups. Overall, 1,230 farmers were sampled, and we obtained adoption data for 924 of them (75.1 percent). There were few refusals. Nearly all of those who do not appear in the dataset were not known by other parents in the school and so could not be traced, or were not at home when ICS enumerators visited their homes.

Overall, in both seasons, the SAFI program had a significant and fairly sizeable impact on fertilizer use. In season one, 45 percent of farmers offered the SAFI program report using fertilizer in that season, compared to 34 percent of those in the comparison group.[10] The 11 percentage point difference is significant at the 1 percent level (see Table 3, panel A). In season two (the 2004 short rains), the basic SAFI program increased adoption by 10.5 percentage points (Table 3, panel B).

Table 4 confirms these results in a regression framework. For season one, we run regressions of the following form:

$$y_i = \alpha + \beta_1 T_{1i}^{LR} + X_i'\gamma + \epsilon_i \tag{16}$$

where y_i is a dummy indicating whether the household of farmer i is using fertilizer, T_{1i}^{LR} is a dummy indicating whether farmer i was offered the SAFI program in season one, and X_i is a vector of control variables for the primary respondent in the household, including the school and class from which the parent was sampled, educational attainment, previous fertilizer usage, gender, income, and whether the farmer's home has mud walls, a mud floor, or a thatch roof, and whether the farmer had received a starter kit in the past.[11] The Table presents fertilizer usage statistics for the season of the program and the two subsequent seasons.

Both specifications suggest a positive and significant program impact on fertilizer adoption in season one: the specification with sparser controls suggests that the program led to an 11.4 percentage point increase in fertilizer adoption, while one with fuller controls suggests a 14.3 percentage point increase. Both are significant at the 1 percent level. Given a baseline usage rate of 24.0 to 24.4 percent among comparison farmers in that season (shown on the last row of Table 4, Panel A), these effects represent a 47 to 60 percent increase relative to the comparison group.

The remaining columns show that the SAFI program does not have persistent impacts: in the two subsequent seasons (the short rains of 2004 and the long rains of 2005), fertilizer usage drops back to the level of the comparison group. This lack of persistence would be expected under our model since the only role of SAFI in this program is to induce the farmer

[10] Throughout this paper, we focus on usage of fertilizer rather than the quantity of fertilizer used because there is substantial underlying variation in the quantity of fertilizer used by farmers, which would make it difficult to pick up effects in average quantities. The standard deviation in kilograms of fertilizer used is 53, whereas farmers that bought fertilizer through the SAFI program bought only 3.7 kilograms, on average.

to buy the fertilizer early in the season, rather than later. In contrast, in learning by doing models, and models of credit constraints, inducing use in one period would in general affect the state variables of wealth and knowledge and thus future behavior.

Panel B shows the impact of the SAFI program in the second season on fertilizer usage. The regression has the same form as for the season one regression, but includes dummies for all the other SAFI treatments, and controls for a dummy for long rains treatment status ($T_{1_i}^{LR}$):[12]

$$y_i = \alpha + \sum_{k=1}^{4} \beta_i^{SR} T_{ki}^{SR} + \beta_5 B_i^{SR} + \beta_6 B_i^{SR} T_{1i}^{SR} + X_i' \gamma + \epsilon_i \qquad (17)$$

In this regression, $T_{1_i}^{SR}$ represents the basic SAFI program, and $T_{2_i}^{SR}$ through T_{4i}^{SR} represent the other treatment groups, respectively, SAFI with *ex ante* choice of timing; the visit at top-dressing time that offered fertilizer at full price; and the visit at top-dressing time that offered fertilizer with a 50 percent subsidy. The dummy B_i^{SR} is a dummy equal to 1 if the farmer was offered the opportunity to sell maize at an above-market price during the post-harvest visit. As before, we present regressions with and without full sets of controls, for season 1 (the season before the programs were offered), season 2 (the season during which the programs were offered), and season 3 (one season after the programs were offered).

The first row in panel B, columns (3) and (4) show the impact of the basic SAFI program on adoption of fertilizer in the season it was offered. Without control variables, the point estimate for the effect (16.5 percentage points) is even larger than in the first season. The point estimate of the effect increases slightly to 18.1 percentage points when controlling for other covariates. Given a baseline usage rate of 24.1 to 26 percent in the comparison group, these effects represent proportional increases of 63 to 75 percent. Columns (1) and (2) show that, reassuringly, there is no difference in adoption across SAFI groups in the season before it was offered. Columns (5) and (6) replicate the results found for the first season: the impact of the SAFI program is not persistent.

These results suggest that a properly timed reduction in the utility cost of using fertilizer can substantially increase adoption. Free delivery saves the farmer a trip to the nearest market town to get the fertilizer and, since taking advantage of free delivery required deciding on the

[11] The starter kit was an intervention conducted in a previous season, which we discuss in a companion paper (Duflo et al., 2010). It involved distributing a small quantity of fertilizer to farmers to let them experiment with it.

[12] Treatment was stratified by prior treatment status.

type and quantity of fertilizer to order during the visit, the program may have reduced the cost of time spent making these decisions and thus the chance of procrastination on those costs. It is therefore plausible that the reason why this program increased adoption is time inconsistency and procrastination as posited in the model.

The model predicts that those stochastically hyperbolic farmers who do not have a high return period 1 investment opportunity will request early delivery. The results for the SAFI with *ex ante* timing choice are consistent with the idea that a sizeable fraction of farmers have a preference for commitment. Almost half of the farmers (44 percent) offered SAFI with timing choice asked the field officer to come back immediately after harvest, and 46 percent of those actually bought fertilizer. Of the remaining farmers, 52 percent requested late delivery and 39 percent of those who requested late delivery eventually purchased fertilizer; the remaining 4 percent declined to participate in the SAFI program. These results are consistent with the model, which predicts that as long as $\tilde{p} > 0$, even quite naïve farmers may want to induce their period 1 selves to purchase fertilizer by requesting the offer of free delivery early unless they have a high return to their period 1 investment opportunity. In contrast, time consistent farmers who attach any probability to using fertilizer would never choose a period 1 discount (so long as the returns to investment are positive).

If the parameters are such that farmers with high return investment opportunities prefer late delivery, our model predicts that fewer farmers should end up using fertilizer under SAFI with choice of timing then under the basic SAFI, in which free delivery is restricted to period 1. This is because the stochastically hyperbolic farmers with high returns to the period 1 investment opportunity buy fertilizer in period 1 under the basic SAFI, but choose a period 2 discount under SAFI with timing choice, and some of those choosing a late delivery date wind up impatient in period 2 and do not buy fertilizer. Empirically, we find that the impact of the "SAFI with *ex ante* timing choice" on fertilizer use is if anything slightly larger than the basic SAFI program. Overall, 41 percent of farmers purchased fertilizer under SAFI with *ex ante* timing choice (compared to 39 percent without timing choice), and more farmers reported using fertilizer under SAFI with *ex ante* timing choice (47 percent versus 38 percent), although these differences are not significant (see the second row of panel B, Table 4). Thus, the model fails to fully account for this result.[13]

[13] A possible interpretation for the larger effect of SAFI with timing choice is that stochastically hyperbolic farmers may differ in their discount rates. In the model, we assume that impatient farmers will never use fertilizer and that all patient farmers value the return to fertilizer higher than their alternative period 1

Note, however, the fact that the effect of the SAFI with *ex ante* choice of timing is as large as the effect of the basic SAFI helps rule out an alternative explanation for the popularity of basic SAFI: an "impulse purchase" effect in which when farmers are offered fertilizer at harvest, when they have money and maize, they feel "flush" and buy it without thinking, as an impulsive purchase (under this hypothesis, if the field officers had offered beer or dresses at that point, they would have bought those). This seems reasonable given that the pre-harvest season is known as the "hungry season" in Kenya, and the field officer does not offer to sell the farmer anything immediately in the SAFI with *ex ante* timing choice. Instead, the field officer offers an opportunity to buy fertilizer in the future: thus, the decision on when to call the field officer back is unlikely to be an impulsive decision.

