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1 May 2023

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Abstract

Herein, we examine the optimal contract design when social norms have a disutility on landowners' participation in payment for environmental services programs. We find that a regulator can use less powerful monetary incentives to induce landowners to retire more land when the regulator appeals to social norms. Next, we consider the case when landowners determine the social norms of land retirement endogenously given that they live in small communities. We find that when there is asymmetric information about personal norms, the high-personal-norm type will retire more than the optimal amount of land and the low-personal-norm type will

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retire less than the optimal amount of land. We also explore when there is asymmetric information about landowners' sensitivities to social norms. We find that the optimal contract design depends on the relative magnitude of landowners' personal norms and the expected social norms. The results differ from the standard mechanism design literature.

Keywords: Social norms, Mechanism design, Payment for environmental services, Asymmetric information.

JEL Classification: D82; D91; Q57.

Acknowledgment: This paper is drawn from one chapter of Qin's Ph.D. dissertation at the University of Wyoming. We would like to thank Thorsten Janus for his extensive comments. We are also grateful to David Aadland, Mariah Ehmke, David Finnoff, Ben Gilbert, Chuck Mason, Sherrill Shaffer, Alexandre Skiba, Klaas van't Veld, Till Requate, and seminal participants at the University of Wyoming, 16th Annual CU Environmental and Resource Economics Workshop, and Heartland Environmental Workshop for their helpful comments. Qin thanks the College of Business at the University of Wyoming for their support. Shogren also thanks the Rasmuson Chair at the University of Alaska-Anchorage for their support.

1 Introduction

1.1 Motivation

Human activities have significantly affected ecosystems, including extinctions of species, loss of ecosystem functions of water supply, and climate change (Millennium ecosystem assessment, 2005). To reverse the trend of ecosystem degradation, many governments have adopted payment for environmental service (PES) programs. Prominent national examples include the Conservation Reserve Program (CRP) in the US, the Sloping Land Conversion Program (SLCP) in China, and afforestation programs in Costa Rica. To address soil erosion and poor water quality, the US congress introduced the CRP in 1985. It pays landowners to retire their unproductive land for a certain duration of time, mostly between 10 and 15 years (Ferris and Siikamäki, 2019). It is the largest federally funded conservation program in the US and currently pays approximately US$1.8 billion a year to landowners to rent environmentally-sensitive land.[1] Following a major flood of the Yangtze River in 1997 due to soil erosion, in 1999, the Chinese central government launched the SLCP. It has a budget of over US$40 billion and has targeted the conversion of approximately 14.67 million hectares of cropland to forests, especially in West China, by 2010 (Bennett, 2008). In Costa Rica, the biodiversity and scenic beauty of the country are threatened by rapid deforestation. The Costa Rican government initiated government-funded projects to promote reforestation between 1979 and 1996. A total area of around 109,000 hectares of land has been reforested with funding of more than $100 million (Zbinden and Lee, 2005). In Europe, agri-environmental policies are examples of payment for environmental services. Governments pay farmers to adopt good farming practices,

[1] http://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Conservation/PDF/summary12.pdf

which reduce negative externality from agricultural production. They also pay farmers for the private provision of public goods such as attractive landscapes produced by agriculture (Baylis et al., 2008). Salzman et al. (2018) provides a review of the global status and trends of PES.

At the state level, incentive programs abound. For example, California's Timber Tax Credit Program, Idaho's Habitat Improvement Program (HIP), and Washington's Salmon Recovery Funding Board are PES programs (Parkhurst and Shogren, 2003). The Defenders of Wildlife 2002 provides a complete survey of state government's incentive programs[2]. At the local level, many local communities have their own conservation trusts. There are over 1700 land trusts which own more than four million acres. They also have over 130,000 conservation easements which cover more than 23 million acres (Langpap et al., 2020). For example, in the Western States, there are Wyoming Wildlife and Natural Resource Trusts and Montana Fish & Wildlife Conservation Trust. These trusts fund conservation projects in local communities.

Most conservation programs pay landowners to convert their land to more environmentally friendly usage. However, several problems exist with these government-funded programs. First, they may not be sustainable as government funding is limited.[3] Second,

[2]Conservation in America: State Government Incentive for Habitat Conservation. http://www.defenders.org/publications/conservation_in_america_state_profiles.pdf

[3]From 2014, China started the second phase of SLCP, but the sudsides are 1600 yuan/mu in total which will be distributed within 5 years. The subsidies are smaller and shorter (https://www.forestry.gov.cn/main/4861/20211123/154627006331729.html). When subsidies stop, farmers are likely to convert their land back to farmland (Kelly and Huo, 2013). The future of the SLCP is uncertain. In Costa Rica, the PES mechanism shifts from government funding towards market oriented mechanism as the funding is a burden on government budgets (Zbinden and Lee, 2005). In the US, government budget deficits make sustainability of the CRP uncertain.

the payment of taxes to support those programs will incur a social cost (Laffont, 1995; Smith and Shogren, 2002). Third, many empirical studies have shown that monetary incentives can crowd out individuals' intrinsic motivation to engage in some activities and result in poor performances in the long run (Deci, 1971; Deci et al., 1999; Lepper et al., 1973; Festré and Garrouste, 2015)[4].

Social psychologists suggest that individuals' decision making is also affected by the social context (Cialdini and Goldstein, 2004). People's behavior is influenced by others' behavior and expectations (Clayton and Brook, 2010). Cialdini et al. (1990) define norms as "shared beliefs within a culture as to what constitutes socially appropriate conduct". Deutsch and Gerard (1955) have argued that there are two types of social norms: the injunctive social norm and the descriptive social norm. An injunctive social norm is what other people expect people to do; a descriptive social norm is what people observe from the behavior of others. Studies have found that social norms can have the same effect as a price change on household energy consumption (Kim and Kaemingk, 2021; Andor and Fels, 2018; Bonan et al., 2021; Ayres et al., 2013; Allcott, 2011; Allcott and Mullainathan, 2010; Schultz et al., 2007). Studies have also found that social norms are effective in increasing towel reuse (Goldstein et al., 2008), reducing water consumption (Jessoe et al., 2021; Jaime Torres and Carlsson, 2018; Ferraro and Price, 2011), and increasing recycling (Schultz, 1999). Chen et al. (2009) use stated choice methods to study participant decisions when the SLCP ends. They find that people are more likely to

[4]Rode et al. (2015) provides a review on the crowding effect of monetary incentives on people's intrinsic motivation to conserve biodiversity and ecosystem. Other literature includes Benabou and Tirole (2003); Benabou and Tirole (2005); Bowles (2008);Gneezy and Rustichini (2000);Frey and Oberholzer-Gee (1997), and Titmuss (1970). For surveys on the effect, see Fehr and Falk (2002) and Frey and Jegen (2001).

participate if they know that their neighbors are participating. The importance of social norms on common pool resource management has been widely studied (Ostrom et al., 1992; Nyborg et al., 2016). Carlsson et al. (2021) and Farrow et al. (2017) provide surveys of the abundant literature on social norms and conservation. Given the importance of social norms in people's decisions, the question we consider is how a mechanism with social norms can be designed to induce more land retirement with less payment in order to save public funds.

Herein, we extend the Smith and Shogren (2002) and Banerjee and Shogren (2012)—henceforth SS and BS—mechanisms by incorporating the role of social norms in contracts for landowners to retire their land for ecosystem services.[5] We assume landowners' land retirement has not only a monetary cost but also a disutility related to social norms. Similar to Fischer and Huddart (2008), we define each landowner's social norms as the weighted average of her personal norm (each landowner's personal belief about the amount of land to retire) and a common social norm, which is the average of others' land retirement. The higher each landowner's social norms, the lower the cost of land retirement.

