Targeting in Environmental Programs: Connecting Additionality and Persistence

October 26, 2026

Abstract

From the USDA to private carbon sequestration companies, a wide range of organizations offer individuals short-term incentives to adopt environmentally beneficial practices. This paper models the connections between during-program additionality and post-program persistence of an incentive contract as an interaction of two factors: immediate adoption costs and long-term recurring net costs. If participants vary by adoption costs but have identical recurring net costs, then targeting individuals with greater additionality will also target those with greater persistent change. If they vary by recurring net costs, targeting participants with smaller recurring net benefits will increase both additionality and persistent change as the program accepts fewer always-adopters. However, targeting those with larger recurring net costs will decrease persistence as the targeted population shifts to those for whom the practice is never utility-maximizing. The paper discusses implications for agricultural practice change and for forest preservation and restoration.

While environmental policymakers may hope to protect natural resources for generations to come, most environmental incentives come with an expiration date. Most soil carbon credit standards today offer farmers contracts lasting 5 to 30 years (Oldfield et al., 2022), the Healthy Forests Reserve Program offers landowners 10, 30, or permanent options, and the USDA's long-running Environmental Quality Incentives Program (EQIP) provides incentives for 1 to 10 years after which a farmer cannot get another EQIP contract for the same practice on the same field (USDA NRCS, 2018). Many consumer energy-reduction programs and incentives last for a few months or years.

In contrast, the benefits these incentives create depend strongly on whether the new practice persists. Soil stores carbon in multiple chemical forms, many of which can degrade and release stored carbon within a decade if a farmer abandons their soil conservation practices (Dynarski et al., 2020). Similarly, forests will stop providing carbon storage and biodiversity values once they are deforested. In many circumstances, we cannot simply solve this problem by creating longer contracts. Farmers in the soil carbon credit market are uninterested in long-term contracts for practices, preferring the flexibility of shorter contracts, and would likely require unfeasibly high payments to bind themselves

for longer terms (Drechsler et al., 2017). To understand the social benefit of these short-term incentive programs, we therefore must understand if or when short-term contracts lead to practice changes that persist after a program ends. Understanding persistence has important implications for the cost-efficacy of incentives and interventions. If post-program persistent change is high, then a few year's spending may create decades of benefits. If it is low, a program may only provide benefits for as long as it continues payments, justifying only lower payments today while suggesting a role for repeated contracts.

This paper explores the relationship between the persistence of program effects and a more commonly discussed aspect of program impact, during-program additionality. Additionality is the degree to which a program creates behavior change compared to what participants would have done in the business-as-usual case. If all participants in a reduced tillage program were already planning to reduce tillage, the program would have no additionality; if none of them would have done so, the program would be completely additional. During-program additionality, the most commonly discussed kind and therefore referred to as "additionality" in this paper, is the level of additional practice change during the contract period. A low-additionality program creates little to no benefit in the short or long run unless it is cheap enough and widespread enough to compensate for the small individual impact. The level of additionality is estimated to vary widely across agricultural practices (Mezzatesta et al., 2013; Pannell and Claassen, 2020), and concerns around additionality have brought the success of several forest carbon crediting programs into question (Jones and Lewis, 2023; Temple and Song, 2021; West et al., 2020).

However, a program must change behavior both during and after a contract to create substantial reductions in environmental damages, particularly in regards to nature-based solutions for climate change. Post-program additional practice change requires two conditions: a participant must have been additional during the program, and the participant must have continued the practice post-program. This paper refers to post-program additional and persistent practice change as "persistence." Low persistence in nature-based solutions would mean a high risk of rerelease of carbon, increasing the optimal ex ante discounting rate of temporary storage (Lötjönen et al., 2024; Murray et al., 2006).

While the literature rarely provides a joint discussion of additionality and persistence, I provide an infinite-period repeated choice model tracing the two problems back to the same economic fundamentals. This paper focuses on a common scenario where a policymaker uses a voluntary incentive program to induce a behavior change that will provide environmental benefits so long as the practice change is sustained. Two factors drive participants' additionality and persistence: the adoption costs they must pay when they first use the environmentally beneficial behavior, and the recurring net costs or benefits that they receive in each period that they use the green practice. These costs may be monetary, behavioral, or social. As an example, the adoption costs of reducing electricity use might include the cost of buying energy-efficient appliances or the effort of forming new habits around light switches, while the recurring costs and benefits might include changes in monthly electricity bills or a continued

loss of utility from keeping the air conditioning at a higher temperature.

Participants with higher adoption costs or recurring net costs are more likely to be additional in the short term, but they are more likely to persist with the practice post-program when a practice is personally utility-maximizing to maintain in the long run. Thus, if potential participants differ by adoption costs and share the same recurring net costs, targeting the participants with the greatest during-program additionality will also target those with the greatest potential for post-program change. However, if potential participants differ mostly by recurring net costs and benefits, the participants with low during-program additionality will be always-adopters for whom the payment makes no difference, and the participants with the highest during-program additionality will be those with high recurring net costs who will be quick to drop the practice after payments end. In this case, targeting the "moderately additional" participants for whom the practice provides some small recurring net benefits will have the highest persistent impact, even though this group has lower levels of during-program additionality.

Adoption and recurring net costs will shape a participant's reserve price for joining a program as well. I analyze the cost-effectiveness of offering contracts to different individuals at their reserve price. Participants with higher adoption costs or recurring net costs will have higher reserve prices, since they expect higher costs of following the contract. I assume an environmental benefits structure where a participant provides an environmental benefit e in periods where they use the green practice and 0 when they do not. With a small transaction cost, programs will tend to maximize environmental benefits per dollar when targeting those who face a moderate barrier to adoption and who expect a modest, near-zero benefit from continuing the practice in the long run. These individuals face enough of an adoption barrier to have high additionality, but are willing to persist in the practice and reasonably priced to include.

This framework also suggests that under some circumstances, offering repeated contracts to past adopters of a practice may be necessary to realizing long-term change. When recurring net costs make a practice too costly to maintain even after paying adoption costs, a repeated contract may provide high levels of additionality during the contract. Since the participant has already paid any needed adoption costs, their reserve cost for a second contract would be weakly lower than their reserve cost for the original contract. However, a repeated contract would create no persistent change post-contract. If the during-program practice change is valuable enough to justify the lower required payment, allowing repeat contracts could help provide valuable long-term change.

This framework thus simplifies the difficult-to-estimate metrics of additionality and persistence into two concrete questions: how large is the adoption barrier to a practice? And how costly or beneficial is the practice to maintain? Encouraging joint consideration of additionality and persistence can help programs better optimize their targeting of participants and choice of practices to influence. I discuss applications to agricultural practice change, forest preservation and restoration, and consumer behavior such as energy use.

This work speaks to the theoretical literature on additionality and mechanism design in incentive programs. Low during-program additionality has decreased the estimated impact of the Conservation Reserve Program (Aspelund and Russo, 2023), forest carbon offsets (Jones and Lewis, 2023), and USDA conservation tillage incentives (Mezzatesta et al., 2013), while additionality for other practices such as cover cropping is much higher (Mezzatesta et al., 2013). Accordingly, researchers have devised a range of mechanisms to improve selection for additionality, such as implementing a waiting period for contract implementation (Globus-Harris, 2020) and including correlates of additionality in conservation auction mechanisms (Aspelund and Russo, 2023). This paper suggests that maximizing during-program additionality will maximize persistent change as well if participants vary by adoption costs, but may fail to do so if the primary variation in possible participants is their recurring net cost of maintaining the practice.

This paper also speaks to the smaller but growing literature on the persistent impact of short-term payment programs. The difficulty of following program participants after a program ends makes persistence challenging to study, leaving persistence under-researched in many key areas of environmental incentives (Dayer et al., 2018; Ferraro et al., 2025; Prokopy et al., 2019). However, the theoretical work on persistence suggests several factors that support persistence, including participant's perceptions of the costs and benefits of a practice, alignment with a participant's values, whether there are resources available to continue the practice, and whether social norms reward the practice (Dayer et al., 2018). In energy use treatments, habit formation is an important channel for long-term energy use reductio((Allcott & Rogers, 2014; Costa & Gerard, 2021; Ito et al., 2018). Many of these factors can be easily integrated into this paper's model by considering them part of the recurring net costs or benefits someone receives from a practice. This paper then connects these drivers of persistence to their influence on additionality, helping researchers consider whether continuing a practice after a program ends is a sign of strong long-term impacts from a program or whether it is a sign that a participant would have adopted on their own.

In the first section, I first model the farmer's practice adoption decision as a function of adoption costs, recurring net costs, and a time-variant shock to practice benefits. Next, I discuss how the persistence/additionality relationship differs depending on whether farmers vary by adoption cost or by recurring net costs. I then explore how this relates to the program's cost of contracting, and how a program can identify the most cost-effective populations to target. I explore applications to agricultural practice change, a setting that illustrates the role of differing recurring net costs, and then discuss forest restoration and avoided deforestation to explore the role of differing adoption costs. I then discuss some extensions of the model and conclude.

1 The Landowner's Practice Choice

1.1 Behavior in Absence of a Contract

This section establishes how a landowner will behave with or without a contract, which allows estimation of their additionality under contract. In this model, a landowner who is not under contract must decide in each time period whether to take a socially beneficial action $x_t = 1$ that produces a social benefit e, or to take the conventional action $x_t = 0$ that produces no social benefit. If under contract the landowner must set $x_1 = 1$, but they may then freely choose their practice in subsequent periods. The landowner's utility in a period t is

$$\begin{aligned} U_t(X_t, \epsilon_t) =& 0 \text{ if } x_t = 0 \\ & \epsilon_t - c - a(1 - \max(X_{t-1})) \text{ if } x_t = 1 \end{aligned} \tag{1}$$

X_t is the history of actions by landowner through time t. $a \geq 0$ is the adoption cost of the beneficial action, which is paid only in the first period the practice is adopted. c is the recurring net cost of the new practice and must be paid in every period the new practice is used. If c is negative, it represents a recurring benefit from using the new practice. ϵ_t is a time-variant shock in the benefit of the beneficial action x_1 in period t, with $\epsilon^t \in [\epsilon^{min}, \epsilon^{max}]$, and $E[\epsilon_t] = 0$. ϵ^t is an iid distribution with pdf $f(x)$. The landowner learns ϵ_t before choosing period t's practice x_t. I assume that the landowner is risk-neutral. The landowner is maximizing over an infinite virtual horizon, so the landowner chooses x_t to maximize

$$V(\max(X_{t-1}), \epsilon) = \sum_{t=1}^{\infty} (1 - r)^{t-1} E[U_t(X_t, \epsilon_t)] \tag{2}$$

The benefits of $x_t = 1$ are strictly increasing in the productivity shock ϵ_t, as shown in Equation 1 . The landowner discounts future utility at rate $0 < r < 1$. The landowner's optimal response function will therefore consist of two threshold productivity shocks above which they use the beneficial practice. First, there will be a minimum productivity shock ϵ^a such that the landowner with $\max(X_{t-1}) = 0$ who has never before adopted the beneficial practice will adopt in period t if $\epsilon_t \geq \epsilon^a$ and will not adopt if $\epsilon_t < \epsilon^a$. Second, there will be a minimum shock ϵ^c above which the landowner with $\max(X_{t-1}) = 1$ who has previously used the beneficial practice will still choose $x_t = 1$ if $\epsilon_t \geq \epsilon^c$ and who will not use the practice if $\epsilon_t < \epsilon^c$.

