Harnessing social norms to gain cost-effectiveness in conservation schemes through dynamic scheme design: implications of bounded rationality and other-regarding preferences for Payments for Ecosystem Services (PES)

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Abstract

Payments for Ecosystem Services (PES) are an incentive-based policy instrument encouraging landowners to adopt conservation practices that enhance ecosystem services in exchange for a compensation payment. PES schemes vary considerably in their design, yielding important implications for their conservation outcome and their cost-effectiveness. Given that a landowner's probability of re-enrolling in a PES scheme is significantly influenced by social norms, this article explores whether the cost-effectiveness of PES schemes could be increased by leveraging on social norms. In particular, we explore whether designing dynamic PES schemes in which a homogenous PES payment is reduced in subsequent contracts would be more cost-effective than static schemes under the assumption that some landowners will enrol or re-enrol in the scheme encouraged by the behaviours of neighbouring landowners. We analyse whether, by initially setting a high payment so as to build a partially conserved landscape, it would be possible to leverage on social norms and reduce the PES payment without losing much conservation engagement. For this purpose, a conceptual agent-based simulation model entailing social norms and bounded rationality as well as other-regarding preferences has been developed.

Keywords: Payment for Ecosystem Services (PES), agri-environment schemes (AES), social norms, bounded rationality, ecological-economic modelling, agent-based modelling (ABM)

JEL Codes: C6, Q57, Q58

Harnessing social norms to gain cost-effectiveness in conservation schemes through dynamic scheme design: implications of bounded rationality and other-regarding preferences for Payments for Ecosystem Services (PES)

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1. Introduction

The world's ecosystems have been experiencing dramatic changes over the last century due to human activities (Pimm et al., 1995; Rosenzweig et al., 2008). Anthropogenic activities, and notably agricultural activities, have substantially and in some instances irreversibly changed life on Earth, causing major losses to biodiversity and ecosystem services (Matson et al., 1997; Millennium Ecosystem Assessment [MA], 2005). Payments for Ecosystem Services (PES) emerged as an incentive-based policy instrument to preserve and enhance the provisioning of ecosystem services (Engel et al., 2008). PES consist in providing landowners with compensation payments for implementing land use activities that deliver ecosystem services but cause profit losses to the landowners (Wunder, 2005). In recent years, PES schemes have steadily gained importance, and as of 2018 more than 550 PES schemes were implemented worldwide (Salzman et al., 2018). However, despite PES schemes representing the most frequently used policy instrument for preserving biodiversity in agricultural landscapes, only few scientific articles assessing the outcome of PES schemes have considered also their cost-effectiveness (Ansell et al., 2016). Indeed, often the effectiveness of PES schemes is unknown (Salzman et al., 2018).

Concerning social aspects, considerable evidence has been gathered regarding the significant effect that social norms exert on the outcome of PES schemes and agri-environment schemes (Chen et al., 2012; Defrancesco et al., 2018; Kuhfuss et al., 2016; Rasch et al., 2021). For instance, it has been estimated that a landowner's probability of re-enrolling in a PES scheme is increased by more than 3% for every 10% of neighbouring landowners that are enrolled in the PES scheme (Chen et al., 2012). This positive effect of social norms implies a deviation from neoclassical economics and from rational choice theory, given that landowners may not enrol in PES schemes driven by self-interest and profit-maximization. Instead, they may enrol because of a tendency to conform with the behaviour of neighbouring landowners. It follows that landowners exhibit bounded rationality and other-regarding preferences rather than complying with rationality assumptions such as self-interest, unlimited cognitive abilities and unlimited willpower, among others (Gsottbauer & van den Bergh, 2011). Yet, despite the fact that in agricultural systems the interactions are often influenced by social norms that are exerted within neighbourhoods or communities (Bell et al., 2016), often little or no attention has been given in modelling to actual human behaviour, which therefore embodies a great source of uncertainty in the modelling outcome (Fulton et al., 2011; Schlüter et al., 2017). Consequently, very often actors do not react to policy instruments as policy-makers intended, as a result of a failure in the representation of actual human behaviour (Fulton et al., 2011).

Against this background, the conceptual agent-based model developed for this article aims at incorporating such aspects of uncertainty and human behaviour into the design of PES schemes, focusing on the influence of social norms. The aim of this article is to explore whether cost-effectiveness in conservation schemes could be increased through the implementation of dynamic (or staggered) PES schemes under the influence of social norms and bounded rationality. We explore the possibility to gain cost-effectiveness in conservation schemes by simulating dynamic PES schemes with varying sizes of initial and reduced payments, under the influence of varying strengths of social norms. The hypothesis is that some landowners will enrol or re-enrol into a PES scheme driven by the influence of neighbouring landowners, so that reducing the PES payment after a partially conserved landscape has been built may allow to save budget without losing much conservation engagement. Confirmation of the hypothesis would imply that by leveraging on the effect of social norms, it may be possible to achieve cost-effectiveness gains in conservation schemes.