1.2 Land conservation, mechanism design, and social norms

To provide ecosystem services to society, many governments choose to pay landowners to retire their land. Since it is costly for governments to raise public funds by collecting taxes, governments only want to pay landowners' opportunity cost of land or even less if landowners derive pleasure from not developing their land (Innes et al., 1998). Several asymmetric information problems can arise when governments decide to pay landowners

[5]See Qin and Shogren (2015) who explore how social norms affect Laffont (1995)'s classic model on monopoly contracts given catastrophic risk; Qin and Janus (2019) study how social norms affect Hoel (1991)'s results on a unilateral action to abate pollutants.

to retire their land. First, land values are usually unknown to regulators and are private information known to landowners. Some landowners have high-quality land, while others have low-quality land. This is the most common type of asymmetric information problem as discussed in SS. Second, some landowners place less value on monetary compensation and care more about their reputations. Paying money to these landowners may crowd out their intrinsic motivation to retire their land. Other landowners value monetary compensation more but do not want others to see them as greedy. They care about their reputations. This is the asymmetric information case studied by BS. Third, some landowners care more about conservation (green landowners), and others care less about conservation (brown landowners). They also conform to the social norms of land retirement, but with different sensitivities: some conform more, and some conform less. These two types of asymmetric information are the focus of this paper. Table 1 shows the key similarities and differences when considering the four types of asymmetric information.

Mechanism design is a useful tool to solve the asymmetric information problem (Laffont, 1995). The regulator can design a contract menu with compensation rates and acres of land retirement for landowners. Landowners with high-value land receive a higher compensation rate and retire less land, while landowners with low-value land receive a lower compensation rate and retire more land. Regulators make contracts for high-value land less attractive to reduce information rent (Innes et al., 1998). SS design a voluntary incentive mechanism with two types of landowners: high-quality land and low-quality land. Table 1 illustrates their results. They find the optimal contract is to induce less than the optimal amount of land from landowners with high-quality land and the optimal amount of land from landowners with low-quality land. Landowners with low-quality land receive positive information rent, and landowners with high-quality land receive no information rent. BS extend the work to incorporate reputation. They assume landowners have concern about their reputations, which depends on how other people perceive them, such as being selfish (low reputation) or socially responsible (high reputation). Their study covers situations in which there is asymmetric information about landowners' type. Table 1 shows their findings. They find that the low-reputation landowners sacrifice information rent to the extent that they buy reputation from regulators and retire the optimal amount of land. The high-reputation landowner obtains no information rent and retires more than the optimal amount of land.

This paper introduces social norms and assumes that landowners conform to the norm of land retirement in their communities. **Social norms are believed to be important factors for private contribution of public goods (Ostrom, 2000). Several papers have studied the optimal policy design when social norms matter (Rege, 2004; Bowles and Hwang, 2008; Hwang and Bowles, 2014; Ulph and Ulph, 2018; Meunier and Schumacher, 2020). Rege (2004) studied the public good provision problem with social norms in a static model. She found governmental subsidization of the public good can promote the society to an all-contributor equilibrium. Meunier and Schumacher (2020) extended Rege (2004)'s model to the dynamic setting and showed the complete adherence to the social norm state is not necessarily optimal. In addition, Bar-Gill and Fershtman (2005) argued public policy can change people's preferences and social norms and they studied the public policy design with endogenous preferences.** We study when the social norms are endogenously determined by landowners (landowners can choose their land retirement to change the social norms), and there is asymmetric information about landowners' type: green (landowners who care about ecosystem service and are willing to retire their land without compensation) and brown (landowners who care less about ecosystem service and are not willing to retire their land without compensation). Table 1 shows our findings. We find that green landowners retire more than the optimal amount of land and that brown landowners retire less than the optimal amount of land. This result differs from both SS and BS, as more land retirement from the green type will reduce the information rent because of a higher social norm. Brown landowners consequently retire less than the optimal amount of land in order to make contracts less attractive to green landowners. Green landowners capture positive information rent. This result is the same as SS but different from BS, who find that high-reputation landowners capture zero information rent and that low-reputation landowners sacrifice information rent to the extent that they buy reputation from regulators. **Our paper is also different from Meunier and Schumacher (2020), Bar-Gill and Fershtman (2005), and Rege (2004) as we use a mechanism design approach.**

The structure of the remaining paper is as follows: In section 2 we establish the benchmark model of exogenous social norms with asymmetric information. In section 3, we extend the model to the situation when social norms are endogenous and there is asymmetric information. Based on our results, we discuss some policy implications in section 4. We conclude in section 5.

Table 1: Comparison of mechanisms and outcomes given reputation and social norms

	SS	BS	This paper		
Types	High-value land	High reputation	Low personal norm	Sensitivity to social norms	
	Low-value land	Low reputation	High personal norm	(collective or individualistic)	
Target	Land retirement	Land retirement	Land retirement	Land retirement	
				$P < S$	$P > S$
High type behavior	Suboptimal land	More than the optimal amount of land	Suboptimal land	Suboptimal land	More or less than the optimal amount of land
High type information rent	Zero	Zero	Zero	Zero	Zero
Low type behavior	Optimal land	Optimal land	More than the optimal amount of land	More or less than the optimal amount of land	More than the optimal amount of land
Low type information rent	Positive	Negative	positive	Positive	Positive

2 Benchmark model of exogenous social norms with asymmetric information

2.1 Basic model definitions with social norms under full information

We use SS as a motivating model—a voluntary incentive design for participating in the PES program. Suppose each landowner voluntarily selects a acres of land to participate in the PES. The cost of land retirement is $f(a)$, which is convex, and $f'(a) > 0, f''(a) > 0$. Landowners receive a compensation rate T for each acre of land retired. Assume that the payment of taxes to support the subsidy incurs a social cost from using public funds; let λ represent this deadweight loss per \$1, where $\lambda > 0$. The social benefit from ecosystem services depends on the amount of land retired by the landowner. Define the social benefit function from ecosystem service as $B(a)$, where $B(i)$ is increasing and concave.

The regulator designs a contract by choosing T and a to optimize net social welfare from ecosystem service, subject to the individual participation constraint

$$max_{T,a} W = B(a) - f(a) - \lambda T a, \tag{1}$$

$$s.t. Ta - f(a) \geq \xi. \tag{2}$$

where ξ denotes the landowner's reservation profit.

The solution to the regulator's decision problem is determined by the first order condition[6]

$$\frac{B'(a^*)}{1+\lambda} = f'(a^*) \tag{3}$$

[6]We assume both the benefit and cost functions are well-behaved. There exists a unique a^*. We assume interior solutions. When $T = 0$, landowners will not voluntarily retire their land as land retirement has an opportunity cost.

where a^* is the optimal land retirement and T^* is the optimal compensation, i.e.,

$$T^* = \frac{f(a^*) + \xi}{a^*}. \tag{4}$$

Equation (3) shows that the marginal benefit from land retirement equals the marginal cost, adjusted for deadweight loss. Equation (4) ensures that the rewards compensate the cost and the reservation profit ξ.

We now add the social norm into the model to explore how it affects landowners' behavior regarding land retirement. Following Fischer and Huddart (2008), we assume the social norm of land retirement will affect each landowner's cost to retire their land. The rent function of a landowner is[7]

$$\Pi_i = T_i a_i - f(a_i - N_i), i = 1, ...n. \tag{5}$$

where f is a cost function with continuous derivatives defined over the real line, and $f' > 0$ and $f'' > 0$. A landowner's cost is influenced by a norm parameter N_i, which affects the landowner's total and marginal costs of land retirement.[8] A higher value for the norm reduces the marginal cost of land retirement because

$$\frac{\partial^2 f(a_i - N_i)}{\partial a_i \partial N_i} = -f'' < 0. \tag{6}$$

Including the norm N_a in the cost function for the land retirement captures the idea that, in addition to any rent loss, land retirement has a disutility that is determined

[7]This modeling approach differs from studies such as Akerlof (1980);Lindbeck (1997);Lindbeck et al. (1999), which usually assume the deviation from the social norm will lead to disutility. We assume landowners conform to the social norm and study how differing sensitivities to social norms will affect the contract design.