First, I characterize the practice choices of previous adopters with $\max(X_{t-1}) = 1$. This landowner has already paid the adoption cost, so the utility of choosing practice $x_t = 1$ will depend only on the change in recurring net costs c and the productivity shock ϵ_t. As derived in Appendix A, the previous adopter will therefore continue practice $x = 1$ if

$$\epsilon_t > \epsilon^1 = c \tag{3}$$

So previous adopters will continue the beneficial practice only if the productivity shock to the new practice exceeds a threshold level equal to the difference in

recurring net costs. The adoption cost a drops out of the formula for ϵ^c because it no longer influences future utility after the initial cost is paid.

On the other hand, optimal ϵ^a if the landowner has never previously adopted will consider the adoption cost and the future benefits of their choices in their actions as well as the recurring net costs. The landowner will choose $x_t = 1$ and adopt the beneficial practice if

$$(1-r)E[V^*(0)] \leq \epsilon - a - c + (1-r)E[V^*(1)]$$

where $E[V^*(\max(X_{t-1}))]$ is the expectation of Equation 2 given the optimal choice of ϵ^a and ϵ^c. This means that

$$\epsilon^a = a + c - (1-r)E[V^*(1) - V^*(0)] \tag{4}$$

where $E[V^*(1) - V^*(0)]$ is the impact of paying the adoption cost on future expected utility. The higher the adoption costs, and the lower the expected later benefits from adoption, the less likely the previously inexperienced landowner will be to adopt the practice. Solving for this further in Appendix A, ϵ^a can be fully characterized by

$$\frac{\epsilon^a}{1-r} - E[\max(\epsilon^a, \epsilon)] = \frac{ra + c}{1-r} - E[\max(c, \epsilon)] \tag{5}$$

1.2 Additionality and Persistence Under Contract

Now I add a conservation contract to the landowner's problem. Before the landowner sees the current ϵ_t and chooses their practices for the period, the policymaker offers the landowner a price p for a single-period conservation contract. I assume here that $x_0 = 0$, so the landowner enters the contract without experience with the beneficial practice. In this section, I derive the additionality and persistence of behavior change created by that contract as a product of adoption cost a and recurring net cost difference c.

First, additionality is the amount of practice change created by the contract during the contract duration, which in this case is period 1. I assume perfect compliance, so any landowner who accepts the contract will set $x_1 = 1$ regardless of their realization of ϵ_1. Therefore, we can retroactively consider the contract additional whenever the productivity shock ϵ_1 is low enough that the landowner would have chosen $x_1 = 0$ on their own, so $\epsilon_1 < \epsilon^a$. At the time of contracting, a contract will provide additionality with probability

$$\textit{Additionality}(a, c) = P(\epsilon < \epsilon^a) \tag{6}$$

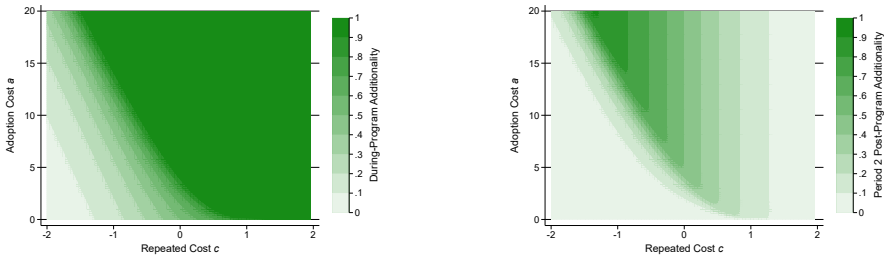
Figure 1a models estimated during-program additionality of the beneficial practice with $\epsilon \sim N(0, 1)$ and a discount rate of 8%. This illustrates the first proposition, proven in Appendix D:

Proposition 1 *During-program additionality is weakly increasing in adoption cost a and recurring net cost c.*

Figure 1: Practice Change Over Time by Adoption and recurring net cost

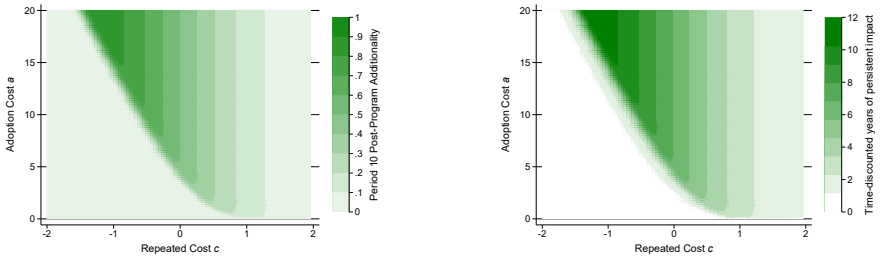
(a) Period 1 Additionality

(b) Period 2 Persistent Change



(c) Period 10 Persistent Change

(d) Time-Discounted Program Impact



Outcomes modeled with ϵ $N(0,1)$ and $r = .08$. Time-discounted program impact is calculated as $Additionality + \sum_{t=2}^{100}(1-r)^{t-1}Persistence_t$.

Both adoption and recurring net costs increase the cost of the green practice relative to the traditional practice. If a landowner faces high adoption costs or does not expect to see a long-term annual benefit, they are very unlikely to adopt the practice on their own, so a contract should substantially change their behavior.

However, practice change during a program is not guaranteed to translate into persistence. If a landowner adopts in period 1 and pays the adoption cost, the landowner will prefer $x_2 = 1$ whenever $\epsilon_2 > c \equiv \epsilon^c$. If the landowner did not adopt in period 1, they will adopt in the second period only if $\epsilon_2 > \epsilon^a$, so they will be less likely to use the practice than previous adopters. Here I define the post-program additionality in period n as the increase in probability that $x_t = 1$ if the policymaker contracts with the landowner in period 1 as opposed to the no-contract case. Derived in more detail in Appendix B, the persistent practice change in period t is equal to

$$Persistence_t(a,c) = P(\epsilon < \epsilon^a)^{t-1} P(\epsilon^c \leq \epsilon < \epsilon^a) \tag{7}$$

Which leads to the following proposition:

Proposition 2 *Proposition: The period t persistent change is increasing in adoption cost a. Persistent change is increasing in recurring net cost c for* $c < c^{max}(t)$ *and decreasing in c for* $c > c^{max}(t)$ *for some* $c^{max}(t)$.

The tth period persistence consists of two terms. The first is the probability that the unconstrained landowner would never have used the green practice in any period before period t. Given Equation 6, this term is simply the additionality raised to the $t - 1^{th}$ power. If it is at all probable that a landowner would adopt the practice of their own accord, this term will shrink the persistent change.

The second term is the probability that having paid the adoption cost will change the landowner's decision. This term is strictly increasing in the adoption cost. If $a = 0$, then past experience with the new practice has no impact on the practice's future utility, and a short-term contract does not impact later choices. However, this term's relationship to the recurring net cost c is more ambiguous. If c is a large net benefit leading landowners to almost always choose to adopt or if c is a large net cost dissuading landowners from ever using the practice without payments, the adoption cost will rarely change their practice decision. This term will be largest for landowners with c slightly below 0 for whom the new practice carries similar costs to the old one.

Persistent change is therefore highest for the landowners for whom the new practice is beneficial in the long run, but who face a substantial barrier to adoption. Figure 1 shows how this varies across c and a for periods $t = \{2, 10\}$ and the time-discounted total change over the first 100 periods.

Persistent change increases with adoption cost similarly to during-program additionality, but it differs in its response to recurring net costs. This leads to Proposition 3, which follows directly from Propositions 1 and 2.

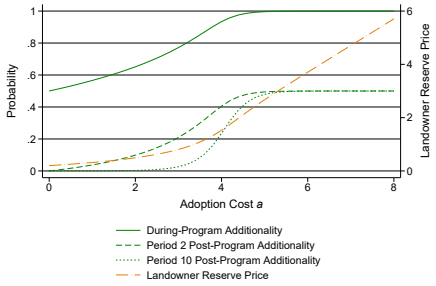
Proposition 3 *When recurring net costs c are fixed and participants vary only by a, persistent change is weakly increasing in additionality. When adoption cost a is fixed and participants vary only by recurring net costs c, persistent change may be increasing or decreasing in additionality.*

Figure 2 traces the changes in additionality and persistence as adoption cost or recurring net cost vary. When adoption costs increase and recurring net costs remain fixed, additionality and persistence both increase, as Figure 2a depicts. They level out as the adoption cost grows so high that a landowner's probability of adopting the new practice without a payment approaches 0, which occurs in Figure 2a around $a > 5$. Above this level, previous contract recipients will choose $x = 1$ in the periods in which $\epsilon > c$, and those who do not have a contract will never do so.

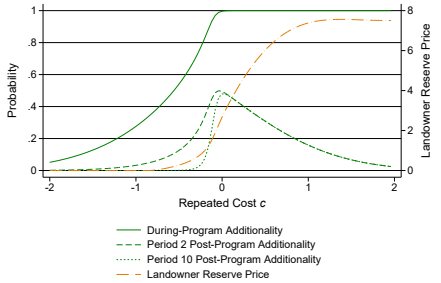
On the other hand, persistent change is increasing and then decreasing in the recurring net cost of the new practice. Figure 2b shows additionality and persistence when recurring net costs vary and adoption cost a is a positive constant. When the practice is particularly beneficial in the long term, landowners are likely to adopt the practice in period 1 even in absence of the contract. The left side of Figure 2b demonstrates this case, where during-program additionality is

Figure 2: Exploring The Effect of Cost Variation

(a) The Effects of Varying Adoption Cost



(b) The Effects of Varying recurring net costs



Outcomes modeled with ϵ $N(0,1)$ and $r = .08$. In Figure a, recurring net cost $c = 0$ while adoption cost a varies. In Figure b, adoption cost $a = 1$ and c varies.

low and so post-program additionality is even lower. Moving right on the graph as the the annual cost of the practice increases, rising during-program additionality increases the first component of post-program additionality in Equation 7. The post-program additionality is stronger if a practice doesn't pay for itself too easily.

However, as we pass $c = 0$, increasing recurring net costs become associated with lower persistent change. Additionality becomes close to guaranteed, meaning higher c's impact on the first term of Equation 7 diminishes. However, $P(\epsilon^c \leq \epsilon < \epsilon^a)$ begins decreasing because it becomes increasingly unlikely that even an experienced landowner would ever find the new practice beneficial without support. Getting a landowner past the adoption cost hurdle no longer matters when the annual utility losses discourage continuing the practice.