Another piece of evidence suggesting that the purchase of fertilizer is not simply an impulse purchase of farmers who feel "flush" is that farmers were no more likely to purchase fertilizer under SAFI when they had cash on hand. To test this, we ran a small test in which the field officer offered to purchase some maize at a favorable price before offering SAFI. Under this condition, while 50.7 percent of farmers sold maize, 41 percent of those sampled to sell maize purchased fertilizer under SAFI (compared to 38% of those not sampled to sell maize), and thus the effects of the "bought maize" dummy on fertilizer use, as well as its interaction with the SAFI dummy, are insignificant and small (the adoption impact is in fact negative and insignificant once regression adjusted). This also helps rule out the possible alternative explanation that SAFI is used by farmers as a safe savings option: if this were the case, one would have expected them to be more likely to take advantage of SAFI when they had cash on hand.

Thus, the impact of the two versions of the SAFI program suggest that time inconsistency and procrastination may play a role in explaining low fertilizer use. To rule out alternative explanations of the role SAFI played in inducing farmers to use fertilizer, we tried two alternative programs with random subsets of farmers, which allow us to test alternative hypotheses and additional predictions of the model.

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investment opportunity (even if the return to that investment is high). However, it may be that some farmers may be (stochastically) intermediately patient (with a discount rate between β_L and β_H) and will commit to fertilizer purchase in period 1 only if their period 1 investment has a low return, if they happen to be intermediately patient in period 1. These farmers will only use fertilizer if they end up being patient (or intermediately patient) in period 2, and so will request a late SAFI date and will never buy fertilizer in the basic SAFI but may buy in the SAFI with timing choice. Another possibility is that by warning farmers in advance, we give them a bit more time to be ready with cash when the field officer arrives.

5.2. Free Delivery, Free Delivery with Subsidy

Both versions of the SAFI program offered free delivery. Our interpretation is that the resulting decrease in the utility cost of using fertilizer is small enough that it would be unlikely to induce large changes in fertilizer use in a purely time-consistent model. However, an alternative explanation is that the free delivery is a substantial cost reduction, and this is why it induces farmers to use fertilizer. To test this hypothesis, and to test prediction three in our model, we offered free delivery later in the season (corresponding to period 2). We also offered a 50 percent subsidy to a separate, randomly selected group of farmers at the same point in the season.

As shown in Table 3, panel B, free delivery later in the season did not lead to fertilizer purchases from ICS as often as under the SAFI program (20 percent under free delivery vs. 39 percent in the SAFI). The difference between the fraction of farmers who purchase fertilizer under free delivery late in the season and any of the other groups is significant at the 1 percent level, while all the other groups have similar levels of adoption. When offered a 50 percent subsidy late in the season, 46 percent of farmers bought fertilizer.[14]

Table 4 (columns 3 and 4) presents the impacts of the different programs on fertilizer use, and shows very consistent results: the offer of free delivery late in the season increased fertilizer use by 9 to 10 percentage points (not significant), less than half the increase due to the SAFI program (or SAFI with *ex ante* timing choice). Our model predicts that free delivery late in the season will have no adoption impact, since those farmers who are patient and take up this offer would have bought fertilizer on their own anyway (so purchase with free delivery would entirely crowd out purchases that would have happened anyway). Indeed, we cannot reject the hypothesis that the program had no effect on fertilizer usage, although the positive point estimate may suggest that there are some people with an intermediate level of patience, for whom free delivery is sufficient to induce fertilizer use. Importantly, however,

[14] As mentioned earlier, one issue when interpreting these results is that fertilizer can be used either at planting or at top dressing (when the plant is knee high), or both. Since farmers in the subsidy and full price groups were visited after planting, it was too late for them to buy planting fertilizer for use in that season (however, while very few of the farmers who were offered fertilizer at full price at top dressing bought planting fertilizer, 17 percent of the farmers offered the subsidy actually bought planting fertilizer—presumably to either sell it or use it in a future season. By contrast, SAFI farmers could choose between planting and top dressing fertilizer, or could get both. This would complicate interpretation of the comparison between the programs if fertilizer at top dressing were not effective. However, our estimates suggest that the average rate of return to using fertilizer at top dressing only is between 54 and 102 percent on an annualized basis. We view the decision between using fertilizer at planting rather than top dressing as a timing decision similar to when to buy.

the difference between the percentage point increase due to SAFI and the percentage point increase due to free delivery has a *p*-value of 0.08. Thus, we can reject that the timing of the offer does not matter.

Interestingly, a 50 percent subsidy in period 2 significantly increases fertilizer use by 13 to 14 percentage points, which is very similar to the impact of the free delivery at harvest time (and statistically undistinguishable). This is consistent with prediction three of the model.

Although these results are indicative that a subsidy on delivery cost is not enough to induce large increases in fertilizer use if it comes late in the season, they could still be consistent with a model in which all farmers are fully time-consistent, but farmers are just indifferent between using and not using fertilizer, and many farmers have low returns to investment. Without the subsidy early in the season, they decide not to use fertilizer and to consume instead. When the fertilizer arrives later, they no longer have resources needed to purchase fertilizer. In section 7 below, we return to this possible explanation, and discuss some additional results which help ruling it out.

6 Calibration and Welfare Comparisons

In this section we calibrate the model to determine the fraction of farmers who are stochastically hyperbolic, the probability that they are patient each period, and the proportion of stochastically hyperbolic farmers who have a high return to the period 1 investment and so choose to take SAFI at a later date. We then show that the calibrated model yields reasonable predictions for the fraction of farmers who never use fertilizer and for ultimate fertilizer usage among farmers who choose early and late delivery when given *ex ante* timing choice under SAFI. This is of course not a final proof that the model is correct, or the only possible model that could fit the facts (we examine some alternative explanations in the next section). Nevertheless, it is a useful check of its internal logic and consistency with the broad facts. Finally, we use the calibrated model to conduct an illustrative exercise in which we compare welfare between laissez faire, heavy Malawian-style subsidies, and small, time-limited discounts.

6.1 Calibrating the Model

Recall that a fraction γ of farmers are always patient and always use fertilizer and a fraction ψ of farmers are always impatient and never use fertilizer.[15] The remaining fraction $1-\gamma-\psi=\phi$ of farmers are stochastically hyperbolic (as described above), and patient in any period with probability p.

To solve for the parameters of the model, note that the model implies that the fraction of farmers using fertilizer without the SAFI program is $\phi p^2+\gamma$ (since stochastically hyperbolic farmers use fertilizer only if patient in both periods 1 and 2). Taking the average comparison group usage from the two SAFI seasons in Table 4 (among the pure comparison group who took part in none of the treatments), this quantity is about 0.24 (Columns 1 and 3). Under SAFI, all stochastically hyperbolic farmers who are patient in the first period will use fertilizer, as will all time-consistent farmers. Hence the proportion of farmers using fertilizer will be $\phi p+\gamma$. Using the average of the regression-adjusted estimates with full controls in Table 4, this percentage is about 0.24+0.162=0.402 in our dataset.[16]

A third equation gives the percentage of non-program farmers that we would expect to find using fertilizer in the three seasons that we follow them. This percentage is given by $\gamma+\phi(p^2)^3$, and is equal to 0.14 in our dataset. Solving these equations gives us that $p=0.38$, $\phi=0.69$, $\gamma=0.14$, and $\psi=0.17$.