[8]We restrict $a_i - N_i > 0$ as evidence shows that people conform to the social norm. Landowners will choose at least N_i due to the social norm effect. With monetary incentives, landowners will retire more than N_i. We can also define the cost function as $f(a_i - bN_i)$. When $b = 1$, it is a social norm model. When $b = 0$, it reduces to the classical model. The inclusion of b will not change our formal results.

in part by the norm of the behavior (Fischer and Huddart, 2008)[9]. For example, a landowner may have a personal ethic that supports environmental protection, which we term a personal norm. In addition, a landowner may be part of a community with a cultural ethic that supports environmental protection with feelings of satisfaction, which we term a social norm. A higher norm of either type causes landowners to be inclined to retire more land for a given level of monetary incentives. We assume a landowner's norm, N_i, is a weighted average of her personal norm P_i and a common social norm for environment protection S_{-i}, which is the per capita average level of land retirement of other landowners in the community. The norm for a landowner in a community is

$$N_i = (1 - \alpha_i)P_i + \alpha_i S_{-i}, \tag{7}$$

where [10]

$$S_{-i} \equiv \frac{\sum a_j}{n}, j \neq i. \tag{8}$$

Parameter $\alpha_i \in [0, \bar{\alpha}]$, where $0 \leq \alpha \leq 1$, represents the extent to which landowner i is influenced by the land retirement decisions of others in the community through the social norm, and $\alpha_i > 0$ implies that i chooses a higher a_i in response to an increase in the average land retirement of her peers. The first-order condition that characterizes landowner i's choice is:

$$T_i = f'(a_i^* - (1 - \alpha_i)P_i - \alpha_i S_{-i}), \tag{9}$$

where a_i^* is the optimal land retirement of landowner i. The second-order condition requires $-f'' < 0$. From equation (9), a landowner equates his marginal benefit from

[9] In Fischer and Huddart (2008), they call the feeling of shame or guilt induced by failing to conform to the norm the "emotional cost". Here we follow most of the literature and call it "disutility".

[10] We assume all other landowners in the neighborhood have equal weight to the social norm. For a heterogenous distance model, see Friedkin and Johnsen (2011).

land retirement to the marginal cost. The cost is the loss of rent due to land retirement and the disutility determined by the social norm.

The regulator knows landowners' personal norms and sensitivities to the social norm. The regulator maximizes the net social benefits from retiring land by choosing a and T, subject to landowners' participation constraints

$$Max_{a_i,T_i} W_i = B(a_i) - f(a_i - (1-\alpha_i)P_i - \alpha_i S_{-i}) - \lambda T_i a_i, \tag{10}$$

$$s.t. T_i a_i - f(a_i - (1-\alpha_i)P_i - \alpha_i S_{-i}) \geq \xi. \tag{11}$$

where ξ is the landowner's reservation rent before participation. Optimal regulation implies the following: i) information rents are zero; and ii)

$$f'(a_i^* - (1-\alpha_i)P_i - \alpha_i S_{-i}) = \frac{B'(a_i^*)}{1+\lambda}. \tag{12}$$

In Equation (12) the right-hand side is the adjusted social benefit from land retirement, and the left-hand side is the marginal cost of land retirement. Optimal land retirement occurs when the marginal benefit from land retirement equals the marginal cost. After solving equation (12) for a_i^*, substituting it into the constraints we obtain

$$T_i^* = (\xi + f(a_i^* - (1-\alpha_i)P_i - \alpha_i S_{-i}))/a_i^*. \tag{13}$$

Compared to the case with no social norm, we find that the optimal land retirement will be higher and the compensation rate will be lower in the full information with the social norm case. This is because social norms tend to reduce landowners' cost of land retirement as stated in Equation (6).

2.2 Allowing for exogenous social norms and asymmetric information

The economics literature usually assumes that people's preferences are exogenous. When there is a large group, one person's actions have little impact on the social norm. They are assumed to be norm-takers (Fischer and Huddart, 2008). We first study the case when landowners behave like norm-takers. We also consider cases when landowners are heterogeneous in their personal norms about land retirement as well as in their sensitivities to the social norm.[11] Moreover, all information about personal norms and sensitivities to the social norm are unknown to the regulator.

First, we assume landowners' sensitivities to the social norm α is constant. There are two types of landowners with a high personal norm and a low personal norm, $P \in \left\{\underline{P}, \overline{P}\right\}$. The high-personal-norm type landowner has a high ethic of land conservation, and the low-personal-norm type has a low ethic of land conservation.

Second, we assume landowners have the same personal norms but differ in their sensitivities to the social norm. Experimental studies have found that people have different sensitivities to social norms. Some people are sensitive to social norms and are conditional cooperators; some people are not sensitive to social norms and are free riders (Ostrom, 2000; Fischbacher et al., 2000). Assume that two types of landowners exist — one with a low sensitivity and one with and high sensitivity to social norms, $\alpha \in \{\underline{\alpha}, \overline{\alpha}\}$. We call the high-sensitivity type the social type and the low-sensitivity type the Econobot type.

We assume that landowners have imperfect information about the social norm S_{-i}. Psychologists find that people can have a perception bias about social norms (Miller and

[11] Fischbacher et al. (2000) find that a third of the subjects are free riders and that 50% of the subjects are conditional cooperators in their experiment.

Prentice, 1994b,a).[12] The most documented misperceptions in the psychology literature are false consensus and uniqueness bias (Ross et al., 1977; Suls and Wan, 1987). False consensus is when people tend to overestimate the proportion of people who behave the same way as they do. Uniqueness bias is also known as "holier than thou". People tend to overestimate their tendency to do charitable, noble things compared to others. For example, in a study about water conservation after a storm, Monin and Norton (2003) report bathers' estimation of people who take showers over three days after a ban on showering to conserve water. They find that bathers tend to overestimate the percent of people who did the same. When the ban was lifted after three days, subjects tended to underestimate the number of people who took a shower. Another study on opinions regarding climate change finds that people significantly overestimate the percent of people who deny climate change (Leviston et al., 2013). The authors also find that people tend to overestimate the percentage of people who share the same opinion as theirs. This finding suggests that there could be an underestimation of the social norm of land retirement (uniqueness bias) or that landowners could believe others would retire the same land as they do (false consensus).

2.3 Benchmark results

We summarize our first result in Proposition 1.

PROPOSITION 1: *Given exogenous social norms and asymmetric information about personal norms, the optimal contract is characterized by the following features:*

(i) The high-personal-norm landowner retires the optimal amount of land, and the low-personal-norm landowner retires less than the optimal amount of land. The high-

[12]For economic studies about perception bias, see Benabou and Tirole (2012) and Cooter et al. (2008)

personal-norm landowner receives positive information rent, and the low-personal-norm landowner receives no information rent.

(ii) *The comparative statics suggest the following: An increase in the personal norm of a low-personal-norm type increases land retirement from the low-personal-norm type; an increase in the high-personal-norm type's norm increases land retirement from the high-personal-norm type and reduces land retirement from the low-personal-norm type. An increase in sensitivity to the social norm reduces land retirement from the high-personal-norm type and increases land retirement from the low-personal-norm type.*

Proof. See appendix. □

The regulator buys less than the optimal amount of land from the low-personal-norm landowner because this would reduce the information rent the regulator has to pay to the high-personal-norm landowner. High-personal-norm type landowners want to retire more land because their high ethic of environmental protection will support more land retirement. If the regulator buys very little from the low-personal-norm type, the high-personal-norm type has fewer incentives to pretend to be a low-personal-norm type. The regulator can pay the high-personal-norm type less information rent. This outcome is consistent with the standard mechanism design concluded in the literature, which is that there is no distortion from the top (Laffont, 1995).