2. Theoretical Background

2.1. Biodiversity conservation, PES schemes and agri-environment schemes (AES)

Preserving the environment and in particular the integrity of biodiversity and ecosystems is of vital importance (Chapin et al., 2000). Rockström et al. (2009) introduced the concept of planetary boundaries, which should not be trespassed if the proper functioning of the Earth system is to be maintained. Importantly, the Earth system processes are distinguished between those that are associated with known and sharp global thresholds, and those that are instead associated with slow processes, which lack thresholds at the continental or global scale but at the same time affect the resilience of the Earth system (Rockström et al., 2009). Among these processes we can find biodiversity loss and land use change, whose continuous decline might lead to functional collapses of the Earth (Rockström et al., 2009; Chapin et al., 2000).

Payments for Ecosystem Services can foster the adoption of those land use practices that provision ecosystem services, which would otherwise be under-provisioned in the absence of the payments (Engel et al., 2008). The implementation of PES schemes has increased rapidly and circa US$36–42 billion were estimated to be spent annually on PES schemes around the world (Salzman et al. 2918). Similarly, in the European Union (EU) agri-environment schemes (AES) represent well-established government-financed PES schemes in which part of the direct payments to farmers are conditional to particular land use practices, and EU Member States have the right and flexibility to design their own agri-environment schemes (Engel, 2016; Batáry et al., 2015). The latest Common Agricultural Policy (CAP) reform of the EU, which concerns the period 2023-2027, has delineated a new tool named eco-schemes (European Commission, 2021). These eco-schemes will complement agri-environment schemes, whose conditionality will also be strengthened, and will reward landowners for voluntary actions that go beyond the conditionality entailed by AES schemes (European Commission, 2021). Indeed, eco-schemes represent new PES schemes towards which a considerable amount of money will be invested, given that the EU has agreed to spend at least €48 billion on eco-schemes for the period 2023-2027 (European Commission, 2021). However, despite the large number of PES schemes and the considerable amount of money that is directed towards them, the cost-effectiveness of PES schemes has often been ignored or poorly assessed by the studies aiming at determining their success (Ansell et al., 2016).

Concerning the design of PES schemes, the minimum PES payment corresponds to the payment that is just sufficient to cover the costs of providing the ecosystem services, which include forgone profits caused by changing land use (opportunity costs) and transaction costs, as well as conversion costs (Engel et al., 2008; Wunder, 2005; Pagiola et al., 2020). Foregone profits are the greatest costs that PES schemes should bear, since they account for more than 50% of the total costs (Mettepenningen et al., 2009). Nevertheless, the conversion costs for switching from one land use practice to another could represent a significant barrier to enrolling in PES schemes, which should therefore not be overlooked (Pagiola et al., 2020; Izquierdo-Tort et al., 2019). PES schemes may be differentiated according to whether they are use-restricting or asset-building (Wunder, 2005). Use-restricting PES schemes reward ecosystem services providers for conservation intended as limited land development or the setting aside of land (Wunder, 2005). Thus, landowners are compensated for the opportunity costs that they bear by enrolling their land in PES schemes (Wunder, 2005). On the other hand, asset-building PES schemes prescribe certain land use practices or activities, meaning that the landowners actively improve the provisioning of ecosystem services (Wunder, 2005). Therefore, in asset-building schemes, the PES payments are also supposed to cover the costs incurred upon changing land use and establishing the new land use practices (Wunder, 2005). The PES contracts may even be renewable indefinitely, although each contract lasts on average for 5 years (Pagiola et al., 2020; Drechsler et al., 2017). The necessity of perpetual renewal stems from the fact that if the contracts were not renewable indefinitely, the landowners (i.e. the ecosystem services providers) would resume the conventional land use practices, and the PES scheme is said to lack permanence (Pagiola et al., 2016, 2020). This effect mainly occurs because the profits arising from the conventional agricultural use (or any other use different than conservation) are higher than the profits arising from performing conservation (Pagiola et al., 2016, 2020). Hence, if the payments ceased, the landowners would convert back to the conventional land use, leading to the necessity of establishing perpetual payments in order to retain the conservation measures (Pagiola et al., 2020).