These estimates are in line with our finding that 57 percent of comparison farmers do not use fertilizer in any season in which we observe them (we followed farmers for three years after the first SAFI). Given the parameters above, we would predict that $\psi+\phi(1-p^2)^3=0.17+0.69*0.855^3=0.60$ of farmers would not use fertilizer in those three seasons.

Note that these estimates were derived solely from data on average use with and without SAFI, not from looking at the correlation in fertilizer use over time, so this provides a first piece of evidence on the fit of the calibration.[17]

Another check of the model is the fraction of farmers who end up using fertilizer under the 50 percent subsidy. If a 50 percent subsidy is enough to induce stochastically hyperbolic

[15] An alternative interpretation is that these farmers have land that is not suitable for fertilizer. Note that under this interpretation, heavy subsidies would be less attractive, because such subsidies could lead these farmers to use fertilizer even if the social planner would not do so.

[16] We calibrate using the comparison group means in Columns 1 and 3 because the pure comparison group is very small in size and those specifications contain a larger number of observations.

[17] It should be noted, however, that the model cannot match the large percentage of farmers who report having never used fertilizer. One possible reason for this is that farmers may have forgetten that they had used fertilizer long in the past.

farmers who were patient in period 1, but impatient in period 2, to use fertilizer, the fraction of farmers using fertilizer under a 50 percent subsidy in period 2 should be $\phi p + \gamma$ which, we have seen, is 40 percent (since the same formula gives us the fraction of farmers who use fertilizer under SAFI). Empirically, the fraction who buy fertilizer is 46 percent in our dataset (Table 3), though the percentage that end up actually using on their maize crop is lower (0.240+0.127=36.7 percentage points).

To calibrate λ, the proportion of farmers with a high-return period 1 investment opportunity, note that under the model, if the value of the discount is large enough to induce those among the stochastically hyperbolic with low-return period 1 investments to choose early delivery but not to induce those with high-return investments to do so, then a proportion $(1-\lambda)\phi$ of farmers choose early delivery and the remainder ask for late delivery. Since 96 percent of those offered SAFI with timing choice accepted it, and 44 percent of those offered it chose early delivery, $(1-\lambda)\phi$ = 0.44/0.96 = 0.46, implying $\lambda = 0.33$.

Note that this calculation assumes that both the always patient and always impatient farmers request delivery in period 2. However, under the model, impatient farmers should be indifferent, so this assumption could be questioned. Moreover, if some farmers had negative returns, some patient farmers may also request early delivery.

There is however, an alternative way to calibrate λ which does not rely on this assumption, using the fraction of farmers who chose to buy fertilizer under SAFI without choice of timing. Under SAFI, all the stochastically hyperbolic farmers who are patient in period 1, as well as the always patient farmers who have a low return opportunity, buy fertilizer. This fraction is equal to $\phi p + (1-\lambda)\gamma$. Empirically, this is about 0.35 in our data, which would imply a λ of about 0.37. The fact that the two ways of calculating λ give very similar answers suggests that the assumption that only stochastically hyperbolic farmers request early delivery is indeed plausible (alternatively, with λ=0.33 the predicted fraction of SAFI buyers would be 0.36, very similar to the 0.35 that we observe). We will see below that this calibration is also consistent with eventual fertilizer use in this treatment.

Using $\lambda = 0.33$, the model predicts that $\frac{\gamma+\lambda\phi p^2}{\gamma+\lambda\phi+\psi} = 32\%$ of those choosing late delivery end up actually buying fertilizer, which is within the confidence interval of our estimate (39%). Since the model predicts that the only farmers who will request early delivery will be the stochastically hyperbolic farmers who prefer committing immediately to saving, we would expect that a proportion $p = 38\%$ of farmers requesting early delivery will eventually purchase. Our point estimate is 46 percent, and again the predicted figure is within the 95% confidence interval.[18]

However, due to the fact that the eventual purchase rate is higher than predicted both for farmers who request early and late delivery, the model under-predicts the adoption impact of the SAFI with *ex ante* timing choice. The model predicts that $\phi((1-\lambda)p+\lambda p^2)+\gamma=35\%$ would end up using fertilizer in this variant (less than the basic SAFI), whereas in reality 47 percent did (more than the basic SAFI). The 35 percent predicted percentage lies outside the confidence interval of our point estimate, and is further from our calibrated estimate than the other figures. As we discussed earlier, this could be explained by a richer version of the model with heterogenous patience, or with factors outside the model (for example, the fact that farmers are warned in advance). Note, however, that this result supports our assumption that only the stochastically hyperbolic farmers request early delivery: if any of the people who requested early delivery were either always patient or always impatient (for whom the program would have no impact on ultimate fertilizer use), the ultimate effect on fertilizer use would be predicted to be even lower (so even further from the truth).

The last two numbers we can check against the prediction of the model are the purchase and usage of fertilizer in the late free delivery treatment. The model predicts that a proportion $\phi p^2+\gamma=24\%$ of farmers purchase when offered free delivery later in the season. This is slightly more than the 20% who actually purchased, most likely because some farmers had already purchased fertilizer. On the other hand, the model underpredicts the actual adoption impact of late free delivery: it predicts no difference between usage under free delivery late in the season, and under laissez-faire, but we find an (insignificant) 9% increase in usage. However, as shown above, the model predicts that $\phi p+\gamma=40\%$ of farmers buy and use fertilizer at half price, which is very close to both the adoption and purchase figures.

Finally, one other check on the plausibility of the estimation is whether it implies an implausibly low discount rate for impatient farmers, β_L. The condition for an impatient farmer to not use fertilizer is $1-f>\beta_L y(1)$. Since the mean seasonal rate of return to fertilizer is 15.0-22.7 percent (see Appendix Table 2), this implies that for f close to 0, $\beta_L\leq 0.81$. This estimate is in line with an estimate from Laibson, et al. (2007), who estimate a β of around 0.7.

[18] Of course, if an equal fraction of always patient and always impatient farmers requested early delivery, we would find the same result.

6.2 Laissez Faire, Heavy Subsidies, or Nudges?

The calibrated model can be used to provide a rough comparison of the welfare impacts of laissez faire, heavy subsidies, and small nudges (this is similar in spirit to the exercise carried out in O'Donoghue and Rabin (2006) to evaluate optimal taxes when some agents are not fully rational). These calculations are closely tied to the model, which makes a number of simplifying functional form assumptions, and it would therefore be a mistake to attach much significance to the precise magnitudes of our welfare comparisons. Nevertheless, we think that this exercise is useful in illustrating that in general, if a significant number of farmers have preferences of the type we model here, and if technological conditions are such that most farmers would want to use fertilizer from an ex ante perspective, welfare comparisons between heavy subsidies and laissez faire will be sensitive to parameters, but that nudges may fairly robustly offer an improvement over laissez faire.

For this calculation, we assume that f is small (effectively zero). We assume that the marginal cost of government funds is 20 percent[19] and consider a two-thirds subsidy similar to that adopted in Malawi. We also use estimates from the experiments described in the background section and in the appendix, which imply that the incremental return to a second unit of fertilizer is at most -52.5 percent at market prices, but at least 41.1 percent under a two-thirds subsidy (Appendix Table 2).

Under the model, a two-thirds subsidy will induce all farmers to use fertilizer but will cause patient farmers to use two units of fertilizer. Unfortunately, testing this prediction directly is difficult: in particular it is necessary to measure actual on-farm usage since farmers who do not intend to use fertilizer might buy fertilizer and then resell it since heavy subsidies would be sufficient to cover the transaction costs, but farmers may not want to report to us that they have done this.[20]

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[19] Warlters and Auriol (2005) estimate a marginal cost of public funds of 17 percent in Sub-Saharan Africa. Kleven and Kreiner (2006) report similar estimates for OECD estimates. The marginal cost of public funds could be substantially higher, depending on the choice of taxes implemented and other parameters (i.e., Ballard and Fullerton, 1992).