We find that information rent is zero for the landowner with a low personal norm and positive for the landowner with a high personal norm. This is because the high-personal-norm type landowners can hide their private information and pretend to be a low-personal-norm type.

Proposition 1(i) shows as the low-personal-norm type landowners have higher costs to retire land, the optimal contract induces them to retire less than the optimal amount of land. The high-personal-norm type landowners have a lower cost and they receive an information rent to reveal their private information about personal norms, which we summarize:

Proposition 1(ii) shows an increase in the personal norm of the low (high) personal norm type will increase land retirement from the low (high) personal norm type. This is because a higher personal ethic of environment conservation supports more land retirement. An increase in the personal norm of the high-personal-norm type reduces land retirement from the low-personal-norm type. This is because it is more costly to induce land retirement from the low-personal-norm type. With higher land retirement from the high-personal-norm type, the regulator can induce less land retirement from the low-personal-norm type to save public funds. An increase in the sensitivity to the social norm reduces land retirement from the high-personal-norm type as she tends to conform to the social norm by reducing her land retirement. An increase in the sensitivity to the social norm increases land retirement from the low-personal-norm type as she tends to conform to the social norm by increasing her land retirement.

Our next result characterizes landowners behavior under the second best contract when social norms are exogenous and there is asymmetric information about landowners' sensitivities.

PROPOSITION 2: *Given exogenous social norms and asymmetric information about landowners' sensitivities to social norms, the optimal contract is characterized by the following features:*

(i) *If landowners' personal norms are lower than the perceived social norm, the high-*

sensitivity landowner retires the optimal amount of land, while the low-sensitivity landowner retires less than the optimal amount of land. The high-sensitivity landowner receives information rent, while the low-sensitivity landowner receives zero information rent.

(ii) *If landowners' personal norms are greater than the perceived social norm, the low-sensitivity landowner retires the optimal amount of land, and the high-sensitivity landowner retires less than the optimal amount of land. The low-sensitivity landowner receives information rent, and the high-sensitivity landowner receives zero information rent.*

(iii) *If landowners' personal norms are identical to the perceived social norm, both types retire the optimal amount of land and both receive zero information rent.*

Proof. See appendix. □

Proposition 2(i) holds because when landowners overestimate other's land retirement, a high-sensitivity type tends to increase her land retirement. The regulator will design a contract with higher compensation rates for the low-sensitivity type landowners to engage them. To reduce information rent, the high-sensitivity type will retire the optimal amount of land and the low-sensitivity type will retire less than the optimal amount of land. We find that information rent is zero for the landowner with a low sensitivity and positive for the landowner with a high sensitivity. To reveal the high-sensitivity type's information, the regulator will design a contract to give them some information rent.

Proposition 2(ii) holds because when landowners underestimate other's land retirement, a high-sensitivity type tends to decrease her land retirement. The regulator will design a contract with higher compensation rate for the high-sensitivity type to engage them. To reduce information rent, the high-sensitivity type will retire less than the optimal amount of land, and the low-sensitivity type will retire the optimal amount of land. We find that information rent is zero for the landowner with a high sensitivity and positive for the landowner with a low sensitivity. To reveal the low-sensitivity type's information, the regulator will design a contract to give them some information rent.

Proposition 2(iii) holds because when landowners have consensus bias and think that other landowners will retire the same amount of land as they do, sensitivity to the social norm does not matter: both types will retire the same optimal amount of land.

Proposition 1 and 2 define our benchmark that follows the classic economic presumption that preferences are exogenous, including for social norms (see e.g., Mas-Colell et al. (1995)). But many people are not norm-takers, but rather they can shape the norm (see Friedkin and Johnsen (2011) on work by psychologists and sociologists). Their preferences for social norms are endogenously determined by the number of population who follow them (see Akerlof (1980); Lindbeck (1997)). In this section, we now consider the case that landowners can endogenously determine the social norms of land retirement. From a strategic point of view, landowners who live in small-knit communities are aware of the impact of their decisions on social norms and take into account the impact when they make land retirement decisions. We explore how the mechanism design is impacted and how behavior changes with this presumption.

3 Introducing endogenous social norms

3.1 Benchmark: full information about personal norms

As a benchmark, we study the full information about personal norms problem. Now we assume there are two types of landowners and both have rational expectations about the social norm, which is defined as the expected value of both type's land retirement.

$$S_{-i} = q\overline{a} + (1-q)\underline{a}. \tag{14}$$

The regulator's problem will be:

$$MaxW_{\overline{a},\overline{T},\underline{a},\underline{T}} = q[B(\overline{a}) - f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) - \lambda \overline{T}\overline{a}] +$$

$$(1-q)[B(\underline{a}) - f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - \lambda \underline{T}\underline{a}], \tag{15}$$

$$s.t. \overline{T}\overline{a} - f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \geq \overline{\xi} \tag{16}$$

$$\underline{T}\underline{a} - f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \geq \underline{\xi} \tag{17}$$

$$S_{-i} = q\overline{a} + (1-q)\underline{a}. \tag{18}$$

The participation constraints are binding. Solving the above problem, we obtain the high-personal-norm type's optimal land retirement:

$$\frac{B'(\overline{a})}{1+\lambda} = (1-\alpha q)f'(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) - \alpha(1-q)f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \tag{19}$$

The first term of the right-hand side is the high-personal-norm type's marginal cost of land retirement adjusted for the social norm effect. The second term is the social norm effect on the low-personal-norm type's marginal cost of land retirement. By comparison with equation (12), we find that both the direct social norm effect on the high-personal-norm type's own marginal cost and the indirect social norm effect on the low-personal-norm type's marginal cost require higher land retirement. Similarly, we obtain the low-personal-norm type's optimal land retirement:

$$\frac{B'(\underline{a})}{1+\lambda} = (1-\alpha(1-q))f'(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) - \alpha q f'(\overline{a}-(1-\alpha)\overline{P}-\alpha S_{-i}) \quad (20)$$

The first term of the right-hand side is the low-personal-norm type's marginal cost of land retirement adjusted for the social norm effect. The second term is the social norm effect on the high-personal-norm type's marginal cost of land retirement. By comparison with equation (12), we find that both the direct social norm effect on the low-personal-norm type's own marginal cost and the indirect social norm effect on the high-personal-norm type's marginal cost require higher land retirement.

3.2 Asymmetric information about personal norms

Our next result characterizes the landowner behavior under the second best contract when social norms are endogenous and there is asymmetric information about personal norms. The key result is summarized in the following proposition:

PROPOSITION 3: *Given endogenous social norms and asymmetric information about personal norms, the optimal contract is characterized by the following features:*

(i) *The high-personal-norm landowner retires more than the optimal amount of land, and the low-personal-norm landowner retires less than the optimal amount of land.*

(ii) *The high-personal-norm landowner receives positive information rent, and the low-personal-norm landowner receives zero information rent.*

Proof. See appendix. □

In Proposition 3, to reduce the information rent to the high-personal-norm type, the regulator will buy less from the low-personal-norm type. This is consistent with the literature that there is a downward distortion for the less efficient type. The regulator's problem under asymmetric information is similar to the complete information benchmark except there is information rent under asymmetric information. We can undertake a marginal analysis of the information rent R.

$$R_P = f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \tag{21}$$

and we have

$$dR_P/d\underline{a} = (1-\alpha(1-q))\left[f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f'(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})\right] > 0 \tag{22}$$

When there is a small increase in the low-personal-norm type's land retirement, information rent increases. To reduce information rent, the optimal contract is to retire less than optimal amount of land from the low-personal-norm type under asymmetric information. Proposition 3 finds that the high-personal-norm landowner retires more than the optimal amount of land. This conclusion is different from the literature, which is that there is no distortion from the top (see Laffont and Martimort (2009)). This is because a higher land retirement from the high-personal-norm type can reduce the information rent due to the social norm effect. Given we define the rent as R_p, we have

$$\frac{dR_P}{d\overline{a}} = -\alpha q\left[f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f'(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})\right] < 0. \tag{23}$$

As the high-personal-norm type's land retirement only affects the information rent through the social norm effect, a higher land retirement of the high-personal-norm type will reduce the information rent.