This means that if a policymaker targets participants or evaluates programs based only on their during-program additionality, whether this maximizes total environmental benefits will depend on whether potential participants vary more by adoption cost or recurring net cost. If adoption cost is the primary driver, the higher additionality participants will also have the greatest persistent benefit (or, if the practice is not beneficial for most to sustain in the long run, will at least be no worse). On the other hand, if recurring net costs drive the variation, pushing for the "most additional" short-run participants may lead a policymaker to target the individuals who simply will not sustain a practice after the end of payments.

1.3 The Cost of Contracting

Landowners with different values of a and c will also differ in the size of contract payment p needed to induce participation. If the landowner accepts the contract, they will be required to choose $x_1 = 1$. In exchange, they will receive payment p in period 1. The landowner's opportunity cost of the program is therefore the cost of choosing $x_1 = 1$ if ϵ_1 is such that $x_1 = 0$ would be utility-maximizing. Using the utility formula from Equation 14 and the practice choice from Equation 4, the landowner will be willing to accept the contract if

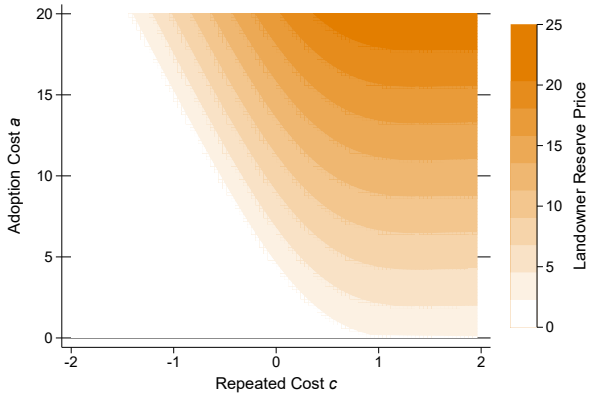
$$p \geq P(\epsilon < \epsilon_0)(a + c - E[\epsilon|\epsilon < \epsilon_0] - (1 - r)E[V^*(1) - V^*(0)])$$

Where $E[V^*(1) - V^*(0)]$ can be calculated according to Equation 2. The reserve price of a contract is therefore increasing in the level of additionality, since the contract will alter their expected utility only when the landowner expects to change their behavior. Similarly, higher adoption costs and recurring net cost increases increase the landowner's reserve price, since they decrease the expected Period 1 utility stemming from $x_1 = 1$.

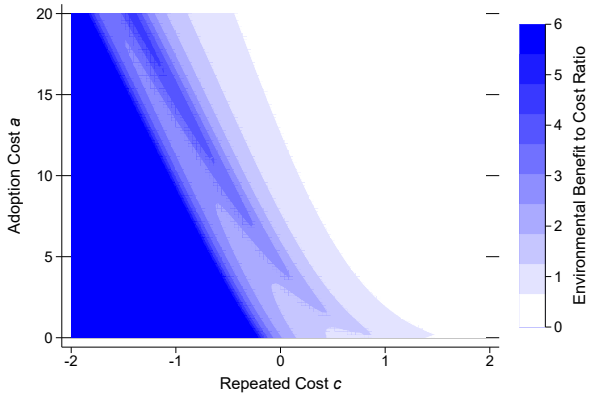
Graphing landowner reserve prices in Figure 3a, reserve prices move in the opposite direction of during-contract additionality. Higher adoption costs and higher recurring net costs increase the chance of during-contract additionality, but they drive the landowner's reserve cost upwards.

Figure 3: Contract Costs and Net Benefits

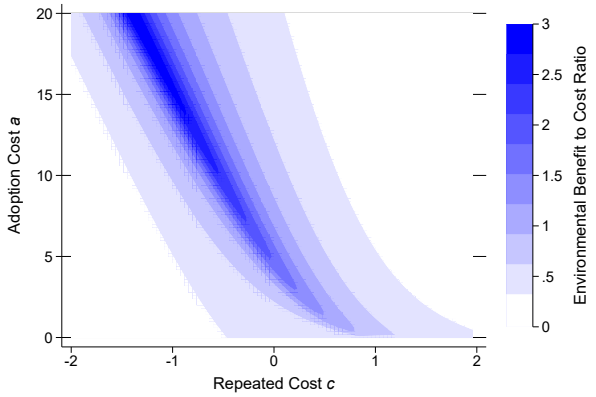
(a) Landowner Reserve Prices for Contract



(b) Contract Efficiency at Reserve Price With No Transaction Costs



(c) Contract Efficiency at Reserve Price With Transaction Costs



Given that during-contract additionality, persistent change, and contract costs may not move together, who should the policymaker target? A range of environmental benefit structures are possible, and will shape what population is the most cost-effective to target. For this example, I assume that a practice provides some fixed environmental value e each year that a landowner uses the beneficial practice and nothing otherwise, and the planner discounts this environmental value at the interest rate r. If the policymaker knows the landowner's value of a and c, they can choose to offer landowners contracts with their reserve price p. In addition, the policymaker must pay a fixed monitoring cost $m \geq 0$ for each contract, which represents the costs of creating and monitoring a contract. The policymaker's expected value per dollar for offering a landowner this contract is therefore

$$Benefit/Cost = e\frac{AddDuring + \sum_{t=2}^{\infty}(1-r)^{t-1}AddPost_t}{p+m} \tag{8}$$

Figure 3b plots the results assuming $e = 1$ and $m = 0$. In this model, it is more efficient for the policymaker to target the landowners with $c < 0$ for whom the new practice is expected to be beneficial in the long run, since they both demand lower subsidies and have a more persistent effect when they are additional. The lowest-additionality contracts become less cost-efficient when a positive monitoring cost is added in Figure 3c. With such a cost, the most cost-effective contracts are those with a moderately high adoption cost and a recurring net cost difference near zero. These factors make these individuals unlikely to adopt on their own, without driving the contract cost beyond the cost-effective range. These populations have high additionality and persistence as seen in Figure 1.

The exact shape of the relationship between additionality and optimal targeting will vary across situations, as environmental benefit structures, adoption costs, recurring net costs, and error structures vary. If environmental benefits are strongly contingent on uninterrupted adoption, such as the case of forest adoption, paying for the high-persistence, high-additionality, high-cost groups would become more worthwhile since persistence is vital. However, it will rarely be the most cost-effective to target purely the "highest-additionality" populations since they will require a large payment to implement a practice they would never find beneficial on their own, and they are not likely to sustain the practice in the long term.

1.4 Selection Effects

Comparing the landowners' reserve price of a contract also offers insight into who will select into a program. Actual contract prices are rarely tailored to individuals. As an example, EQIP offers a price per acre p^{EQIP} for cover cropping that is fixed at the state level. Within a state, any eligible farmer with $p \leq p^{EQIP}$ should therefore want to apply for EQIP. This means the pool of applicants will look like the sample in Figure 3a with p below a given price level, represented by the lighter share of the graph. These applicants

would disproportionately include landowners with low adoption prices and high recurring net benefits, who are therefore particularly willing to adopt. Figure 1 demonstrates that these farmers are also the ones with the highest chance of adopting a cover crop on their own and thus have lower additionality.

This applicant selection effect explains why papers that compare successful applicants to nonapplicants may overestimate the program's additionality. Matching papers comparing participants to other landowners often control for a wide set of covariants, hoping to avoid omitting any variables that might determine a landowner's odds of adopting a practice on their own. However, a landowner's decision whether to apply to such a program or not is a particularly strong signal of willingness to adopt. A landowner who would never apply to a support program also would have little or no interest in adopting the practice without support, while the applicant pool will include a mix of always-adopters and sometimes-adopters. If a paper limits analysis to the applicant pool, it limits comparisons to this more similar group.

1.5 Contracting with Past Adopters

In the world of payments for ecosystem services, programs vary widely in their willingness to offer contracts to past adopters of a practice, either to those who used a practice on their own or those who received past contracts for a practice. Some programs, like EQIP, only allow participants to recontract for a practice if they add new practices along with it; other programs may not allow recontracting at all. In this section, I explore the dynamics of a period 2 contract offered to those who accepted the period 1 contract. Such contracting with past adopters can have additional effects, though not persistent effects, and the landowner will be willing to renew for a price equal to or lower than the initial contract's price. Recontracting may therefore provide cost-effective value when a practice's recurring net costs make it unlikely that a landowner will continue the practice without any incentive, and when the during-program environmental benefits are high enough to justify the lack of persistence.

First, let us consider the landowner's second period choice. Our policymaker is only offering contract renewals to those who accepted the period one contract. Therefore, the targeted landowners have $x_1 = 1$ and paid the adoption cost. If they sign a contract renewal, they will be required to set $x_2 = 1$. If they do not sign a contract renewal, they will use the practice only when it is utility-maximizing, requiring that ϵ_2 be high enough to cover the repeat cost of the practice in line with Equation 3. Because of this, the repeated contract's during-program additionality will be

$$Additionality_2(a, c) = P(\epsilon < c) \tag{9}$$

So the probability that this second-period contract creates change depends purely on how likely it is that a landowner will find the practice beneficial to repeat after adoption costs are paid. Figure 4a shows the relationship between recontracting additionality and recurring net costs. If the new practice provides

high recurring benefits, the participant needs no incentive to continue it, and the repeated contract will not provide any additionality. If the new practice is difficult and costly to sustain, the participant is likely to discontinue it without support, and a new contract will have a substantial additional impact during the contract. This leads to Proposition 4, proven in Appendix G:

Proposition 4 *$Additionality_2(a, c) \leq Additionality_1(a, c)$, and $Additionality_1(a, c) - Additionality_2(a, c)$ is weakly increasing in a.*

This states two truths about these contracts: a recontract will never have higher expected during-program additionality than the first contract, and the difference between the two will be larger if the adoption cost is higher. If a landowner faced no adoption cost, then the landowner's problem would be the same in both periods and the level of additionality would be the same. If the adoption cost is high, the first-period landowner faces a barrier to the practice that the second-period landowner has already overcome.

However, this second period contract has no effect on what choice the landowner will make after this new contract expires. Post-program additionality comes from paying the adoption cost, which the landowner did the first time that they were under contract. Therefore, the full effect of the contract will be $e * AddDuring_2$, the additional environmental impact that occurs in period 2.