[20] Though the subsidy in our experiment was 1/2 the price of fertilizer, rather than 2/3, we take a first pass at examining usage from those getting the subsidy by regressing the quantity of fertilizer used, conditional on using some fertilizer, on receiving the subsidy. The coefficient is insignificant, but suggests that conditional on using some fertilizer, those getting the subsidy used 40% more than those who didn't. If fertilizer displays normal diminishing returns, we would expect a larger quantity impact for a bigger subsidy. We do not have the data to know whether this increase in fertilizer use is due to a higher intensity of fertilizer application on the land where fertilizer was used, or to using fertilizer on a higher proportion of land.

We assume that only patient farmers (the always patient farmers and those stochastically hyperbolic farmers who end up being patient in both periods) will use two units of fertilizer at a two-thirds subsidy (as discussed below, if even impatient farmers use two units of fertilizer under a two-thirds subsidy, heavy subsidies would yield even lower welfare). These categories comprise a proportion $0.14 + 0.69 * 0.38^2 = 24\%$ of farmers. The remaining 76 percent use one unit of fertilizer.

The relative welfare ranking of laissez faire and heavy subsidies will be sensitive to parameter values within our model, and more generally, to the functional form assumptions we use. In particular, it will be very sensitive to the profitability of fertilizer, since the benefits of inducing fertilizer use by impatient farmers and the costs of overuse by patient farmers are key elements of the welfare calculation. Nonetheless, the model and calibration illustrate several important points, which should hold more generally beyond the particular context of our model: the cost of subsidy-induced fertilizer overuse among rational farmers rises faster than linearly in the subsidy. Small-time limited subsidies therefore create fairly modest distortions from overuse, so to the extent they are able to overcome commitment and procrastination problems for stochastic hyperbolic farmers, they are attractive relative to laissez faire if these problems prevent even a modest proportion of the population from undertaking profitable investments. However, they do not induce all stochastic hyperbolic farmers to use fertilizer, so if the proportion of rational farmers is small enough, heavy subsidies perform better than both laissez faire and small, time-limited subsidies.

To compare welfare under laissez faire, heavy subsidies, and small, time-limited subsidies, we first normalize welfare under laissez faire to zero, and then calculate the costs and benefits of heavy subsidies and small, time-limited subsidies relative to laissez faire. With a 20 percent marginal cost of funds, the deadweight loss of financing a two-thirds fertilizer subsidy will be 0.2*0.67*[2*0.24+0.76] = 0.166. The deadweight loss from farmers inefficiently using a second unit of fertilizer is $0.24 * r_{inc}$, where r_{inc} is the incremental rate of return from increasing the quantity per hole from 1 to 2 units (equivalent to increasing fertilizer usage from ½ teaspoon to 1 teaspoon in our framework), which we set to -0.525.

The benefit of this subsidy is $(y(1) - 1 - f)(\psi + \phi(1 - p^2))$, where the first term is the benefit from the first unit of fertilizer and the second term is the proportion of farmers who would not use fertilizer without the subsidy.

By contrast, the SAFI program described in this paper provided farmers a much smaller, time-limited discount, arguably worth less than 10 percent of the cost of fertilizer. Since

SAFI would be taken up by the 14 percent of farmers who always use fertilizer and the stochastically hyperbolic farmers who are patient in period 1, the total deadweight cost incurred in financing these subsidies is therefore $0.1 * 0.2(\gamma + p\phi) = 0.008$. In addition, there is a further loss of $(\gamma + p\phi)(\lambda\overline{R} + (1 - \lambda)\underline{R})$ from farmers inefficiently forgoing the period 1 investment opportunity. Also note that if some farmers have very high rates of return investment opportunity, they would not take up SAFI. The benefit would be $(y(1) - 1 - f)(\phi(p - p^2))$.

The overall welfare effect clearly depends on the estimated returns to fertilizer. Therefore, in Table 5, we present welfare under two estimates of the profitability of fertilizer (from Appendix Table 2). If we use relatively high estimates of the additional labor required to use fertilizer, the overall welfare benefit of SAFI is 0.016, compared to -0.178 for heavy subsidies. At lower estimated of the additional labor hours associated with fertilizer, the benefits are 0.029 and -0.119, respectively. For the particular parameter values we examine, the costs of heavy subsidies relative to laissez faire exceed their benefits, but this conclusion will clearly be sensitive to assumptions on parameters on profitability.

Note that various aspects of the model and the parameter values we have chosen for this calculation are favorable to heavy subsidies. The impact of heavy subsidies would look worse if: (1) the marginal cost of public funds is higher than 20 percent in developing countries or if providing subsidies encourages costly rent-seeking, (2) subsidies induce impatient farmers to overuse fertilizer, (3) the never patient farmers in our model actually have land that is unsuitable to fertilizer such that the returns to fertilizer are lower for them than for other farmers, (4) overusing fertilizer has additional environmental costs (5) even heavy subsidies do not induce the never patient to adopt fertilizer or (6) returns to half a teaspoon of fertilizer are lower.

A key conclusion from the calibration is that if there is a sufficient proportion of procrastinating farmers, small, time-limited subsidies are likely to be preferable to a laissez faire policy. For example, assume that 17% of farmers are always impatient, as in our calibration. If the amount of additional labor required to use fertilizer is relatively low (so that the estimated net returns are relatively high), the small-subsidy policy dominates laissez-faire as long as at least 24% of farmers are stochastically hyperbolic (the remaining 59% are always patient). If the amount of additional labor is relatively high, the small subsidy policy dominates laissez faire as long as at least 40% of farmers are stochastically hyperbolic.

Given that returns to fertilizer are likely to be heterogenous and difficult to assess for any given area or crop, an important advantage of using small subsidies is that even if returns to fertilizer are in fact negative, such policies will not induce large distortions, since they will not induce fertilizer use: nobody will take advantage of the policy. Since small, time-limited subsidies fairly robustly deliver greater welfare than laissez faire, but the ranking of heavy subsidies and small time-limited subsidies is sensitive to parameter values, small subsidies may be attractive for policy makers who are concerned about the risks of heavy subsidies or concerned that political economy factors may make fertilizer subsidies hard to remove once they are in place.

7 Alternative Explanations

The empirical results in this paper are consistent with the predictions of the model in section 2. We now review three alternative models that could have similar qualitative predictions, and report additional evidence on whether these models can explain the data.

7.1 All farmers are time-consistent

An alternative explanation for the large impact of the free delivery of fertilizer is that farmers are time-consistent, but the fixed cost of acquiring fertilizer is high, so fertilizer is only worth purchasing in large enough quantities such that credit constraints bind. In this case, free delivery of fertilizer from a trusted source may increase purchase substantially. Alternatively, if the returns are lower than we have estimated them to be, and farmers are close to indifferent about using fertilizer, the small SAFI discount may be sufficient to induce investment.

Under this alternative model, unannounced subsidies at planting or top dressing time may not increase purchase and use of fertilizer as much as announced subsidies, because farmers would have already consumed in period 1.[21] On the other hand, free delivery later in the season would increase usage as much as free delivery at harvest *if the free delivery were announced in advance*. This suggests an additional treatment in which the free delivery in period 2 is announced in period 1. Prior to implementing the full scale SAFI program described above, ICS conducted a number of small pilot SAFI programs with farmers who

[21] This is not strictly true in our model where patient farmers may decide to save anyway, but it would be true if returns to saving were generally low compared to discount rates.

had previously participated in demonstration plots on their farms (see DKR (2008) for a description of the demonstration plot programs). Three randomly assigned variants were conducted in different seasons in different villages, each with its own comparison group. Farmers were always informed about the program immediately after harvest, but the timing of the free delivery differed across years. In the first variant, pilot SAFI program farmers were asked to pay for the fertilizer right away (as in the basic SAFI program). In the second variant, farmers were informed about the program, asked whether they wanted to order fertilizer, and given a few days before the field officer returned to collect the money and provide the voucher. The third variant was similar, but the field officer only went back to collect the money just before planting.