3.3 Benchmark: full information about landowners' sensitivities

As a benchmark, we assume there are two types of landowners with high and low sensitivities to social norms. Landowners' sensitivities information is known to the regulator. The regulator's problem will be:

$$MaxW_{\overline{a},\overline{T},\underline{a},\underline{T}} = q[B(\overline{a}) - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - \lambda\overline{T}\overline{a}] + $$

$$(1-q)[B(\underline{a}) - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) - \lambda\underline{T}\underline{a}], \quad (24)$$

$$s.t.\overline{T}\overline{a} - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) \geq \overline{\xi} \quad (25)$$

$$\underline{T}\underline{a} - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) \geq \underline{\xi} \quad (26)$$

$$S_{-i} = q\overline{a} + (1-q)\underline{a}. \quad (27)$$

The participation constraints are binding. Solving the above problem, we obtain:

$$\frac{B'(\overline{a})}{1+\lambda} = (1-\overline{\alpha}q)f'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - \underline{\alpha}(1-q)f'(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) \quad (28)$$

$$\frac{B'(\underline{a})}{1+\lambda} = (1-\underline{\alpha}(1-q))f'(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) - \overline{\alpha}qf'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) \quad (29)$$

The intuition at work in expressions (28)-(29) is similar to that in (19) and (20).

3.4 Asymmetric information about sensitivities to the social norm

Our next result characterizes landowner behavior under the second best contract when social norms are endogenous and there is asymmetric information about sensitivities. The key results are summarized in the following proposition:

PROPOSITION 4: *Given endogenous social norms and asymmetric information about landowners' sensitivities to the social norm, the optimal contract is characterized by the following features:*

(i) *If landowners' personal norms are lower than the perceived social norm, the low-sensitivity type retires less than the optimal amount of land, whereas the high-sensitivity type's land retirement is ambiguous compared to the optimal land retirement. The high-sensitivity type receives positive information rent, and the low-sensitivity type receives no information rent.*

(ii) *If landowners' personal norms are greater than the perceived social norm, the low-sensitivity type retires more than the optimal amount of land, while the high-sensitivity type's land retirement is ambiguous compared to the optimal amount of land retirement. The low-sensitivity type receives positive information rent, and the high-sensitivity type receives no information rent.*

(iii) *If landowners' personal norms are identical to the perceived social norm, both types will retire the land until the marginal benefit equals zero.*

Proof. See appendix. □

Proposition 4(i) suggests that the low-sensitivity type retires less than the optimal amount of land. This is because buying less from the low-sensitivity type can reduce the information rent, which is illustrated in expression (30):

$$dR_{\alpha 1}/(d\underline{a}) = (1-\underline{\alpha}(1-q))f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - (1-\overline{\alpha}(1-q))f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) > 0 \quad (30)$$

where information rent $R_{\alpha 1} = f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i})$,and $\underline{\alpha} < \overline{\alpha}, P < S_{-i}$.

Case 1 can occur when environmental services matter significantly or land retirement costs are low. The regulator induces large land retirement from both types. Case 1 can also happen when landowners have low personal norms.

Proposition 4(ii) suggests that the low-sensitivity type retires more than the optimal amount of land. This is because asking the low-sensitivity type to conserve more will increase the social norm, which will reduce the high-sensitivity type's cost more than it will reduce the low type's cost of imitating the high type. As a result, the information rent falls:

$$dR_{\alpha 2}/d\underline{a} = (-\overline{\alpha}(1-q))f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i})- \\ (-\underline{\alpha}(1-q))f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) < 0 \quad (31)$$

where $R_{\alpha 2} = f(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) - f(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i})$. To reduce information rent, the low-sensitivity type retires more than the optimal amount of land.

Case (2) can happen when ecosystem services are less important or the costs of land retirement are high. The regulator will induce small land retirement from both types. This case can also happen when landowners have high personal ethics of environment protection.

4 Policy implications

Implementing the insight gleaned from our model in the real world has several challenges relative to the original SS model. Recall in SS that the problems were to collect specific information and minimize information rent. The information needed is species survival function $S(.)$, a level for the minimum acceptable probability of survival (MAPS) constraint A, the deadweight loss to society λ, the distribution of landholder types, and landowners' rental function π.

Now, to design a mechanism with endogenous social norms, we also need parameter values such as the deadweight loss to society λ, landowners' reservation profit ξ, the society's benefit function $B(\cdot)$ from land retirement, and landowners' cost function $f(\cdot)$ from land retirement. Some information such as the distribution of land values is available from USDA's Farm Service Agency. Some other information such as the benefits to society from land retirement is hard to estimate. Therefore, the profit maximization problem reduces to a cost minimization problem. In addition, the regulator faces other challenges. The endogenous social norms work through a bottom-up approach. The key to the success of the implementation is to use social norms to induce landowners in local groups to retire more land and save public funds. The national program could be a success if a groundswell can be triggered. This is also the approach advocated by Ostrom (2010) to solve global problems such as climate change. She wrote, "The familiar slogan 'Think Globally but Act Locally' hits right at the dilemma facing all inhabitants of the world"(Ostrom (2010), p.551).

To implement this mechanism in local communities, first, we need the distribution of landowner types about their personal norms of land retirement. This can be done through surveying landowners' attitudes towards land conservation. Second, we need to inform landowners about the common social norm, which is the average of their neighbors' land retirement[13]. We can use the average land retirement in the previous period as a proxy for the common social norm. The regulator can send letters to landowners to inform them about the common social norm or post the information publicly. Third, the regulator can design a menu and offer a higher compensation rate for the low-personal-norm landowner

[13]The neighbor can be a physical neighbor or a co-member in the identity group.

and a lower compensation rate for the high-personal-norm type. The regulator buys less from the low-personal-norm type.

When the information about landowners' sensitivities is asymmetric, the regulator needs to determine landowners' perception about the common social norm. If landowners overestimate the common social norm of land retirement, the regulator can design a menu and give the low-sensitivity type a higher compensation rate and the high-sensitivity type a lower compensation rate. The regulator buys less from the low-sensitivity type and more from the high-sensitivity type. If landowners underestimate the common social norm, the regulator can give the high-sensitivity type a higher compensation rate and buy less from this type.

These same lessons could be extended to energy conservation. Several empirical field studies exist that explore how to use social norms to induce consumers to save energy (Kim and Kaemingk, 2021; Bonan et al., 2021; Andor and Fels, 2018; Ayres et al., 2013; Allcott, 2011; Allcott and Mullainathan, 2010; Schultz et al., 2007). Our paper offers a theoretical framework to help motivate these empirical studies. In this case, one can posit that households have personal norms about how much energy to consume each month. Households also care about the social norms of energy consumption. They will conform to the average of their neighbor's energy consumption, which is the social norm. These empirical energy studies could use our modeling framework to help understand better how a policy works to induce more energy saving while saving public funds in three ways.