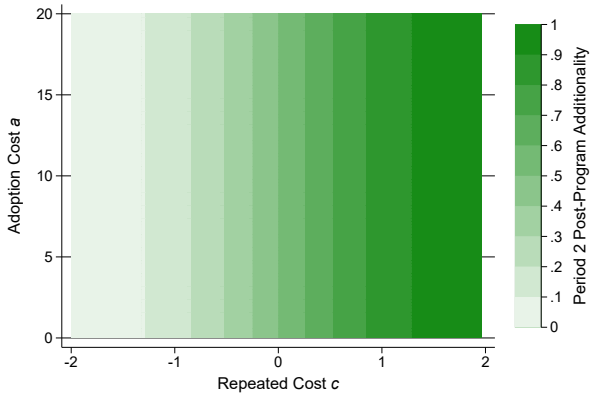
While contracting with past adopters has a smaller behavioral impact, the landowner's cost to participate is also lower. The landowner's cost of committing to a period 2 contract is the expected loss from choosing $x_2 = 1$ when $x_2 = 0$ would be utility-maximizing. Since they've already paid the adoption cost, they will accept the contract if

$$p \geq (c - E[\epsilon | \epsilon < c])P(\epsilon < c) \tag{10}$$

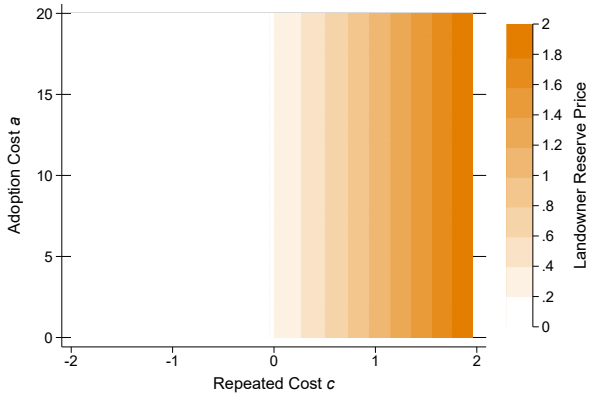
meaning that the price must exceed the expected value of the losses if the contract does alter their Period 2 practice choice. The modeled results, mapped in Figure 4b, show that this reserve price is increasing in the recurring net costs c. If the policymaker is able to offer the landowner their reserve price, there is a possibility for beneficial transactions. The most beneficial transactions may target those for whom the repeat costs of maintaining the practice are slightly higher than the old practice. Figure 4c shows the expected net benefit to cost ratio with a fixed $m = 1$ transaction cost. The benefits peak for those individuals with small recurring net costs, since they have reasonably high during-program additionality but do not need a large payment to compensate their participation.

Figure 4: Period 2 Contracts with Past Adopters

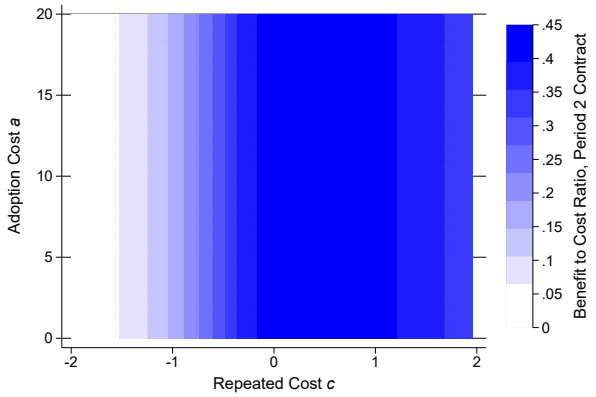
(a) During-Program Additionality of Period 2 Contract



(b) Landowner Reserve Prices for Period 2 Contract



(c) Contract Efficiency for Period 2 Contract with Transaction Costs



2 Applications

To consider what implications this model might have for a range of key environmental settings, we can use existing research on additionality, persistence, and recurring net and adoption costs. In this section, I review the literature surrounding the model components in three key settings: cover cropping in agriculture, reforestation and avoided deforestation, and electricity use. I discuss the implications for optimal policy design.

2.1 Agricultural Practice Change: Contrasting Recurring Costs

Short-term incentive programs are widely used to promote agricultural practice change, and reduced tillage and cover crops are two of the most commonly supported practices. Cover crops are planted during times when the ground would otherwise be left fallow, protecting the soil until the farmer kills the cover crop to make way for the cash crop. Reduced tillage practices involve reducing the frequency of tillage, decreasing disturbance to the soil. In no-till, farmers stop tilling altogether. Both these practices can provide a range of environmental benefits, including controlling runoff and erosion, reducing water pollution, and increasing soil carbon sequestration. Accordingly, the USDA EQIP program spent more than $1 billion on cover crop payments and $178 million on reduced tillage and no-till between 2017 and 2024 (Environmental Working Group, 2023).

Both of these practices require initial investments to adopt. These adoption barriers include capital expenditures, such as no-till drills for planting without tillage or mechanical crimpers for killing a cover crop (Bergtold et al., 2019). The learning costs of adopting these new technologies also represent a substantial barrier. As a farmer surveyed by the Conservation Technology Information Center (2023) noted, "recipes... don't work in a living biological system." As such, adopting farmers must learn how to avoid damaging their cash crop through terminating a cover crop too late (Curran, 2016) while waiting long enough for termination to see nitrogen benefits (Morton et al., 2006; Sainju & Singh, 2001), and they must adjust N fertilizer use as cover crops and reduced tillage change N availability (Snapp et al., 2005). In addition, these practices require an adjustment period to benefit a farm, even if the practice is optimally implemented. Soil quality improvements accumulate slowly over several years of cover cropping, so many farmers will not see substantial benefits from a cover crop until the soil has improved for 3-5 years (Myers et al., 2019), and yield benefits for corn-soy fields that have used cover crops for a decade or more are 10 times as large as the effect in the first year (Deines et al., 2019).

While both practices face adoption barriers, the recurring costs or benefits are quite different for the two. While no-till offers recurring benefits for large shares of US farmers, cover crops come at a recurring cost for many. This bears out in the patterns of additionality and persistence widely seen in the literature, and suggests that no-till and cover cropping incentives should focus

their targeting differently on additionality and persistence.

2.1.1 No-Till

Adopting reduced or no-till offers long-run recurring net benefits in a range of settings. In the short run, no-till is associated with increased herbicide costs and lower yields (Pittelkow et al., 2015). However, long-term studies consistently show benefits as no-till improves soil structure and increases soil organic matter (Derpsch et al., 2010). The yield decrease from no-till ends within 3-10 years for most crops (Pittelkow et al., 2015). Over adoption periods longer than 10 years, no-till is associated with reduced field operation costs in Maryland, Ohio, and Michigan (Che et al., 2023; Zhang et al., 2025) and higher yields in Michigan (Cusser et al., 2020).

Since recurring net benefits of no-till are common, we would expect to see adopters continue the practice with or without payments, and that is what the research shows. Users of no-till are highly likely to continue the practice across years, and satellite images suggest that increased field residue, a sign of no-till, remains high on EQIP fields post-EQIP (Wallander et al., 2017).

However, the additionality of incentives for no-till is quite low. No-till and reduced tillage incentives through EQIP created an estimated 19% additional adoption in Ohio (Mezzatesta et al., 2013) and approximately 50% additionality in the broader United States (Claassen et al., 2018), some of the lowest levels of additionality among studied EQIP-eligible practices. This suggests that the recurring net benefits of no-till are high enough that a significant share of farmers are willing to bear the adoption costs themselves, even in absence of a payment program. Accordingly, almost 90% of farmers using no-till by 2011 had reported adopting no-till without a payment (Claassen et al., 2014). This low additionality sabotages a program's ability to create persistent change: if farmers have a high probability of adopting no-till on their own, they are likely to be using no-till or reduced tillage in five years whether or not they are currently paid.

This suggests that no-till payments should target for additionality, whether it is through targeting those with high adoption barriers or through relatively low recurring net benefits. So long as recurring net benefits of no-till are positive or neutral, a program participant is likely to continue the practice after adoption. Given that recurring net benefits are quite widespread, targeting the "more additional" should still include those who will persist: the only concern is avoiding always-adopters. No-till may be ripe for targeting on expected additionality as in Aspelund and Russo (2023), paying more for no-till contracts in places where adoption is less likely. Policymakers might also limit no-till contracts to farms where no-till is less strongly profitable. As this drives up the additional share of participants, it should drive up a program's persistent effect as well.

2.1.2 Cover Cropping

Cover cropping has highly variable recurring net costs, creating recurring net benefits for some farmers and recurring net costs for some. Cover crops can improve soil quality through improving moisture management, reducing soil compaction and erosion, and increasing soil organic matter (Bergtold et al., 2019). In Corn Belt corn and soy systems, the areas that benefit the most from cover cropping may see yield increases of 15%, while the areas that are least suited for cover cropping may see a 5% decrease in yields (Deines et al., 2019). Cover crops can also help with water management, improving yields in drought years in regions of the Corn Belt (O'Connor, 2013), though cover crops in arid regions of the Great Plains may harm yields by depriving cash crops of needed moisture (Robinson and Nielsen, 2015). Cover cropping's effects on input use are also variable. 21% of corn growers surveyed by Conservation Technology Information Center (2023) said that they reduced fertilizer costs by $20 or more per acre, though half reported spending the same on fertilizer after integrating cover cropping. Cover crops can also reduce herbicide costs in no-till systems, and can help with pest management (Snapp et al., 2005), though the ability of cover crops to help depends on what weed and pest pressure the field previously faced. Cover crops also require considerable work to implement: the farmer must plant and terminate the cover crop, typically adding two extra passes the farmer must make over the field.

Since recurring net costs for cover cropping are common, many cover crop adopters later discontinue their use of the practice. Ferraro et al. (2025) find that only 36% of Illinois fields with cover crops in 2014 planted them again in 2015, and only 41% had them in 3 or more years between 2014 and 2019. Nationally, most fields using a cover crop in one year do not report them in any of the next five years in three of four USDA data sources (Pratt et al, 2026).

On the other hand, cover crop programs often show high levels of additionality. Most papers examining the additionality of cover crop payments have estimated that they are at least 80% additional(Claassen et al., 2018; Fleming et al., 2018; Mezzatesta et al., 2013; Rosenberg et al., 2024), though cover cropping in Iowa has a lower estimated additionality of 54% (Sawadgo & Plastina, 2021). This follows from the level of repeated costs. If cover cropping is likely to remain unprofitable for many farms over the long run, few farmers will choose to adopt cover crops without payments.

This suggests that for cover crops, additionality is not the key problem. A large share of current applicants are already additional. The key challenge here is attracting those likely to continue cover cropping and therefore create persistent change. EQIP and other programs that pay for cover cropping may want to focus on attracting participants where recurring net benefits from cover cropping are expected, such as areas with higher levels of precipitation. If these programs want to adjust their incentives, targeting on additionality in the style of Aspelund and Russo (2023) could end up attracting participants with high recurring costs and a low likelihood of persisting with cover cropping. Targeting payments instead at those with expected net benefits may improve performance.

2.2 Forestry: Contrasting Adoption Costs

Short- and medium-term conservation incentives also commonly crop up in the space of forest protection and restoration. Such incentives take a range of forms, including payments for ecosystem services, carbon crediting programs such as REDD+, USDA EQIP's funding for tree and shrub establishment and forest stand improvement, and private eco-marketing tree planting initiatives. Forest protection and regrowth can both protect biodiversity and assist in carbon sequestration, as long as the forest remains standing. In these settings, avoiding even a single-period default to the original behavior—a single forest-cutting incident—is required to maintain environmental value, since regrowing a forest and the environmental benefits it provides may take decades.

Forest programs often contract for two kinds of practices: avoided deforestation and forest restoration. Avoided deforestation programs provide payments for protecting existing stands of trees. Forest restoration involves regrowing forest in previously degraded or cleared areas, either through passively protecting natural regrowth of plants or through actively placing new plants (Vincent et al., 2021).