For the three pilot SAFI programs, data is available only on purchase under the program, not on eventual fertilizer use. Results are presented in Table 6.[22] In all the versions of the program, between 60 percent and 70 percent of the farmers initially ordered fertilizer. These rates are substantially higher than under the full-scale SAFI program, most likely because these were farmers with whom ICS had been working intensely for several months and because in the pilot SAFI, the field officer harvested with the farmer and SAFI was offered on the very day of the harvest. In the full-scale version of the SAFI program, the visit took place in the week following the harvest. When the field officer did not immediately collect the payment, fertilizer purchase falls significantly: from Table 6, when farmers are given a few days to pay, the fraction who actually purchase fertilizer falls from 64 percent to 30 percent; when they are given a few months, purchase falls to 17 percent. These differences in purchase rates remain significant when controlling for various background characteristics.

These different SAFI programs were conducted among the parents of children in different schools. To confirm that the SAFI options, rather than other differences between parents in different communities, explain the differential take-up results, 52 farmers in the same schools were offered the three options in the same season. Though the sample size is small, the results follow the same stark pattern: among farmers who had to pay for fertilizer the day after the harvest, 47 percent purchased fertilizer. Among farmers who had to wait a few days to pay, 47 percent of farmers initially ordered fertilizer, but only 29 percent eventually purchased fertilizer. Among farmers who had to wait several months to pay, 50 percent initially made an order but none eventually purchased fertilizer. While this extreme

[22] The different SAFI groups look very similar on observables (see Appendix Table 4).

result is probably not representative of what would happen in a larger sample, the sharp decline across the options is evident.

7.2 Farmers are Fully Sophisticated, but Resale of Fertilizer is Possible

Another alternative hypothesis is that farmers are stochastically hyperbolic (as in our model) but fully sophisticated. Since these farmers fully anticipate the probability that they will be impatient in the future, they would like to tie their hands even in the absence of SAFI—in particular, these farmers could buy fertilizer on their own immediately after harvest and hold it until it is needed. However, if resale of fertilizer is possible, with reasonably high probability these farmers may end up being so impatient in the future that they will sell the fertilizer to increase consumption. Thus, if these farmers buy fertilizer, they would pay a purchase cost f in period 1, and a resale cost in period 2, but would still end up without fertilizer. Anticipating this, fully sophisticated farmers who are patient in period 1 may prefer to delay buying fertilizer until period 2 to see if they are still patient, rather than to buy in period 1 and risk incurring resale costs.

Data on the choice of delivery time under the basic SAFI program provides some evidence against this hypothesis. Recall that when farmers purchased vouchers through SAFI, they chose a date on which the fertilizer would be delivered by the NGO. Therefore, farmers could only receive fertilizer at the pre-chosen delivery date.[23] This feature was introduced precisely to be useful to farmers needing strong commitment. Under the hypothesis above, patient sophisticated farmers would take advantage of the SAFI program to lock up resources to protect them from impatient period 2 farmers by requesting delivery just before the time that fertilizer needs to be applied. In practice, however, over 90 percent of farmers requested almost immediate fertilizer delivery (this could be because they thought there was some hazard rate of ICS bankruptcy or because they wanted to keep the flexibility of selling back the fertilizer in case of a serious problem, but in any case, there does not seem to be strong motivation to guard against resale by future selves). Furthermore, the evidence suggests that almost nobody sold the fertilizer after buying it. While our data is self-reported, and farmers may have felt bad admitting to the field officer that they re-sold the fertilizer, field officers were very careful to emphasize to farmers that this was not a subsidy program, and that the farmers were free to do whatever they wanted with the fertilizer they bought under the program. Of farmers that bought through the SAFI program, 83.9 percent report having used

[23] Farmers could also come to the ICS office if they lived near town, but in practice very few farmers did this.

the fertilizer on their plot or that of a spouse, 8.1 percent still had the fertilizer and planned to use it in another season, 4.8 percent used it on another crop, and 1.6 percent of farmers reported that the fertilizer had been spoiled. Thus, unless farmers lied about fertilizer use, the upper bound on the fraction re-sold is probably 1.6 percent. This suggests that while selling fertilizer is possible in theory, it is probably sufficiently costly in practice, and involves sufficient time delays and fixed costs of searching for buyers that even impatient period 2 farmers do not think it is worthwhile.

Further evidence against the hypothesis that the main benefit of the program for farmers was the opportunity of strong commitment it offered comes from the farmers from whom an ICS field officer offered to purchase some maize at a premium price at the very beginning of the SAFI visit (this program was described above). Since cash is more liquid than maize, farmers might particularly want to get strong commitment when they have cash on hand. However, as discussed above, farmers who were asked to sell their maize were no more likely to take up the SAFI program than other farmers.

7.3 Farmers are Absent-Minded

Another possible alternative explanation is that while farmers are aware of their own time inconsistency problems, they deal with so many competing pressures and issues that they simply do not remember to buy fertilizer early in the season even when they know they should (see, for instance Banerjee and Mullainathan, 2008b). Under this hypothesis, the field officer's visit acts as a reminder to stochastically present-biased farmers who happen to be patient in period 1 to buy fertilizer while they are still patient.

A "reminder" intervention provides little support for this explanation. During collection of post-treatment adoption data in 2005 (two seasons after the initial SAFI treatment, and one season after the second), field officers visited farmers right after harvest (at the same time the SAFI intervention would normally be conducted), and read farmers a script, reminding them that fertilizer was available at nearby shops and in small quantities, and that we had met many farmers in the area who had made plans to use fertilizer, but subsequently did not manage to implement them. The field officers then urged the farmers to buy fertilizer early if they thought they were likely to have this problem (note that this intervention would also increase fertilizer take up under our model if it raised $\tilde{p}$, making farmers more aware of their time inconsistency problem). To measure the impact of the intervention, field officers surveyed farmers at the time of top dressing for the following season to determine if they had purchased fertilizer or planned to. The reminder intervention did not significantly affect whether the farmers either bought or planned to buy top dressing fertilizer by the time they were surveyed (see Table 7).

8. Conclusion

The model we propose in this paper suggests small, time-limited discounts can potentially help present-biased farmers commit to fertilizer use, and thus overcome procrastination problems, while minimally distorting the investment decisions of farmers who do not suffer from such problems. Empirically, small, time-limited reductions in the cost of purchasing fertilizer at the time of harvest induce substantial increases in fertilizer use, comparable to those induced by much larger price reductions later in the season.

For expositional clarity our model is cast in terms of two types and two discrete levels of fertilizer application. However, generically one might expect there to be a range of potential levels of fertilizer application, a range of types of farmers, and a range of rates of return to fertilizer due to differing soil and weather conditions. Generically, high levels of subsidy will carry the potential of serious distortions relative to smaller levels of subsidy for at least some farmers.

Small, time-limited subsidies may therefore be attractive. They would increase fertilizer use for present-biased farmers for whom higher fertilizer use would be optimal, but would create minimal distortions for farmers who are satisfying their first order conditions for fertilizer application initially, unlike heavy subsidies. They would thus presumably be environmentally more attractive than heavy subsidies, and would be less likely to encourage heavy rent-seeking. They would have no impact if fertilizer had low returns: if the return to fertilizer use were negative or heterogeneous among farmers, only those farmers who would benefit from fertilizer use at almost market price would buy them in this context. However, these small, time-limited discounts do not achieve the first best, since farmers who are impatient in period 1 will not take advantage of such a discount. Indeed, it is worth noting that while the SAFI program boosted fertilizer use substantially from pre-existing levels, take-up remained quite low.