First, a regulator could send households information about their neighbor's energy consumption level, which is exactly what the firm Opower has done (Allcott, 2011). To avoid the rebound effect (or what psychologists call the boomerang effect) by the low energy users who increase their consumption to conform to the norm, the regulator can use injunctive social norms to approve energy saving (see Schultz et al. (2007)).

Second, given asymmetric information about households' types, a regulator can offer some monetary incentives for energy saving. For example, many states in the US offer tax credits, rebates, and savings for energy-efficient purchases and improvements. However, if a regulator wants to engage the brown households without overpaying green households who adopt energy efficient purchases, she can design a menu for both households: (T(green), A_g), (T(brown), A_b), where T is the compensation rate and A is the adoption level of energy-efficient products. The regulator can use this menu to separate the two types. The compensation rate for brown households is higher than the rate for green households. Now, the regulator buys less from the brown households' energy saving as it is costly.

Third, given asymmetric information exists about households' sensitivities, a regulator could divide households into two groups: households that have (i) higher energy usage than the average, and (ii) households that have lower energy usage than the average. The regulator designs different menus for the two groups. For the high energy users group, the menu is (T(high sensitivity), A_{high}), (T(low sensitivity), A_{low}). The compensation rate is higher for the low-sensitivity type and lower for the high-sensitivity type. The regulator buys less from the low-sensitivity type's energy saving since it is costly. The regulator again can use this menu to separate the high- and low-sensitivity types. For the low energy users group, the compensation rate is higher for the high-sensitivity type and lower for the low-sensitivity type. The regulator buys less from the high-sensitivity type as it is costly to do so.

5 Concluding remarks

This paper applies the social psychology concept of social influence and designs a contract between the regulator and landowners to retire their land for conservation. The first insight from the model is that the regulator can use lower monetary incentives to induce more land retirement when the regulator appeals to the social norm. Second, the increase in both personal and social norms can reduce the transfer of money from the regulator to landowners. This result supports the idea of social norms campaign for more environmentally friendly behavior. We also study cases in which landowners differ in their personal norms or sensitivities to the social norm to protect the environment, and when this information is unknown to the regulator.

Next we explore the case when landowners endogenously determine the social norms given that they live in small tight-knit communities. When landowners take into account the effect of their land retirement decisions on the social norm, more monetary incentives are recommended as the multiplier effect of the social norm will reduce the cost and lead to more land retirement. We also find that land retirement is higher when landowners take social norms as endogenous. When there is asymmetric information about landowners' personal norms, we find that the high-personal-norm type will retire more than the optimal amount of land and that the low-personal-norm type will retire less than the optimal amount of land. When there is asymmetric information about landowners' sensitivities, the optimal contract design depends on the relative magnitude of the personal norm and the perceived social norm.

Although we build a theoretical model in the context of PES programs, it can also be applied to energy saving and climate change mitigation. If regulators want to use policy instruments such as taxes or subsidies to induce households to conserve energy, given the asymmetric information about households' sensitivities to the social norm, this model can be used to design the mechanism.

This paper studies the static contract design when there is asymmetric information about landowners' types. However, landowners may take a dynamic perspective to reveal their private information about personal norms or sensitivities to the social norms. The dynamic contract design will be different and is worthy of future research. Moreover, some results of this paper depend on how landowners perceive the social norms. What kind of misperceptions may landowners have about the social norms?[14] This is an empirical question worthy of future research.

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[14]See, for example, Chen et al. (2009), who find that landowners in China's Sichuan Province respond to the social norms of participation in the SLCP, and Primmer and Karppinen (2010), who observe that social norms have a strong influence on foresters' habitat delineation practice.

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A Appendix

PROOF OF PROPOSITION 1(i): The incentive compatibility constraints for the two types are:

$$\underline{Ta} - f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \geq \overline{Ta} - f(\overline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \quad \text{(A.1)}$$

$$\overline{Ta} - f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \geq \underline{Ta} - f(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \quad \text{(A.2)}$$

The participation constraints for the both types are:

$$\underline{Ta} - f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \geq \underline{\xi} \quad \text{(A.3)}$$

$$\overline{Ta} - f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \geq \overline{\xi} \quad \text{(A.4)}$$

Because the regulator pays the low-personal-norm landowner a higher compensation rate to engage her, the landowner with a high personal norm will pretend to have a low personal norm and capture information rent. Constraints A.2 and A.3 are binding.

Assuming that q is the probability that the landowner is a high-personal-norm type, the regulator's problem is to solve

$$MaxW_{\underline{a},\overline{a},\underline{T},\overline{T}} = q[B(\overline{a}) - f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) - \lambda\overline{Ta}] + (1-q)[B(\underline{a}) - f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - \lambda\underline{Ta}]. \quad \text{(A.5)}$$

From the binding constraints, we obtain:

$$\underline{Ta} = \underline{\xi} + f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) \quad \text{(A.6)}$$

$$\overline{Ta} = \underline{\xi} + f(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) + f(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) - f(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}) \quad \text{(A.7)}$$

Solving A.5-A.7, we obtain

$$\frac{B'(\underline{a})}{1+\lambda} = f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) + \frac{\lambda q}{1+\lambda q}\left[f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f'(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})\right], \quad \text{(A.8)}$$

$$\frac{B'(\overline{a})}{1+\lambda} = f'(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i}). \quad \text{(A.9)}$$

Comparing the first-order condition in equation (A.9) with the first-order condition in equation (12), we find that the landowner with a high personal norm retires the optimal amount of land. Comparing the first-order condition in equation (A.8) with the first-order condition in equation (12), we observe the landowner with a low personal norm will retire less than the optimal amount of land. This is because the last term in the bracket is positive, since $f'(\cdot) > 0$ and $f''(\cdot) > 0$.

PROOF OF PROPOSITION 1(ii):

In equation (A.9), using implicit function theory, we get:

$$\frac{\partial \overline{a}}{\partial \overline{P}} = \frac{-(1-\alpha)f''(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})}{\frac{B''(\overline{a})}{1+\lambda} - f''(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})} > 0 \quad \text{(A.10)}$$

$$\frac{\partial \overline{a}}{\partial \underline{P}} = 0 \quad \text{(A.11)}$$

$$\frac{\partial \overline{a}}{\partial \alpha} = \frac{(\overline{P} - S_{-i})f''(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})}{\frac{B''(\overline{a})}{1+\lambda} - f''(\overline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})} < 0 \quad \text{(A.12)}$$

These expressions hold because $B''(\cdot) < 0, f'' > 0, P < S_{-i} < \overline{P}$.

In equation (A.8), using implicit function theory we get:

$$\frac{\partial \underline{a}}{\partial \overline{P}} = \frac{\frac{\lambda q}{(1+\lambda)(1-q)}(1-\alpha)f''(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})}{\frac{B''(\underline{a})}{1+\lambda} - f''(\underline{a} - (1-\alpha)\underline{p} - \alpha S_{-i}) - \frac{\lambda q}{(1+\lambda)(1-q)}\Delta f''} < 0 \quad \text{(A.13)}$$

where $\Delta f'' = \left[f''(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f''(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})\right]$

We assume the cost function is a well-behaved convex function and has $f'' > 0, f''' = 0$ (f'' is a constant). The nominator is positive as $f'' > 0$. $\Delta f'' = 0$ as $f''' = 0$. The denominator is negative as $B'' < 0, f'' > 0$. Therefore, $\partial \underline{a}/\partial \overline{P} < 0$.