Both of these types of restoration have widely varying repeated costs or benefits, which largely take the form of the opportunity cost of keeping the land in its forested use rather than cutting it down. However, they differ widely in adoption costs. Avoided deforestation typically has low or nonexistent adoption costs, while forest restoration has substantial adoption costs. This difference in adoption cost implies that persistence, targeting, and recontracting should be handled differently for the two kinds of forest programs.

2.2.1 Avoided Deforestation

Avoided deforestation requires few changes to adopt. The landowner does not need to make new capital investments or learn new skills: they simply need to refrain from chopping down trees. When adoption costs are zero, we expect no persistent effect of these avoided deforestation programs, since the economic fundamentals of the land-clearing choice have not changed due to program participation.

However, additionality of avoided deforestation may vary widely with recurring net costs and benefits, which in this case take the form of harvest revenues or profits from cleared land. A parcel will be additional to a program if the landowner would have found it profitable to harvest in absence of the incentives. This is not true of many forest parcels, since harvesting and transporting wood can be costly. Some settings have found high levels of nonadditionality in avoided deforestation programs, such as California's forest credit program (Stapp et al., 2023) and a range of REDD+ programs in tropical countries (Barbier & Burgess, 2025). This problem is particularly common because those with the lowest expected benefit of logging will have the lowest price of participation, leading to adverse selection of low-additionality participants into avoided deforestation programs. Since we expect no persistent effect of avoided deforestation

programs, improving targeting for additionality will unambiguously improve the program's overall impact.

These low adoption costs also suggest that prevented deforestation programs can benefit from allowing contract renewals. As adoption costs are near zero, the landowner's reserve price for recontracting is likely to be similar to their reserve price for the original contract, and both contracts offer a similar amount of additionality and persistent change. Contracts for carbon crediting in particular should be prepared for the likelihood that landowners will not persist without payments. Depending on the structure of the credit market, the market can prepare for this carbon rerelease by using a discounting system that takes a lack of persistence into account or through including buffers to replace credits after carbon is released (Brandão and Levasseur, 2011; Fearnside et al., 2000; van Benthem and Kerr, 2013).

2.2.2 Forest Restoration

Forest restoration behaves quite differently from avoided deforestation because restoring a forest requires a clear adoption cost. Both passive and active forms of forest restoration can involve substantial initial costs. Active restoration requires investment in labor and seeds or plants, which in Panama can cost from $1200 to $ 1500 USD per hectare (Sinacore et al., 2023). Passive restoration may need fencing and monitoring to protect the area from grazing in the initial stages of regrowth (Zahawi et al., 2014). In both cases, the landowner faces an immediate dip in revenue as well as the forest may need more than a decade of investment before the landowner can begin to harvest sustainably from the forest (ibid, Sinacore et al., 2023). These adoption costs will vary substantially based on labor costs, land quality, environmental conditions, and material costs, and may vary widely even within a country (Brancalion et al., 2019).

Since adoption costs are positive, persistence in restored forests is possible but not guaranteed. Persistence then depends on whether the forested use of the land has high enough recurring benefits to keep the landowner from choosing to clear it again. Unfortunately, many forest restoration projects fail to persist for this reason: 50% of Costa Rican secondary forests were cleared within 20 years of establishment (Reid et al., 2019), and secondary vegetation in Brazil is cleared at a higher rate than established forests (Nunes et al., 2020).

To maximize persistent impact, program designers can look to identify opportunities for reforestation that both overcome an establishment barrier and create a sustainable income for landowners in the long term. In such cases, unlike with avoided deforestation, recontracting may not be necessary for long-term maintenance of the forest. This depends on landowners being able to acheive recurring net benefits from reforestation, which requires that they can earn more through their regrown forest than they could through harvesting wood and using the cleared land. When this is not possible, lower-price repeated contracts may be necessary to sustain the restored forest.

3 Extensions

This model is simplified to illustrate the roles of adoption and recurring net costs of a practice in determining additionality and persistence, but it could be extended to accommodate a range of further considerations. Here, I offer a noncomprehensive list of possible extensions and variations and offer some insights on how these changes might impact the relationships described in this paper's model. In particular, I consider the roles of risk, uncertainty, switching costs, and dynamic environmental benefits. Some new features, like risk, can be easily collapsed into the current variables of adoption costs and recurring net costs. Others, like uncertainty and dynamic environmental benefits, represent more fundamental shifts in the model.

3.1 Risk Aversion

Changing risk structures could create new opportunities for efficient contracting. I currently assume a risk-neutral participant, but this model could include a risk-adverse participant facing different risks from the traditional and green practices. For example, cover cropping can reduce yield impacts from drought or irregular moisture patterns (Myers et al., 2019). Green practices may be risk increasing in other circumstances such as passive forest restoration, where leaving the land to regrow may increase the risk of land expropriation in some developing countries (Zahawi et al., 2014).

We can think of the landowner's actual or perceived change in risk as shifting the landowner's adoption cost or recurring net cost for the practice. If cover cropping decreases risk of yield loss in a drought and the landowner is risk adverse, the decrease in risk will increase their recurring benefits of the practice. If a company is uncertain how expensive or difficult it will be to install a new emissions-reducing piece of equipment, they will effectively face a higher adoption cost than if they anticipated no risk. If a practice increases risk, risk-neutral policymakers may be able to find more cost-efficient incentive solutions by offering insurance policies as well as fixed payments.

Uncertainty about the recurring benefits of a practice would create more drastic changes to the model's predictions. A landowner may have uncertainty around whether the practice will have long-term benefits until they experiment with adopting the practice. In this case, the uncertainty around the recurring benefits creates another adoption cost. It also weakens the impact of a landowner's true recurring net cost on their initial willingness to adopt. If before adoption the landowner with different levels of recurring net costs and benefits don't yet know their true types, they may have similar reserve prices for a contract. Their post-program behavior would depend on what they believe their recurring net cost or benefit to be after their learning period under contract.

3.2 Discount Rate Variation

So far, I have assumed that landowners all have the same fixed discount rate r. While market pressures may force some agricultural decisions to conform to the market interest rate, many studies of farmers find considerable heterogeneity in their reported or revealed discount rates (Wuepper et al., 2023). Allowing landowners to have varying discount rates creates another dimension that can shape additionality, persistence, and contracting costs.

Variation in discount rates behaves much like variation in adoption costs. A higher discount rate causes a farmer to care more about present losses than the potential of future benefits, making adoption costs a greater barrier to using the practice. Landowners with higher discount rates therefore have higher additionality and persistence and a higher reserve price for a contract. This is discussed in more depth in Appendix H.

3.3 Switching Costs

Variations on this model could explore different structures of transition costs between practices. In this model, the private benefits from practice choice depend on previous practice choice only through adoption cost. In forestry, the value of harvest faces both irregular shocks from changes in wood prices but also an expected increase in harvest value as harvest is delayed and the trees continue to grow. Including this year-to-year change in expected payouts would be necessary for predicting additionality and persistence in a real-world forestry setting. In addition, real-world settings may include switching costs from the green practice to the traditional practice if transitioning back also requires changes in capital expenses. These switching costs include behavioral aspects like habit formation. In this case, the landowner would take this cost into account, and it would reduce the value option of a temporary switch to the green practice as the participant anticipates the switching cost of returning to the previous practice. This may create a screening mechanism for participants who are unlikely to persist since they will not want to make a costly transition if they anticipate reversing it. High switching costs to quit the green practice would increase the contract's value to the policymaker, however, as the participant would be more likely to persist with the green practice.

3.4 Time-Variant Costs

In the current model, an individual's adoption and recurring net costs are constant over time. If we anticipate they will vary, this will change both during- and post-contract additionality. If adoption cost a is expected to fall, then the current value of paying the adoption cost today, $E[V_t^*(1) - V_t^*(0)]$, will also decline. This would increase current additionality because the landowner would prefer to wait to adopt until the prices fall. However, this also increases the probability of adoption in later periods as the barrier to adoption lowers, so the net effect on the persistent change from a contract made today would be

ambiguous.

If the recurring net cost c is expected to fall in the future, this would decrease during-program additionality due to the increased appeal of overcoming the adoption cost today. However, the effect on post-program additionality is ambiguous, since decreasing recurring net costs would increase a landowner's willingness to use the green practice in the future. That would both increase their odds of future adoption in absence of a contract and increase their odds of persisting after a contract.

3.5 Environmental Cost Structures

Finally, this model can easily be altered to accommodate different structures of the accumulation and loss of environmental value over time. This model assumes that society realizes the full environmental value of a practice in every period where it is implemented, and zero in every period where it is not. This is a reasonable structure for consumer energy use, but a less neat fit for agricultural practice change or forestry. Soil carbon gradually accumulates as farmers implement soil conservation practices and is gradually lost when they do not (Dynarski et al., 2020). Forest carbon disappears after a single period's decision to log. In these cases, environmental value only builds up with recurring periods of practice use and disappears with any reversion.

In these cases, targeting those with high recurring benefits of the practice becomes more worthwhile, since it increases the gap in value between the permanent adopters and the occasional adopters. These individuals will be less additional, since they do have an incentive to consider the practice on their own, but they are more likely to provide the consistently recurring use of the practice that these environmental values depend on. Alternatively, longer or repeated contracts may play a particularly important role in preventing environmentally costly practice reversions.

4 Conclusion

Many environmentally beneficial practices require effort both to adopt and to maintain. The perceived size of the adoption costs and the recurring net costs or benefits can determine whether an individual will adopt the practice on their own, whether they will participate in incentive programs, and whether they will continue the practice after incentives end.

Few studies today address additionality and persistence as a joint concern, often due to the lack of availability of long-term data. In absence of such studies, policymakers may be tempted to focus on improving their programs purely through improving during-program additionality, which can be evaluated over shorter timeframes and with less attention to long-run tracking of participants. These changes could create an unambiguous improvement if participants mostly vary by adoption costs. However, if this variation in during-program additionality is driven by differences in recurring net costs, policymakers risk cutting

into their program's persistent impact. Persistence of additional participants will vary most if the practice's recurring benefits are expected to be positive for some and negative for others. This seems particularly true for cases like agricultural practice adoption and for forest protection and regrowth, where weather, soil, and local economic conditions may greatly alter the profitability of practices even across nearby areas.

In addition, policymakers can use this framework of short-term and long-term costs to improve the structure of repeat payment programs. One-time contracts can provide all needed support for changes that need adoption costs but face few if any recurring net costs, such as building water management structures. However, many environmentally beneficial practices may produce long-term environmental benefits but not enough financial benefits for the producer to continue them on their own. In those cases, repeat contracts with smaller payments that cover these ongoing costs could create a substantial impact. This highlights a role for programs like the Conservation Stewardship Program (CSP), a USDA program that pays past conservation practice adopters to enhance or add new conservation practices while sustaining previous ones.

This paper also illustrates the need for more work in this area that controls for the application decision and that follows practices over longer periods of time. Future programs should put care into tracking unsuccessful applicants, since they are a subgroup that are likely to be more similar in terms of unobservables than any other group. In addition, they are particularly relevant when exploring the likely effects of marginal increases or decreases in program funding. If long-term tracking of participants is difficult, researchers may also focus on improving our estimates of the long-term costs and benefits of a new practice, a key indicator of potential post-contract additionality.