It is important to note that we have not considered the whole spectrum of potential policies in our calibrated model. The "heavy subsidy" policy could be made more attractive by limiting the quantity of fertilizer available to each farmer. Doing this would help avoid overuse of fertilizer and would also help address the problem of high fiscal costs of heavy subsidies because people would use lower quantities. Another potential policy would be to provide farmers with bank accounts that could allow them to "soft commit" to fertilizer but would not force farmers to completely tie up their money, for instance by making money available in case of other emergencies. The transactions costs of such accounts would fall in an intermediate category—far less liquid than holding cash on hand, but more liquid than reselling fertilizer that has already been purchased. To the extent that liquidity is valuable, these types of bank accounts could be preferable to a targeted discount.[24] Choosing among these options will depend to a large extent on issues of administrative feasibility and cost.

While the results are intended to be illustrative, rather than definitive, calibration suggests that, under the assumptions we have made here (and our estimate of the average rate of returns to fertilizer use), small, time-limited subsidies are likely to yield higher welfare than either heavy subsidies or laissez faire. However, that calibration ignored the administrative and staff costs of implementing either type of program. With those costs figured in, the SAFI program itself, with its delivery of small quantities of fertilizer to farmers by field officers, is too expensive (in terms of staff costs) to be cost effective and therefore could not be directly adopted as policy. However, preliminary results from a pilot program designed to mimic key elements of SAFI without individual free delivery (and thus expensive visits to farms) suggest that time-limited coupons for small discounts on fertilizer could cost effectively increase take-up. In 2009, during school meetings or after church service, coupons for a reduction of 15 percent in the price of up to 25 kilograms of fertilizer were distributed to 329 individuals at several schools and churches. Coupons had to be redeemed at a set of identified shops in the region with a deadline set to coincide to a short time after harvest. Field officers observed fertilizer sales in these selected locations to ensure that the coupons were actually redeemed by farmers. Overall, 30 percent of farmers who received the coupon purchased fertilizer (most of them at the end of the redemption period). The average quantity purchased was about 10 kilograms, corresponding to a subsidy about 1 dollar per farmer. Since we have yet to examine the adoption impact of the program, we cannot know how much of this was offset in reduced purchases from other sources. We also cannot rule out the possibility of some resale of fertilizer, though as described above, given the discount at which fertilizer is re-sold, a strategy of purchase and resale is unattractive. Nevertheless, the popularity of this pilot version of the time-limited subsidy (with rates of

[24] Accounts similar to these are being implemented in Malawi by Xavier Giné, Jessica Goldberg, and Dean Yang.

take up just below SAFI, at negligible administrative costs) is encouraging that a time-limited small discount program on fertilizer may be an effective, easy to scale up, policy to encourage fertilizer use without distorting decision making and inducing excessive use of fertilizer. In future work, we are planning to test these policies on a substantially larger scale and monitor their impact on fertilizer use.

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Table 1. When do Farmers Purchase Fertilizer?

	Mean (1)	Observations (2)
A. 2009 Long Rains Harvest		
Farmer Used Top Dressing Fertilizer during Long Rains 2009	0.583	139
Farmers Bought Top Dressing Fertilizer Immediately after the Previous Harvest	0.022	137
Of those who used fertilizer		
Bought Fertilizer Immediately after the Prior Harvest	0.038	79
B. 2009 Short Rains, 2009 Long Rains, and 2008 Short Rains		
Always used fertilizer	0.180	139
Always Bought Fertilizer at Least 2 months before the time it was needed for the 2008 SR the 2009 SR, and the 2009 LR	0.004	139
Of those Who Used Fertilizer in at Least 2 Seasons		
Always Bought Fertilizer at Least 2 months before the time it was needed for the 2008 SR the 2009 SR, and the 2009 LR[1]	0.022	46

Notes: Data is collected from a sample of farmers participating in agricultural pilots in Western Kenya.

[1]The variable for always buying early is non-missing only for those who use top dressing fertilizer in at least 2 seasons.

Table 3. SAFI & Subsidy Programs

Panel A. SAFI for Season 1	SAFI (1)	Comparison (2)	Difference (3)
SAFI Season 1			
Income (in 1,000 Kenyan shillings)	2.02	2.84	-0.82
	(5.39)	(6.80)	(0.55)
Years Education Household Head	6.60	7.19	-0.59
	(3.96)	(4.13)	(0.337)*
Household had Used Fertilizer Prior	0.43	0.43	0.00
to Season 1	(0.50)	(0.50)	(0.04)
Home has Mud Walls	0.92	0.87	0.04
	(0.28)	(0.33)	(0.03)
Home has Mud Floor	0.90	0.85	0.06
	(0.30)	(0.36)	(0.029)*
Home has Thatch Roof	0.58	0.51	0.07
	(0.50)	(0.50)	(0.041)*
Observations	191	646	837
Post Treatment Behavior			
Household bought fertilizer through	0.31	-	-
program	(0.46)	-	-
Observations	242	-	
Adoption in Season of Program	0.45	0.34	0.11
	(0.50)	(0.47)	(0.038)***
Observations	204	673	877

Note: In each Panel, means and standard deviations for each variable are presented, along with differences (and standard errors of the differences) between each treatment group and the comparison group. The comparison group in Panel A consists of those not sampled for SAFI, even if they had been sampled for other treatments (see text). We report background characteristics for only those who could be traced for at least 1 post-treatment adoption survey.
Exchange rate was roughly 70 Kenyan shillings to US $1 during the study period.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 3 (continued). SAFI & Subsidy Programs

Panel B. Season 2 Treatments	SAFI (1)	SAFI with Timing Choice (2)	Subsidy at Top Dressing (3)	Full Price and Free Delivery at Top Dressing (4)	Comparison (5)
SAFI Season 2					
Means					
Baseline Characteristics					
Income (in 1,000 Kenyan shillings)	2.82	2.76	2.29	2.94	2.19
	(7.55)	(7.41)	(4.02)	(6.95)	(4.17)
Years Education Household Head	6.96	6.84	7.12	7.09	7.47
	(4.02)	(4.10)	(4.14)	(4.07)	(4.21)
Household had Used Fertilizer Prior	0.41	0.40	0.37	0.45	0.53
to Season 1	(0.49)	(0.49)	(0.49)	(0.50)	(0.50)
Home has Mud Walls	0.88	0.88	0.86	0.90	0.88
	(0.32)	(0.32)	(0.35)	(0.30)	(0.32)
Home has Mud Floor	0.82	0.87	0.85	0.89	0.87
	(0.39)	(0.33)	(0.36)	(0.31)	(0.34)
Home has Thatch Roof	0.54	0.53	0.51	0.54	0.50
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Observations	211	213	147	145	121
Post Treatment Behavior					
HH bought fertilizer through program	0.39	0.41	0.46	0.20	-
	(0.49)	(0.49)	(0.50)	(0.40)	-
Observations	208	207	145	143	-
Adoption in Season of Program	0.38	0.47	0.41	0.33	0.28
	(0.49)	(0.50)	(0.49)	(0.47)	(0.45)
Observations	179	208	133	135	102
Differences Between Treatment and Comparison					
Baseline Characteristics					
Income	0.63	0.57	0.10	0.75	-
	(0.77)	(0.76)	(0.53)	(0.75)	-
Years Education Household Head	-0.51	-0.63	-0.36	-0.38	-
	(0.47)	(0.47)	(0.51)	(0.51)	-
Household had Used Fertilizer Prior	-0.12	-0.13	-0.16	-0.08	-
to Season 1	(0.057)**	(0.056)**	(0.060)**	(0.06)	-
Home has Mud Walls	0.00	0.00	-0.02	0.02	-
	(0.04)	(0.04)	(0.04)	(0.04)	-
Home has Mud Floor	-0.05	0.01	-0.02	0.02	-
	(0.04)	(0.04)	(0.04)	(0.04)	-
Home has Thatch Roof	0.03	0.03	0.01	0.03	-
	(0.06)	(0.06)	(0.06)	(0.06)	-
Observations	211	213	147	145	-
Post Treatment Behavior					
Adoption in Season of Program	0.105	0.197	0.139	0.051	-
	(0.059)*	(0.059)***	(0.063)**	(0.060)	-
Observations	179	208	133	135	-