Similarly we have:

$$\frac{\partial \underline{a}}{\partial \underline{P}} = \frac{-(1-\alpha)\left[f''(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) + \frac{\lambda q}{(1+\lambda)(1-q)}\Delta f''\right]}{\frac{B''(\underline{a})}{1+\lambda} - f''(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) - \frac{\lambda q}{(1+\lambda)(1-q)}\Delta f''} > 0 \tag{A.14}$$

Both the nominator and the denominator are negative as $B'' < 0, f'' > 0$,and $f''' = 0$. Therefore, $\frac{\partial \underline{a}}{\partial \underline{P}} > 0$.

$$\frac{\partial \underline{a}}{\partial \alpha} = \frac{(\underline{P}-S_{-i})f''(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) + \frac{\lambda q}{(1+\lambda)(1-q)}\Delta f''}{\frac{B''(\underline{a})}{1+\lambda} - f''(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) - \frac{\lambda q}{(1+\lambda)(1-q)}\Delta f''} > 0 \tag{A.15}$$

Because $P < S_{-i} < \overline{P}, f'' > 0, f''' = 0$, both the first term and the second term in in the nominator is negative. The nominator is negative. The denominator is also negative as $B'' < 0, f'' > 0, f''' = 0$. Therefore, $\frac{\partial \underline{a}}{\partial \alpha} > 0$.

PROOF OF PROPOSITION 2: The incentive compatibility constraints for the two types are:

$$\underline{Ta} - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha} S_{-i}) \geq \overline{Ta} - f(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha} S_{-i}) \tag{A.16}$$

$$\overline{Ta} - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha} S_{-i}) \geq \underline{Ta} - f(\underline{a} - (1-\overline{\alpha})P - \overline{\alpha} S_{-i}) \tag{A.17}$$

The participation constraints for both types are

$$\underline{Ta} - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha} S_{-i}) \geq \underline{\xi} \tag{A.18}$$

$$\overline{Ta} - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha} S_{-i} \geq \overline{\xi} \tag{A.19}$$

For theoretical completeness, we consider three cases:

Case 1 If $P < S_{-i}$, landowners' personal norms are lower than the perceived social norm. The low-sensitivity type will get a higher compensation rate as his cost is higher than the high-sensitivity type. The high-sensitivity type landowner will have incentives to hide his type and pretend to be a low-sensitivity type. The high-sensitivity type will capture a positive information rent. Constraints (A.17) and (A.18) are binding. Assume q is the probability that the landowner is a high-sensitivity type, the regulator's problem is to solve

$$MaxW_{\underline{a},\overline{a},\underline{T},\overline{T}} = q[B(\overline{a}) - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - \lambda\overline{T}\overline{a}] + \\ (1-q)[B(\underline{a}) - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) - \lambda\underline{T}\underline{a}]. \quad \text{(A.20)}$$

From the binding constraints we get:

$$\underline{Ta} = \underline{\xi} + f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) \quad \text{(A.21)}$$

$$\overline{Ta} = \underline{\xi} + f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) + \\ f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - f(\underline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) \quad \text{(A.22)}$$

Solving A.20-A.22 we get

$$\frac{B'(\underline{a})}{1+\lambda} = f'(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) + \\ \frac{\lambda q}{1+\lambda q}\left[f'(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) - f'(\underline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i})\right], \quad \text{(A.23)}$$

$$\frac{B'(\overline{a})}{1+\lambda} = f'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}). \quad \text{(A.24)}$$

Comparing equation (A.24) with the complete information problem solution (12), we find the landowner with a high sensitivity will retire the optimal land. Since $f'(\cdot) > 0, f''(\cdot) > 0$, and $P < S_{-i}$, the last term in the bracket of equation (A.23) is positive. Comparing equation (A.23) with (12), we find the landowner with a low sensitivity will retire less than the optimal land.

Case 2: if $P > S_{-i}$, landowners' personal norms are higher than the perceived social norm. The high-sensitivity type will get a higher compensation rate as his cost is higher than the low-sensitivity type. The low-sensitivity type landowner will have incentives to hide his type and pretend to be a high-sensitivity type. The low-sensitivity type will capture a positive information rent. Constraints (A.16) and (A.19) are binding.

$$\overline{Ta} = \overline{\xi} + f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) \tag{A.25}$$

$$\underline{Ta} = \overline{\xi} + f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i} + f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - f(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) \tag{A.26}$$

Solving the optimization problem given by equation (A.20), (A.25), and (A.26), we get

$$\frac{B'(\overline{a})}{1+\lambda} = f'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) + \frac{\lambda q}{1+\lambda q}\left[f'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - f'(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i})\right], \tag{A.27}$$

$$\frac{B'(\underline{a})}{1+\lambda} = f'(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}). \tag{A.28}$$

Comparing equation (A.28) with the complete information problem solution (12), we find the landowner with a low sensitivity will retire the optimal land. Since $f'(\cdot) > 0, f''(\cdot) > 0$, and $P > S_{-i}$, the last term in the bracket of equation (A.27) is positive. Comparing equation (A.27) with (12), we find the landowner with a high sensitivity will retire less than the optimal land.

Case 3: $P = S_{-i}$, landowners' personal norms are the same as the perceived social norm. The sensitivities of landowners to the social norm do not matter in this case. There is no asymmetric information problem. The social norm each landowner facing is the same and $P = S_{-i}$. The regulator's problem is to solve:

$$max_{T,a} W = B(a) - f(a-P) - \lambda Ta, \tag{A.29}$$

$$s.t. Ta - f(a-P) \geq \xi. \tag{A.30}$$

Optimality implies

$$\frac{B'(a)}{1+\lambda} = f'(a-P), \tag{A.31}$$

and

$$Ta = f(a-P)+\xi. \tag{A.32}$$

Comparing equation (A.31) and (A.32) with equation (12) and (13), we see both types retire the same optimal land and no type gets any information rent.

PROOF OF PROPOSITION 3: The incentive compatibility constraints for the two types are the same as equation (A.1) and (A.2). The participation constraints for the both types are the same as equation (A.3) and (A.4). As before, constraints (A.2) and (A.3) are binding. Assume q is the probability that the landowner is a high-personal norm type, the regulator's problem is to solve

$$MaxW_{\underline{a},\overline{a},\underline{T},\overline{T}} = q[B(\overline{a}) - f(\overline{a}-(1-\alpha)\overline{P}-\alpha S_{-i}) - \lambda\overline{T}\overline{a}]+$$
$$(1-q)[B(\underline{a}) - f(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) - \lambda\underline{T}\underline{a}]. \tag{A.33}$$

From the binding constraints we get equations (21) and (22). Solving the above problem we get

$$\frac{B'(\underline{a})}{1+\lambda} = \frac{(1+\lambda-q)(1-\alpha+\alpha q)}{(1-q)(1+\lambda)}f'(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i})-$$
$$\frac{q}{(1-q)(1+\lambda)}[\alpha(1+\lambda)(1-q)f'(\overline{a}-(1-\alpha)\overline{P}-\alpha S_{-i})+$$
$$\lambda(1-\alpha(1-q))f'(\underline{a}-(1-\alpha)\overline{P}-\alpha S_{-i})] \tag{A.34}$$

$$\frac{B'(\overline{a})}{1+\lambda} = (1-\alpha q)f'(\overline{a}-(1-\alpha)\overline{P}-\alpha S_{-i}) + \frac{\lambda\alpha q}{1+\lambda}f'(\underline{a}-(1-\alpha)\overline{P}-\alpha S_{-i})-$$
$$\frac{[(1-q)(1+\lambda)\alpha-\lambda q]}{1+\lambda}f'(\underline{a}-(1-\alpha)\underline{P}-\alpha S_{-i}) \tag{A.35}$$

Comparing equation (A.34) with (20) we find

$$(A.34) \quad - \quad (20) \quad = \quad \frac{\lambda q(1-\alpha(1-q))}{(1-q)(1+\lambda)}R'_P \quad > \quad 0 \tag{A.36}$$

where $R'_P = f'(\underline{a} - (1-\alpha)\underline{P} - \alpha S_{-i}) - f'(\underline{a} - (1-\alpha)\overline{P} - \alpha S_{-i})$. This is because f' is increasing and $\underline{P} < \overline{P}$. The low personal norm type retires less than the optimal land. Comparing equation (A.35) with (19) we find:

$$(A.35) - (19) = -\frac{\lambda\alpha q}{1+\lambda}R'_P < 0 \tag{A.37}$$

As the right hand side of the above equation is marginal cost, this means in the asymmetric information case, the marginal cost curve shifts down compared to the complete information benchmark. The high-personal norm type retires more than the optimal land.