In future work, researchers can also explore how the full range of nature-based solutions fit into this framework of recurring net and adoption costs. Nature-based solutions could provide up to 30% of the emissions reductions needed to meet global goals (Miles et al., 2021). They include a wide range of practice changes, including improved forestry management, reduced tillage and other agricultural changes, regenerative rangeland management, agroforestry, and shifts in nutrient management. Achieving the full potential of these changes will require tailoring incentives to a wide variety of economic and biological contexts. The adoption cost and recurring net cost framework of this paper can provide a starting point for that work through estimating adoption and recurring net costs and their variance within and between populations.

References

Allcott, H., & Rogers, T. (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review*, *104*(10), 3003–3037. https://doi.org/10.1257/aer.104.10.3003

Aspelund, K., & Russo, A. (2023, November 3). *Additionality and asymmetric information in environmental markets: Evidence from conservation auctions*. Retrieved August 6, 2024, from https://economics.yale.edu/sites/default/files/2024-01/Russo%20Additionality%20and%20Asymmetric%20Information.pdf

Barbier, E. B., & Burgess, J. C. (2025). Economics of nature-based solutions for mitigating climate change. *Review of Environmental Economics and Policy*, *19*(2). https://doi.org/https://doi.org/10.1086/735742

Bergtold, J. S., Ramsey, S., Maddy, L., & Williams, J. R. (2019). A review of economic considerations for cover crops as a conservation practice. *Renewable Agriculture and Food Systems*, *34*(1), 62–76. https://doi.org/10.1017/S1742170517000278

Brancalion, P. H. S., Meli, P., Tymus, J. R. C., Lenti, F. E. B., M. Benini, R., Silva, A. P. M., Isernhagen, I., & Holl, K. D. (2019). What makes ecosystem restoration expensive? a systematic cost assessment of projects in brazil. *Biological Conservation*, *240*, 108274. https://doi.org/10.1016/j.biocon.2019.108274

Brandão, M., & Levasseur, A. (2011, January 1). *Assessing temporary carbon storage in life cycle assessment and carbon footprinting: Outcomes of an expert workshop*.

Che, Y., Rejesus, R. M., Cavigelli, M. A., White, K. E., Aglasan, S., Knight, L. G., Dell, C., Hollinger, D., & Lane, E. D. (2023). Long-term economic impacts of no-till adoption. *Soil Security*, *13*, 100103. https://doi.org/10.1016/j.soisec.2023.100103

Claassen, R., Duquette, E. N., & Smith, D. J. (2018). Additionality in u.s. agricultural conservation programs. *Land Economics*, *94*(1), 19–35. https://doi.org/10.3368/le.94.1.19

Claassen, R., Horowitz, J. K., Duquette, E. N., & Ueda, K. (2014, July 28). *Additionality in u.s. agricultural conservation and regulatory offset programs* (Economic Research Report No. 170). US Department of Agriculture Economic Research Service. Washington DC. Retrieved July 28, 2026, from https://www.ers.usda.gov/publications/45245

Conservation Technology Information Center. (2023, August). *National cover crop survey report 2022-2023*.

Costa, F., & Gerard, F. (2021). Hysteresis and the welfare effect of corrective policies: Theory and evidence from an energy-saving program. *Journal of Political Economy*, *129*(6). https://doi.org/10.1086/713729

Curran, W. S. (2016). Persistence of herbicides in soil [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.2134/cs2016-49-0504]. *Crops & Soils*, *49*(5), 16–21. https://doi.org/10.2134/cs2016-49-0504

Cusser, S., Bahlai, C. A., Swinton, S. M., Robertson, G. P., & Haddad, N. M. (2020). Long-term research needed to avoid spurious and misleading trends in sustainability attributes of no-till. *Global Change Biology*, *26*, 3715–3725. https://doi.org/10.1111/gcb.15080

Dayer, A. A., Lutter, S. H., Sesser, K. A., Hickey, C. M., & Gardali, T. (2018). Private landowner conservation behavior following participation in vol-

untary incentive programs: Recommendations to facilitate behavioral persistence [_eprint: https://conbio.onlinelibrary.wiley.com/doi/pdf/10.1111/conl.12394]. *Conservation Letters*, *11*(2), e12394. https://doi.org/10.1111/conl.12394

Deines, J. M., Wang, S., & Lobell, D. B. (2019). Satellites reveal a small positive yield effect from conservation tillage across the US corn belt. *Environmental Research Letters*, *14*(12), 124038. https://doi.org/10.1088/1748-9326/ab503b

Derpsch, R., Friedrich, T., Kassam, A., & Li, H. (2010). Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*, *3*(1), 1–25. Retrieved July 29, 2026, from https://ijabe.org/index.php/ijabe/article/view/223

Drechsler, M., Johst, K., & Wätzold, F. (2017). The cost-effective length of contracts for payments to compensate land owners for biodiversity conservation measures. *Biological Conservation*, *207*, 72–79. https://doi.org/10.1016/j.biocon.2017.01.014

Dynarski, K. A., Bossio, D. A., & Scow, K. M. (2020). Dynamic stability of soil carbon: Reassessing the "permanence" of soil carbon sequestration. *Frontiers in Environmental Science*, *8*. https://doi.org/10.3389/fenvs.2020.514701

Environmental Working Group. (2023). EWG conservation database. https://conservation.ewg.org/index.php

Fearnside, P. M., Lashof, D. A., & Moura-Costa, P. (2000). Accounting for time in mitigating global warming through land-use change and forestry. *Mitigation and Adaptation Strategies for Global Change*, *5*(3), 239–270. https://doi.org/10.1023/A:1009625122628

Ferraro, P. J., Bowman, M., Correia, H. E., Gao, J., Larson, K. R., Messer, K. D., Paul, L. A., Pratt, B., & Prokopy, L. S. (2025). Beyond adoption: The persistence of conservation and climate-smart agricultural practices in the united states. *Proceedings of the National Academy of Sciences*, *122*(43), e2518373122. https://doi.org/10.1073/pnas.2518373122

Fleming, P., Lichtenberg, E., & Newburn, D. A. (2018). Evaluating impacts of agricultural cost sharing on water quality: Additionality, crowding in, and slippage. *Journal of Environmental Economics and Management*, *92*, 1–19. https://doi.org/10.1016/j.jeem.2018.08.007

Globus-Harris, I. (2020). Waiting periods as a screening mechanism for environmental subsidies. *Journal of the Association of Environmental and Resource Economists*, *7*(6), 1151–1180. https://doi.org/10.1086/710319

Ito, K., Ida, T., & Tanaka, M. (2018). Moral suasion and economic incentives: Field experimental evidence from energy demand. *American Economic Journal: Economic Policy*, *10*(1), 240–267. https://doi.org/10.1257/pol.20160093

Jones, J. P. G., & Lewis, S. L. (2023). Forest carbon offsets are failing. *Science*, *381*(6660), 830–831. https://doi.org/10.1126/science.adj6951

Lötjönen, S., Kulovesi, K., Lång, K., & Ollikainen, M. (2024). Offset ratios and temporary contract designs for climate integrity in carbon farming [_eprint: https://doi.org/10.1080/17583004.2024.2329593]. *Carbon Management*, *15*(1), 2329593. https://doi.org/10.1080/17583004.2024.2329593

Mezzatesta, M., Newburn, D., & Woodward, R. (2013). Additionality and the adoption of farm conservation practices. *Land Economics*, *89*. https://doi.org/10.3368/le.89.4.722

Miles, L., Agra, R., Sengupta, S., Vidal, A., & Dickson, B. (2021, November 4). *Nature-based solutions for climate change mitigation*. UN Environmental Programme. Retrieved November 2, 2024, from https://portals.iucn.org/library/node/49781

Morton, T., Bergtold, J., & Price, A. (2006). The economics of cover crop biomass for corn and cotton.

Murray, B. C., Sohngen, B., & Ross, M. T. (2006). Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects [Last Modified: 2018-06-08T10:25-04:00]. *Climatitic Change*, *2007*(80), 127–143. Retrieved January 22, 2024, from https://nicholasinstitute.duke.edu/environment/publications/naturalresources/economic-consequences-of-consideration-of-permanence-leakage-and-additionality-for-soil-carbon-sequestration-projects-1

Myers, R., Weber, A., & Tellatin. (2019, June). *Cover crop economics*. SARE. Retrieved January 17, 2024, from https://www.sare.org/resources/cover-crop-economics/

Nunes, S., Oliveira, L., Siqueira, J., Morton, D. C., & Souza, C. M. (2020). Unmasking secondary vegetation dynamics in the brazilian amazon. *Environmental Research Letters*, *15*(3), 034057. https://doi.org/10.1088/1748-9326/ab76db

O'Connor, C. (2013). Soil matters: How the federal crop insurance program should be reformed to encourage low-risk farming methods with high-reward environmental outcomes [Number: 156789]. *2013 AAEA: Crop Insurance and the Farm Bill Symposium*. Retrieved October 15, 2024, from https://ideas.repec.org//p/ags/aaeaci/156789.html

Oldfield, E. E., Eagle, A. J., Rubin, R. L., Rudek, J., Sanderman, J., & Gordon, D. R. (2022). Crediting agricultural soil carbon sequestration. *Science*, *375*(6586), 1222–1225. https://doi.org/10.1126/science.abl7991

Pannell, D. J., & Claassen, R. (2020). The roles of adoption and behavior change in agricultural policy [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/aepp.13009]. *Applied Economic Perspectives and Policy*, *42*(1), 31–41. https://doi.org/10.1002/aepp.13009

Pittelkow, C. M., Liang, X., Linquist, B. A., van Groenigen, K. J., Lee, J., Lundy, M. E., van Gestel, N., Six, J., Venterea, R. T., & van Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture [Number: 7534]. *Nature*, *517*(7534), 365–368. https://doi.org/10.1038/nature13809

Prokopy, L. S., Floress, K., Arbuckle, J. G., Church, S. P., Eanes, F. R., Gao, Y., Gramig, B. M., Ranjan, P., & Singh, A. S. (2019). Adoption of agricultural conservation practices in the united states: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation*, *74*(5), 520–534. https://doi.org/10.2489/jswc.74.5.520

Reid, J. L., Fagan, M. E., Lucas, J., Slaughter, J., & Zahawi, R. A. (2019). The ephemerality of secondary forests in southern costa rica [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/conl.12607]. *Conservation Letters*, *12*(2), e12607. https://doi.org/10.1111/conl.12607

Robinson, C., & Nielsen, D. (2015). The water conundrum of planting cover crops in the great plains: When is an inch not an inch? [_eprint: https://onlinelibrary.wiley.com/doi/pdf/ 48-1-7]. *Crops & Soils*, *48*(1), 24–31. https://doi.org/10.2134/cs2015-48-1-7

Rosenberg, A. B., Pratt, B., & Szmurlo, D. (2024). Impacts of an increase in federal assistance for cover cropping: Evidence from the environmental quality incentives program [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ajae.12502]. *American Journal of Agricultural Economics*, *n/a*. https://doi.org/10.1111/ajae.12502