Note: In each Panel, means and standard deviations for each variable are presented, along with differences (and standard errors of the differences) between each treatment group and the comparison group. We report background characteristics for only those
who could be traced for at least 1 post-treatment adoption survey.
The number of observations is the number of farmers in each group with non-missing adoption data in the season of the program.
Exchange rate was roughly 70 Kenyan shillings to US $1 during the study period.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4. Adoption for Parents Sampled for SAFI & Subsidy Programs

	Used Fertilizer Season 1		Used Fertilizer Season 2		Used Fertilizer Season 3	
Panel A. 2004 Season 1 Treatments	(1)	(2)	(3)	(4)	(5)	(6)
SAFI Season 1	0.114	0.143	0.007	0.007	0.006	0.01
	(0.035)***	(0.038)***	(0.041)	(0.044)	(0.037)	(0.041)
Starter Kit Farmer	0.059	0.080	0.024	0.005	-0.009	-0.027
	(0.042)	(0.046)*	(0.047)	(0.051)	(0.043)	(0.048)
Starter Kit Farmer * Demonstration Plot	-0.026	-0.061	0.024	-0.005	0.004	-0.031
School	(0.060)	(0.066)	(0.068)	(0.075)	(0.063)	(0.070)
Demonstration Plot School	0.006	0.441	0.362	0.464	0.362	0.437
	(0.314)	(0.435)	(0.460)	(0.463)	(0.335)	(0.465)
Household had Used Fertilizer Prior	0.369	0.315	0.319	0.284	0.281	0.251
to Season 1	(0.031)***	(0.035)***	(0.035)***	(0.040)***	(0.033)***	(0.037)***
Male		0.012		0.014		0.026
		(0.033)		(0.037)		(0.034)
Home has mud walls		-0.193		-0.183		-0.021
		(0.081)**		(0.091)**		(0.085)
Education primary respondent		0.004		-0.004		0.015
		(0.004)		(0.005)		(0.005)***
Income in past month		0.004		0.006		0.002
(in 1,000 Kenyan shillings)		(0.003)		(0.003)**		(0.003)
Mean Usage Among Season 1 Comparison	0.244	0.240	0.311	0.328	0.395	0.421
Mean Usage Among Pure Comparison Group	0.296	0.227	0.182	0.111	0.423	0.381
Observations	876	716	756	626	902	734

	Used Fertilizer Season 1		Used Fertilizer Season 2		Used Fertilizer Season 3	
Panel B. 2004 Season 2 Treatments	(1)	(2)	(3)	(4)	(5)	(6)
SAFI Season 2	-0.009	0.042	0.165	0.181	-0.024	-0.005
	(0.053)	(0.057)	(0.061)***	(0.066)***	(0.056)	(0.061)
SAFI Season 2 with Choice	-0.014	0.030	0.207	0.216	-0.027	0.003
on Date of Return	(0.048)	(0.053)	(0.055)***	(0.060)***	(0.050)	(0.056)
Half Price Subsidy Visit at Top Dressing	-0.035	-0.039	0.142	0.127	0.023	0.041
	(0.052)	(0.057)	(0.059)**	(0.065)*	(0.054)	(0.061)
Full Price and Free Delivery Visit at Top Dressing	-0.065	-0.034	0.096	0.104	-0.053	-0.031
	(0.052)	(0.058)	(0.059)	(0.066)	(0.054)	(0.061)
Bought Maize	-0.002	-0.011	-0.042	-0.079	0.002	-0.014
	(0.043)	(0.048)	(0.049)	(0.054)	(0.046)	(0.050)
Bought Maize * SAFI Season 2	-0.048	-0.073	-0.085	-0.057	0.005	-0.011
	(0.075)	(0.082)	(0.087)	(0.096)	(0.080)	(0.087)
Household had Used Fertilizer Prior	0.369	0.316	0.325	0.283	0.278	0.248
to Season 1	(0.031)***	(0.035)***	(0.035)***	(0.040)***	(0.033)***	(0.037)***
Male		0.01		0.014		0.028
		(0.033)		(0.037)		(0.035)
Home has mud walls		-0.197		-0.197		-0.017
		(0.081)**		(0.091)**		(0.086)
Education primary respondent		0.004		-0.003		0.015
		(0.004)		(0.005)		(0.005)***
Income in past month		0.004		0.006		0.003
(in 1,000 Kenyan shillings)		(0.003)		(0.003)**		(0.003)
Mean Usage Among Season 2 Comparison	0.372	0.329	0.260	0.241	0.479	0.472
Mean Usage Among Pure Comparison Group	0.296	0.227	0.182	0.111	0.423	0.381
Observations	876	716	756	626	902	734

Note: Dependent variable is an indicator equal to 1 if the farmer adopted planting or top dressing fertilizer in the given season. All regressions include school controls, and a control for whether the farmer was a parent of a Standard 5 or 6 child (see text). Panel B also include controls for the Season 1 Treatments listed in Panel A. Two comparison group means are listed in the bottom of each Panel: those who did not participate in any trial that season, and those who did not participate in any trial in either season.
Exchange rate was roughly 70 Kenyan shillings to US $1 during the study period.
Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5. Estimated Welfare Under 2/3 Subsidy and SAFI Program

	2/3 Subsidy (1)	*SAFI* (2)
A. Relatively Little Extra Labor Time Required to Use Fertilizer[1]		
Return to 1/2 Teaspoon Fertilizer	0.227	
Incremental Return from Going from 1/2 Teaspoon to 1 Teaspoon Fertilizer	-0.525	
Deadweight Loss of Financing Program	-0.166	-0.008
Deadweight Loss Cost of Using 2nd Unit of Fertilizer	-0.126	0.000
Benefit	0.173	0.037
Overall Welfare	-0.119	0.029
B. Relatively Much Extra Labor Time Required to Use Fertilizer		
Return to 1/2 Teaspoon Fertilizer	0.150	
Incremental Return from Going from 1/2 Teaspoon to 1 Teaspoon Fertilizer	-0.525	
Deadweight Loss of Financing Program	-0.166	-0.008
Deadweight Loss Cost of Using 2nd Unit of Fertilizer	-0.126	0.000
Benefit	0.114	0.024
Overall Welfare	-0.178	0.016

Notes:
[1]See Appendix Table 2 for details on these calculations. The hours needed for fertilizer in Panel A are calculated by using the labor hours in Suri (2009) for farmers who use top dressing fertilizer only. The hours in Panel B are calculated for those farmers who use any type of fertilizer.
See profitability appendix for formulas used for calculations.
Welfare under laissez-faire normalized to 0.
We use the same incremental return to the 2nd unit of fertilizer in both Panels because the estimated return differs little for farmers who use top dressing only and farmers who use any type of fertilizer.