PROOF OF PROPOSITION 4: The incentive compatibility constraints for the two types are (A.16) and (A.17). The participation constraints for both types are (A.18) and (A.19).

We assume landowners have imperfect information about the social norm S_{-i}.

Case 1: If $P < S_{-i} = q\overline{a} + (1-q)\underline{a}$, landowners' personal norms are lower than the perceived social norm. Assume q is the probability that the landowner is a high-sensitivity type, the regulator's problem is to solve

$$MaxW_{\underline{a},\overline{a},\underline{T},\overline{T}} = q[B(\overline{a}) - f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - \lambda\overline{T}\overline{a}] +$$
$$(1-q)[B(\underline{a}) - f(\underline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) - \lambda\underline{T}\underline{a}],$$
$$S_{-i} = q_1\overline{a} + (1-q_1)\underline{a} \tag{A.38}$$

From the binding constraints, we get the same equations (A.21) and (A.22). Solving the above problem, we get

$$\frac{B'(\underline{a})}{1+\lambda} = \frac{(1+\lambda-q)(1-\underline{\alpha}+\underline{\alpha}q)}{(1-q)(1+\lambda)} f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - \frac{q}{(1-q)(1+\lambda)}[\overline{\alpha}(1+\lambda)(1-q)f'(\overline{a}-(1-\overline{\alpha}P-\overline{\alpha}S_{-i}) + \lambda(1-\overline{\alpha}(1-q))f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i})] \quad \text{(A.39)}$$

$$\frac{B'(\overline{a})}{1+\lambda} = (1-\overline{\alpha}q)f'(\overline{a}-(1-\overline{\alpha})\overline{P}-\overline{\alpha}S_{-i}) + \frac{\lambda\overline{\alpha}q}{1+\lambda} f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) - \frac{(1-q+\lambda)\underline{\alpha}}{1+\lambda} f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) \quad \text{(A.40)}$$

Comparing equation (A.40) with (28) we find:

$$(A.40)-(28) = \frac{\lambda q}{1+\lambda}[\overline{\alpha}f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) - \underline{\alpha}f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i})] \quad \text{(A.41)}$$

The sign of equation (A.41) depends on $\overline{\alpha}f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i})-\underline{\alpha}f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i})$, which is ambiguous. Comparing equation (A.39) with (29) we find:

$$(A.39)-(29) = \frac{\lambda q}{(1-q)(1+\lambda}(1-\underline{\alpha}(1-q))R_{\alpha 1} \quad \text{(A.42)}$$

The low sensitivity type retires less than the optimal land.

To see the intuition behind this ambiguity, note the information rent is $R_{\alpha 1}$.

$$\frac{dR_{\alpha 1}}{d\overline{a}} = (-\underline{\alpha}q)f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - (-\overline{\alpha}q)f'(\underline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) \quad \text{(A.43)}$$

If the social norm effect of reducing the low-sensitivity type's cost (the first term in the preceding expression) is larger than the social norm effect of reducing the high-sensitivity type's when he pretends to be a low-sensitivity type (the second term), the above equation is negative. The optimal contract is then to induce more than the optimal land retirement for the high-sensitivity type. If the social norm effect of reducing the high-sensitivity type's cost when he pretends to be a low-sensitivity type dominates the social norm effect of reducing the low-personal norm type's cost, the above term is positive. The optimal contract is then to induce less than the optimal land retirement for the high-sensitivity type.

Case 2: If $P > S_{-i} = q\overline{a} + (1-q)\underline{a}$, landowners' personal norms are higher than the perceived social norm. Constraints (A.16) and (A.19) are binding, and we get the same equation as (A.25) and (A.26). Solving this problem, we get

$$\frac{B'(\overline{a})}{1+\lambda} = \frac{(1-\overline{\alpha}q)q(1+\lambda)+(1-q)\lambda}{q(1+\lambda)} f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) \\ -\underline{\alpha}(1-q)f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - \frac{\lambda(1-q)(1-\underline{\alpha}q)}{q(1+\lambda)} f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) \tag{A.44}$$

$$\frac{B'(\underline{a})}{1+\lambda} = (1-\underline{\alpha}(1-q))f'(\underline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) \\ + \frac{\lambda\underline{\alpha}(1-q)}{1+\lambda} f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - \frac{\overline{\alpha}(q+\lambda)}{1+\lambda} f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) \tag{A.45}$$

Comparing equation (A.44) with (28) we find:

$$(A.44) - (28) = \\ \frac{\lambda(1-q)}{(1+\lambda)q}\left[(1-\overline{\alpha}q)f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) - (1-\underline{\alpha}q)f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i})\right] \tag{A.46}$$

As $(1-\overline{\alpha}q) < (1-\underline{\alpha}q)$ and $f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i}) > f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i})$, the sign of expression (A.46) is ambiguous.

Comparing equation (A.45) with (29) we find:

$$(A.45) - (29) = \\ \frac{\lambda(1-q)}{1+\lambda}\left[\underline{\alpha}f'(\overline{a}-(1-\underline{\alpha})P-\underline{\alpha}S_{-i}) - \overline{\alpha}f'(\overline{a}-(1-\overline{\alpha})P-\overline{\alpha}S_{-i})\right] < 0 \tag{A.47}$$

The low-sensitivity type will retire more than the optimal land.

In Proposition 4(ii), the high-sensitivity type's land retirement is ambiguous compared to the complete information benchmark. This is because an increase of the high-sensitivity type's land retirement has an ambiguous effect on the information rent R_α.

$$R_{\alpha 2} = f(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - f(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i}) \tag{A.48}$$

$$\begin{aligned}\frac{dR_{\alpha 2}}{d\overline{a}} &= [f'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - f'(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i})] \\ &\quad - [\overline{\alpha}qf'(\overline{a} - (1-\overline{\alpha})P - \overline{\alpha}S_{-i}) - \underline{\alpha}qf'(\overline{a} - (1-\underline{\alpha})P - \underline{\alpha}S_{-i})]\end{aligned} \tag{A.49}$$

Since both terms in the expression are positive, the sign of (A.49) depends on which term dominates. If the first term dominates, (A.49) is positive—the direct cost effect of a change of $\overline{\alpha}$ on the information rent is larger than the social norm effect on the information rent. The optimal contract is to induce less than the optimal land from the high-sensitivity type. If the direct cost effect of a change of $\overline{\alpha}$ on the information rent is smaller than the social norm effect, (A.49) is negative. The optimal contract is to induce more than the optimal land from the high-sensitivity type.

Case 3: If $P = S_{-i}$, the sensitivities of landowners to the social norms do not matter in this case. The social norm each landowner faces is the same and is $P = S_{-i} = a$. The regulator's problem will be to solve:

$$max_{T,a} W = B(a) - f(a-a) - \lambda T a, \tag{A.50}$$

$$s.t. Ta - f(a-a) \geq \xi. \tag{A.51}$$

Optimality implies $B'(a) = 0$ and $Ta = \xi$. From the solution we can see both types will retire the land until the marginal benefit equals zero.