Sainju, U. M., & Singh, B. P. (2001). Tillage, cover crop, and kill-planting date effects on corn yield and soil nitrogen [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.2134/agronj2 *Agronomy Journal*, *93*(4), 878–886. https://doi.org/10.2134/agronj2001.934878x

Sawadgo, W., & Plastina, A. (2021). Do cost-share programs increase cover crop use? empirical evidence from iowa. *Renewable Agriculture and Food Systems*, *36*(6), 527–535. https://doi.org/10.1017/S1742170521000132

Sinacore, K., García, E. H., Finkral, A., van Breugel, M., Lopez, O. R., Espinosa, C., Miller, A., Howard, T., & Hall, J. S. (2023). Mixed success for carbon payments and subsidies in support of forest restoration in the neotropics. *Nature Communications*, *14*(1), 8359. https://doi.org/10.1038/s41467-023-43861-4

Snapp, S. S., Swinton, S. M., Labarta, R., & Mutch, D. (2005). Evaluating cover crops for benefits, costs and performance within cropping system niches [Num Pages: 11 Place: Madison, United States]. *Agronomy Journal*, *97*(1), 322–332. Retrieved October 15, 2024, from https://www.proquest.com/docview/194507436/citation/A73C0A2EC94F4CBAPQ/1

Stapp, J., Nolte, C., Potts, M., Baumann, M., Haya, B. K., & Butsic, V. (2023). Little evidence of management change in california's forest offset program. *Communications Earth & Environment*, *4*(1), 1–10. https://doi.org/10.1038/s43247-023-00984-2

Temple, L., & Song, J. (2021, April 29). *The climate solution actually adding millions of tons of CO2 into the atmosphere* [ProPublica]. Retrieved June 10, 2025, from https://www.propublica.org/article/the-climate-solution-actually-adding-millions-of-tons-of-co2-into-the-atmosphere

USDA NRCS. (2018, April). *Title 440-conservation programs manual, part 512 - conservation program contracting* (No. 440-512-M). USDA NRCS.

van Benthem, A., & Kerr, S. (2013). Scale and transfers in international emissions offset programs. *Journal of Public Economics*, *107*, 31–46. https://doi.org/10.1016/j.jpubeco.2013.08.004

Vincent, J. R., Curran, S. R., & Ashton, M. S. (2021). Forest restoration in low- and middle-income countries. *Annual Review of Environment and Resources*, *46*, 289–317. https://doi.org/10.1146/annurev-environ-012220-020159

Wallander, S., Bowman, M., Beeson, P., & Claassen, R. (2017, December 1). *Farmers and habits: The challenge of identifying the sources of persistence in tillage decisions* (2018 Allied Social Sciences Association (ASSA) Annual Meeting, January 5-7, 2018, Philadelphia, Pennsylvania No. 266307). Agricultural and Applied Economics Association. Retrieved January 22, 2024, from https://econpapers.repec.org/paper/agsassa18/266307.htm

West, T. A. P., Börner, J., Sills, E. O., & Kontoleon, A. (2020). Overstated carbon emission reductions from voluntary REDD+ projects in the brazilian amazon. *Proceedings of the National Academy of Sciences*, *117*(39), 24188–24194. https://doi.org/10.1073/pnas.2004334117

Wuepper, D., Henzmann, S., & Finger, R. (2023). Measuring farmer time preferences: A systematic literature review for europe and north america [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/jaa2.97]. *Journal of the Agricultural and Applied Economics Association*, *2*(4), 823–837. https://doi.org/10.1002/jaa2.97

Zahawi, R. A., Reid, J. L., & Holl, K. D. (2014). Hidden costs of passive restoration [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/rec.12098]. *Restoration Ecology*, *22*(3), 284–287. https://doi.org/10.1111/rec.12098

Zhang, Y., Rejesus, R. M., Cavigelli, M. A., White, K. E., Knight, L., Dell, C., Hollinger, D., & Lane, E. D. (2025). Long-term economic impacts of no-till adoption in the US midwest [Number: 361069]. *2025 AAEA & WAEA Joint Annual Meeting, July 27-29, 2025, Denver, CO*. Retrieved July 29, 2026, from https://ideas.repec.org//p/ags/aaea25/361069.html

A Deriving The Farmer's Optimal Unconstrained Choice

The landowner's optimal strategy requires choosing two cutoffs: the productivity shock ϵ^a above which the landowner will choose $x_t = 1$ if they have never adopted before, meaning $\max(X_{t-1}) = 0$, and the productivity shock ϵ^c above which the previously adopting landowner with $\max(X_{t-1}) = 1$ will choose $x_t = 1$. The landowner seeks to maximize their value function, $V(\max(X_{t-1}), \epsilon) = E[\sum_{t=1}^{\infty}(1-r)^{t-1}U(x_t, \epsilon_t)]$ with $U(x_t, \epsilon_t)$ given by Equation 1.

First, I derive the landowner's optimal choice if they have adopted in a previous period, so $\max(X_{t-1}) = 1$. In this case, the landowner's valuation for either option becomes

$$\begin{aligned} V(1, \epsilon_t) =& (1-r)E[V^*(1)] \text{ if } x_t = 0 \\ & \epsilon_t - c + (1-r)E[V^*(1)] \text{ if } x_t = 1 \end{aligned} \tag{11}$$

If the farmer has already adopted, their optimal future choice is to choose $x_t = 1$ if

$$\epsilon - c + (1-r)E[V^*(1)] \geq (1-r)E[V^*(1)]$$
$$\epsilon \geq c$$

So the threshold productivity shock required for continued practice use by previous adopters is $\epsilon^c = c$: the productivity shock must be higher than any cost the beneficial practice imposes or at least must not be so negative that it cancels out the benefits the beneficial practice provides.

I now input this threshold into the valuation function to calculate $E[V^*(1)]$, the expected future value of having previously adopted:

$$E[V^*(1)] = P(\epsilon \geq c)(E[\epsilon|\epsilon \geq c]) - P(\epsilon \geq c)c + (1-r)E[V^*(1)] \tag{12}$$

Taking the infinite geometric sum, this solves to

$$E[V^*(1)] = \frac{P(\epsilon \geq c)(E[\epsilon|\epsilon \geq c]) - P(\epsilon \geq c)c}{r} = \frac{E[\max(c, \epsilon)] - c}{r}$$

(13)

Next, I derive the landowner's choice if $\max(X_{t-1}) = 0$: the initial adoption decision. The landowner's payoffs in this period are

$$\begin{aligned} V(0, \epsilon_t) =& (1-r)E[V^*(0)] \text{ if } x_t = 0 \\ & \epsilon_t - a - c + (1-r)E[V^*(1)] \text{ if } x_t = 1 \end{aligned} \tag{14}$$

Note two key differences. First, if the landowner does not adopt this period, they now expect $(1-r)E[V^*(0)]$ instead of $(1-r)E[V^*(1)]$ next period. Second, if the landowner does adopt this period, they must pay the adoption cost a.

At the threshold ϵ^a, the payoffs of either option must be equal. So

$$(1-r)E[V^*(0)] = \epsilon^a - c - a + (1-r)E[V^*(1)]$$

$$E[V^*(0)] = \frac{\epsilon^a - c - a}{1-r} + E[V^*(1)]$$

where $E[V^*(1)]$ can be calculated using Equation A. We can then use the definition of $E[V^*(0)]$ to get

$$E[V^*(0)] = P(\epsilon < \epsilon^a)(1-r)E[V^*(0)] + P(\epsilon \geq \epsilon^a)(E[\epsilon|\epsilon > \epsilon^a] - c - a + (1-r)E[V^*(1)])$$

$$\frac{\epsilon^a - c - a}{1-r} + E[V^*(1)] = P(\epsilon < \epsilon^a)((1-r)(\frac{\epsilon^a - c - a}{1-r} + E[V^*(1)]))$$
$$+P(\epsilon \geq \epsilon^a)(E[\epsilon|\epsilon > \epsilon^a] - c - a + (1-r)E[V^*(1)])$$

$$\frac{\epsilon^a - c - a}{1-r} + E[V^*(1)] = -a - c + (1-r)E[V^*(1)] + E[\max(\epsilon^a, \epsilon)]$$

Substituting in $V^*(1)$ from Equation A,

$$\frac{\epsilon^a}{1-r} - E[\max(\epsilon^a, \epsilon)] = \frac{ra + c}{1-r} - E[\max(c, \epsilon)] \tag{15}$$

This equation fully characterizes ϵ^a.

B Deriving Persistent Change

Here I derive the persistent change of the contract from ϵ^a and ϵ^c, the policy cutoffs. The contract forces the landowner to set $x_1 = 1$. In all future periods, $\max(X_{t-1}) = 1$, so the landowner repeats the beneficial policy whenever $\epsilon_t \geq \epsilon^c$. In absence of the contract, the landowner has chosen each period whether to do the beneficial action. Since ϵ is iid, $\max(X_{t-1}) = 0$ in period t with probability $P(\epsilon < \epsilon^a)^{t-1}$. In total, the ex ante probability that the uncontracted landowner sets $x_t = 1$ is

$$P(x_n = 1) = P(\epsilon < \epsilon^a)^{n-1}(P(\epsilon \geq \epsilon^a)) + (1 - P(\epsilon < \epsilon^a)^{n-1})(P(\epsilon \geq \epsilon^c))$$

To derive the persistent effect in period t, we subtract the probability $x_t = 1$ for noncontracted individuals from the probability $x_n = 1$ for contracted individuals. Together,

$$Persistence_t = P(e \geq \epsilon^c) - P(\epsilon < \epsilon^a)^{t-1}(P(\epsilon \geq \epsilon^a)) - (1 - P(\epsilon < \epsilon^a)^{t-1})(P(\epsilon \geq \epsilon^c))$$

$$Persistence_t = P(\epsilon < \epsilon^a)^{t-1}(P(\epsilon \geq \epsilon^c) - (P(\epsilon \geq \epsilon^a))$$

$$Persistence_t = P(\epsilon < \epsilon^a)^{t-1}(P(\epsilon^c \leq \epsilon < \epsilon^a))$$

C The Effects of Interest Rate Variation

A change in the interest rate does not affect the practice choice of past adopters captured by ϵ^c, since they use the practice when $\epsilon \geq c$. However, a higher interest rate will make a landowner less willing to adopt for the first time. ϵ^a, defined in Equation 4, will be increasing because the terms $E[V^*(1) - V^*(0)]$ is decreasing in r and $(1-r)$ is decreasing in r.

This means that landowners with higher interest rates will have higher additionality and persistence, holding adoption costs and net recuring costs constant. Correspondingly, landowners with higher interest rates will demand higher prices for a contract today, since they place less value on the future benefits of having paid the adoption cost. Interest rates will also increase the landowner's sensitivity to adoption costs relative to recurring net costs and benefits: a landowner with a higher discount rate will place greater weight on adoption costs paid today and less on recurring net costs or benefits realized in the future.