Table 6. Acceptance of Various Commitment Savings Pilot Products (SAFI Program)

	--------------- All Pilots ---------------				Versions Offered in Same Season			
	Initially Accepted	*Initially Accepted*	*Bought Fertilizer*	*Bought Fertilizer*	*Initially Accepted*	*Initially Accepted*	*Bought Fertilizer*	*Bought Fertilizer*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SAFI Variants								
option 1: take-it-or-leave-it	0.637	0.591	0.637	0.651	0.471	0.58	0.471	0.644
	(0.048)***	(0.079)***	(0.044)***	(0.074)***	(0.125)***	(0.210)***	(0.097)***	(0.163)***
option 2: return in a few days	0.700	0.662	0.300	0.311	0.471	0.514	0.294	0.395
to collect money	(0.068)***	(0.086)***	(0.063)***	(0.080)***	(0.125)***	(0.165)***	(0.097)***	(0.128)***
option 3: return in a few months	0.611	0.563	0.167	0.164	0.500	0.555	0.000	0.090
to collect money	(0.057)***	(0.069)***	(0.053)***	(0.064)**	(0.121)***	(0.150)***	(0.094)	(0.117)
Other Controls								
Household had Used Fertilizer		0.144		0.114		0.244		0.080
Prior to the Program		(0.068)**		(0.064)*		(0.175)		(0.136)
Years of Education		-0.002		-0.008		-0.024		-0.026
Household Head		(0.009)		(0.008)		(0.023)		(0.018)
F-test, option 1 = option 2 (p-value)	0.451	0.397	0.001***	0.001***	1.000	0.725	0.202	0.095*
F-test, option 1 = option 3 (p-value)	0.724	0.716	0.001***	0.001***	0.866	0.895	0.001***	0.001***
F-test, option 2 = option 3 (p-value)	0.317	0.269	0.106	0.079*	0.866	0.816	0.034**	0.03**
Observations	224	222	224	222	52	52	52	52

Notes: Figures are from the pilot SAFI programs, which were conducted among farmers that participated in demonstration plot trials. Averages are pooled across a number of different seasons. The dependent variable is take-up (not actual usage of fertilizer). Means are reported, along with p-values for F-tests for pairwise testing of take-up rates. Regressions include school controls. Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 7. Reminder Intervention

	Bought Top Dressing Fertilizer			Planned to Buy Top Dressing Fertilizer			Bought or Planned to Buy Top Dressing Fertilizer		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SAFI Season 2	-0.033	-0.021	-0.064	0.049	0.032	0.059	0.019	0.016	0.028
	(0.055)	(0.055)	(0.069)	(0.074)	(0.077)	(0.090)	(0.072)	(0.074)	(0.089)
Household had Used Fertilizer		0.057	0.064		0.111	0.134		0.141	0.14
Prior to Season 1		(0.058)	(0.073)		(0.081)	(0.097)		(0.077)*	(0.094)
Male			0.042			-0.133			-0.100
			(0.068)			(0.091)			(0.089)
Home has mud walls			-0.132			0.188			0.009
			(0.099)			(0.133)			(0.132)
Education primary respondent			0.01			0.01			0.017
			(0.010)			(0.013)			(0.013)
Income in past month			-0.002			0.001			-0.001
(in 1,000 Kenyan shillings)			(0.005)			(0.006)			(0.006)
Mean of Dependent Variable among Comparison Farmers	0.224	0.206	0.240	0.330	0.345	0.295	0.514	0.510	0.493
Observations	195	188	141	172	166	121	193	186	139

Notes: See text for description of program. The dependent variable in columns 1-3 is an indicator variable equal to 1 if the farmer had already bought top dressing fertilizer, the dependent variable in columns 4-6 is an indicator variable equal to 1 if the farmer planned to buy top dressing fertilizer that season, and the dependent variable in columns 7-9 is an indicator variable equal to 1 if the farmer had already bought or planned to buy fertilizer in that season. In addition to variables listed, all regressions control for all demonstration plot, SAFI, and subsidy treatments, and include school controls.
Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

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

[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.

difference is small. These estimates are consistent with our data and observations, since we 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]

[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.

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 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)

Act	(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)	(2)	(3)	(4)	(5)
	Farmers Who Do Not Use Fert.	Farmers Who Use Any Fert.	Farmers Who Use TD Fert. Only	Difference	
				Any Fert.	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)	(2)	(3)	(4)	(5)
	Control Plot	1/2 Teaspoon Plot	Difference (2)-(1)	1 Teaspoon Plot	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	

	(1)	(2)	(3)	(4)
	1/2 Teaspoon		1 Teaspoon	
C. Adjusted Rate of Return	Gross	Annualized[7]	Gross	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

	(1)	(2)	(3)	(4)
	Full Price		2/3 Subsidy	
D. Incremental Return to 2nd 1/2 Teaspoon[8]	Gross	Annualized	Gross	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.

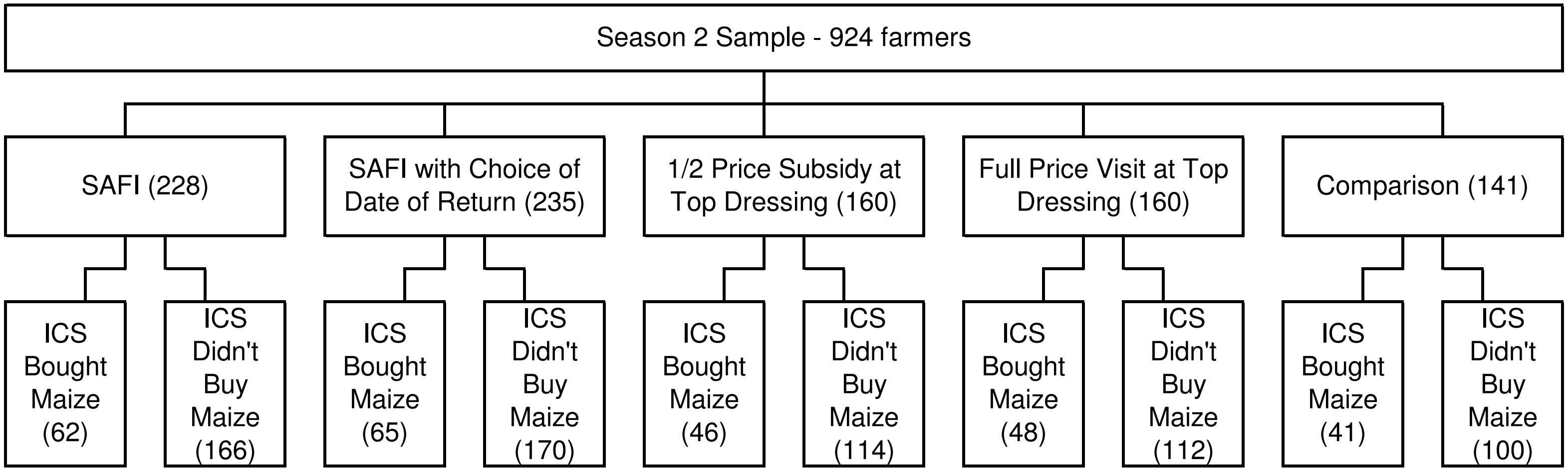
[8]The incremental return is calculated for those farmers that kept 1/2 teaspoon and 1 teaspoon plots during the same season.

Appendix 2: Supplementary Information (not for publication)

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 presents information on attrition from the experiment. The results suggest relatively low attrition, and minor differences across the various treatment groups. Finally, Appendix Table 4 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.
See Appendix Table 3 for attrition figures.

NOT FOR PUBLICATION

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.

NOT FOR PUBLICATION

Appendix Table 4. Verifying Randomization for Pilot SAFI Programs

	Household had Ever Used Fertilizer Before	Years Education	Home has Mud Walls	Home has Mud Floors	Home has Thatch Roof	Income in Month Prior to Survey^	Number of Children	Acres of Land Owned
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(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)
F-test, option 1 = option 2 (p-value)	0.470	0.162	0.901	0.565	0.452	0.665	0.834	0.355
F-test, option 1 = option 3 (p-value)	0.847	0.077*	0.350	0.965	0.630	0.332	0.208	0.645
F-test, option 2 = option 3 (p-value)	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 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%