D Deriving the Additionality of Repeated Contracting

I derive the additionality of allowing recontracting in period 2. Since the repeated contract is only offered to those who previously contracted, we know that $x_1 = 1$ as we enter the period 2 contracting process. Additionality in period 2 is therefore

$$Additionality_2(a, c) = 1 - P(x_2 = 1 | x_1 = 1) \tag{16}$$

Since $x_1 = 1$, the landowner has already paid the adoption cost. From Equation 3, the landowner will choose $x_2 = 1$ if $\epsilon_2 \geq \epsilon^c = c$. So the recontract additionality is

$$Additionality_2(a, c) = P(\epsilon_2 < c) \tag{17}$$

Proving Proposition 1

Proposition 1 states that additionality is 1) strictly increasing in adoption cost a and 2) strictly increasing in recurring net cost c.

Part 1: First, I prove that additionality is strictly increasing in adoption cost a. By equation 6, $Additionality(a, c) = P(\epsilon < \epsilon^a(a, c))$, so additionality is increasing in ϵ^a: if the threshold for adoption without incentives is higher, additionality is higher. So I set out below to prove that $\frac{d\epsilon^a}{da} > 0$.

Take the condition for optimal ϵ^a derived in Equation 5. This can be rearranged to

$$\frac{ra}{1-r} = \frac{\epsilon^a - c}{1-r} - E[\max(\epsilon, \epsilon^a)] + E[\max(c, \epsilon)]$$

Taking partial derivatives and applying the envelope theorem to $E[\max(\epsilon, \epsilon^a)]$,

$$\frac{rda}{1-r} = (\frac{1}{1-r} - P(\epsilon < \epsilon^a))d\epsilon^a$$

$$\frac{d\epsilon^a}{da} = \frac{r}{1-(1-r)P(\epsilon < \epsilon^a)}$$

Since $1 > (1-r)P(\epsilon < \epsilon^a)$ and $r > 0$, it must be that $\frac{d\epsilon^a}{da} > 0$, and so additionality is increasing in adoption cost a.

Part 2: Next, I prove that additionality is strictly increasing in recurring net costs c. I rearrange Equation 5 to

$$\frac{\epsilon^a - ra}{1-r} - E[\max(\epsilon, \epsilon^a)] = \frac{c}{1-r} - E[\max(c, \epsilon)]$$

$$(\frac{1}{1-r} - P(\epsilon < \epsilon^a))d\epsilon^a = (\frac{1}{1-r} - P(\epsilon < c))dc$$

$$\frac{d\epsilon^a}{dc} = \frac{1-(1-r)P(\epsilon < c)}{1-(1-r)P(\epsilon < \epsilon^a)}$$

Both the numerator and denominator are ¿0, so $\frac{d\epsilon^a}{dc} > 0$ and additionality is increasing in c.

E Proving Proposition 2

Proposition: The period t persistent change is increasing in adoption cost a. Persistent change is increasing in recurring net cost c for $c < c^{max}(t)$ and decreasing in c for $c > c^{max}(t)$ for some $c^{max}(t)$.

Part 1: First, I prove that the persistent change is increasing in adoption cost a. From Equation 7,

$$Persistence_t(a, c) = P(\epsilon < \epsilon^a)^{t-1}(P(\epsilon \leq \epsilon^a) - P(\epsilon < c))$$

Taking the derivative,

$$\frac{dPersistence}{da} = \frac{d\epsilon^a}{da} f(\epsilon^a) P(\epsilon < \epsilon^a)^{t-2}(tP(\epsilon < \epsilon^a) - (t-1)P(\epsilon < c))$$

From Appendix D, we know that $\frac{d\epsilon^a}{da} \geq 0$. $f(\epsilon^a) \geq 0$ and $P(\epsilon < \epsilon^a) \geq 0$ by definition as a pdf and probability respectively. Finally, we know $\epsilon^a \geq c$, since by Equation 5,

$$\frac{\epsilon^a}{1-r} - E[\max(\epsilon^a, \epsilon)] = \frac{c}{1-r} - E[\max(c, \epsilon)] + \frac{ra}{1-r}$$

Which means that $tP(\epsilon < \epsilon^a) - (t-1)P(\epsilon < \epsilon^c) \geq 0$. Since all components of this derivative are ≥ 0, then $\frac{dPers}{da} \geq 0$.

Part 2: The limit of persistence goes to 0 as recurring net cost c increases to ∞ and goes to 0 as c decreases to $-\infty$. By assumption, $\epsilon^t \in [\epsilon^{min}, \epsilon^{max}]$, so $P(\epsilon \leq \epsilon^{max}) = 1$ and $P(\epsilon \leq \epsilon^{min}) = 0$. From Equation 7,

$$Persistence_t(a, c) = P(\epsilon \leq \epsilon^a)^{t-1}(P(\epsilon \leq \epsilon^a) - P(\epsilon \leq c))$$

First, to show that $\lim_{c\to\text{inf}} Persistence^t(a,c) = 0$: Using Equation 5, we can find a value c^{max} such that $\epsilon^a(a,c) = \epsilon^{max}$. From Proposition 1, we know that ϵ^a is increasing in c, so $P(\epsilon \leq \epsilon^a) = 1 \forall c \geq c^{max}$. We also know that $P(\epsilon \leq c) = 1 \forall c \geq \epsilon^{max}$. Therefore, when $c \geq c^{max}$ and $c \geq \epsilon^{max}$,

$$Persistence_t(a,c) = 1^{t-1}(1-1)$$

$$Persistence_t(a,c) = 0$$

So $\lim_{c\to\text{inf}} Persistence^t(a,c) = 0$.

Next, I show that $\lim_{c\to-\text{inf}} Persistence_t(a,c) = 0$. Using Equation 5, we can find a value c^{min} such that $\epsilon^a(a,c) = \epsilon^{min}$. From Proposition 1, we know that ϵ^a is increasing in c, so $P(\epsilon \leq \epsilon^a) = 0 \forall c < c^{min}$. We also know that $P(\epsilon \leq c) = 0 \forall c < \epsilon^{min}$. Therefore, when $c < c^{min}$ and $c < \epsilon^{min}$,

$$Persistence_t(a,c) = 0^{t-1}(0-0)$$

$$Persistence_t(a,c) = 0$$

So $\lim_{c\to-\text{inf}} Persistence_t(a,c) = 0$.

F Proving Proposition 3

Proposition: When recurring net costs c are fixed and participants vary only by a, persistent change is weakly increasing in additionality. When adoption cost a is fixed and participants vary only by recurring net costs c, persistent change may be increasing or decreasing in additionality.

Part 1: When recurring net costs c are fixed and participants vary only by a, persistent change is weakly increasing in during-program additionality.

This follows from Proposition 1. Since during-program additionality is weakly increasing in a and persistent change is weakly increasing in a, then persistent change must be weakly increasing in during-program additionality holding all else fixed.

Part 2: When adoption cost a is fixed and participants vary only by recurring net costs c, persistent change may be increasing or decreasing in during-program additionality.

This follows from Proposition 2. Additionality is weakly increasing in recurring net costs. Since persistence goes to 0 as recurring net costs go sufficiently negative, so over some range of possible recurring net costs, during- and post-program additionality would be positively correlated. Since persistence also goes to 0 as recurring net costs go sufficiently to infinity, over some range of possible recurring net costs, additionality and persistence would be negatively correlated.

G Proving Proposition 4

Proposition: $Additionality_2(a,c) \leq Additionality_1(a,c)$, and $Additionality_1(a,c) - Additionality_2(a,c)$ is weakly increasing in a.

Part 1: $Additionality_2(a,c) \leq Additionality_1(a,c)$ Using the definitions of each, this proposition holds if

$$P(\epsilon < c) \leq P(\epsilon < \epsilon^a)$$

$$c \leq \epsilon^a$$

$\epsilon^a(0,c) = c$, and from Proposition 1, ϵ^a is increasing in a. So it must hold that $c \leq \epsilon^a$ and the proposition holds.

Part 2: $Additionality_1(a,c) - Additionality_2(a,c)$ is weakly increasing in a follows directly. $Additionality_2(a,c)$ does not depend on a, and $Additionality_1(a,c)$ is weakly increasing in a, so $Additionality_1(a,c) - Additionality_2(a,c)$ must be weakly increasing in a.

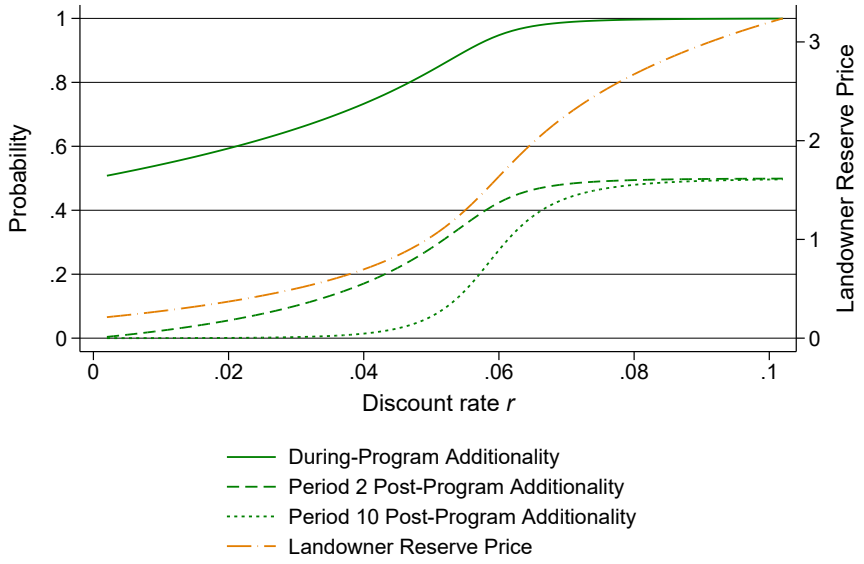
H Interest Rate Variations

The discount rate impacts landowner decision making purely through its effect on the probability of initial adoption defined by ϵ^a. In Equation 4, the interest rate enters the definition of ϵ^a through the term subtracting $(1-r)[E(V(1) - V(0)]$. Both terms shrink as the discount rate grows since the landowner cares more about current expenditures and less about the value of future profits. ϵ^a rises as the discount rate grows, reflecting that landowners demand higher current period benefits to overcome their adoption costs. However, once a landowner has adopted, the discount rate no longer matters for decision-making because the current-period choice does not impact future profits. For those who have already adopted, they persist if and only if $\epsilon_t \geq c$, meaning the green practice is more profitable in this period. This leads to the following proposition:

Proposition 5 *Additionality, persistence, and reserve price of a contract are strictly increasing in the landowner's discount rate r.*

This decrease in the willingness to adopt the practice translates into landowners with higher interest rates having higher additionality and persistence. Figure 5 demonstrates this relationship. As discount rates rise, additionality and persistence rise as well as it becomes more improbable that the landowner will adopt the practice without assistance. This figure bears considerable similarities to Figure 2a demonstrating the effect of a changing adoption cost, since both of these impact the adoption decision and do not change the post-program choice. If discount rate variation matters most, then additionality and persistence will move together.

Figure 5: The Effects of Different Discount Rates



Outcomes modeled with ϵ $N(0,1)$, recurring net cost $c = 0$, and adoption cost $a = 5$ while discount rate r varies.