By contrast, asset-building PES schemes do not provide payments for an indefinite period of time, but are instead short-term, thus lasting for finite periods (Pagiola et al., 2020). The reason lies in the fact that in such schemes the profits arising from the land use activities prescribed by the PES schemes are greater than the profits arising from the conventional land uses (Pagiola et al., 2020). Thus, once the barriers for switching from the conventional land use to its alternative have been overcome, the landowners will supposedly have no incentive to convert back to the old land use (Pagiola et al., 2020). Such barriers include also eventual conversion costs that are incurred by switching from one land use to the other (Pagiola et al., 2020; Izquierdo-Tort et al., 2019). In fact, financial constraints caused by high conversion costs can largely limit the adoption of environmentally-sound practices, even despite being privately profitable (Pagiola et al., 2020). Consequently, offering a short-term PES payment may represent a solution for overcoming the financial barriers of adoption, and the payments could be permanently terminated once the new land use activity has been established and become profitable (Pagiola et al., 2020). Yet, the possibility that the landowners will convert back to the conventional land use would still remain (Pagiola et al., 2020). All things considered, in asset-building PES schemes the conversion costs and the long-term benefits arising from the conservation activities play a crucial role in determining whether the landowners will convert back to the old land uses or not (Pagiola et al., 2020).

It is evident that the design and implementation of PES schemes may involve decisions regarding many features, which eventually determine the overall appropriateness and rate of success of PES schemes (Engel, 2016). In practice, PES payments and budgets are determined according to the opportunity costs of landowners, rather than the true value of ecosystem services (Engel et al., 2008; Engel, 2016; Mettepenningen et al., 2009). Besides the payment structure, there are also other aspects that are crucial for the design of PES schemes. As already mentioned, permanence represents another important aspect of PES schemes, which refers to whether the conservation benefits induced by the land use changes prescribed by the PES schemes are long-term or not (Wunder, 2005; Pagiola et al., 2016). The growing evidence regarding permanence in PES schemes shows that its degree varies considerably across land uses due to differences in profitability, technical complexity and the socio-economic characteristics of landowners (Pagiola et al., 2016). Therefore, in order to attain permanence, these characteristics should be assessed and taken into consideration during PES design (Pagiola et al., 2016). Besides, all the above-mentioned aspects should be considered in order to achieve an effective PES design (Engel, 2016). Notably, it has been estimated that PES schemes which consider intrinsic motivation in their design lead to much better outcomes compared to those schemes that do not consider them, given that their probability to meet socio-economic and ecological goals is threefold as high (Cetas & Yasué, 2017). Finally, also fairness and distributional aspects are particularly important, since they may significantly affect the successfulness of PES schemes or lack thereof (Sommerville et al., 2010).

2.2. Social norms in PES

The evidence regarding the significant effect that social norms have on a variety of environmental issues is substantial (e.g. Ostrom, 2000; Cialdini, 2003; Goldstein et al., 2008; Nolan et al., 2008). Over the past decade, social norms and social interactions have been found to play a crucial role in PES schemes and agri-environment schemes as well (Chen et al., 2012; Defrancesco et al., 2018; Kuhfuss et al., 2016; Rasch et al., 2021; van der Horst, 2011). In particular, Chen et al. (2012) produced empirical evidence regarding the effect of social norms on landowners' decisions to participate in China's "Grain to Green Program" (GTGP). The authors found that each 10% of neighbouring landowners participating in the conservation scheme would increase a landowner's probability to re-enrol in the scheme by 3.5% (Chen et al., 2012). Moreover, the authors also found that an additional 11% of land parcels could be enrolled at the same cost if re-enrolment was done in waves, given that the landowners enrolling in later waves hold information regarding the choices of the landowners who have enrolled in earlier waves (Chen et al., 2012). Similarly, Defrancesco et al. (2018) found that the effect of social norms – or the neighbourhood effect, as the authors call it – is statistically significant and remarkable. In fact, the authors found that a 1% increase in the number of participants in a PES scheme increased a landowner's odds to re-enrol in the scheme by 3.3% (Defrancesco et al., 2018). In an earlier study, van der Horst (2011) had already elaborated on the neighbourhood effect with respect to the Scottish agri-environment scheme “Environmentally Sensitive Area” (ESA). Eventually, van der Horst (2011) found that such neighbourhood effect is quite prominent within small and remote communities. Furthermore, Rasch et al. (2021) presented empirical evidence regarding the positive correlation between social connectedness and participation rates in PES schemes in Costa Rica, highlighting the important role that social interactions play.

Comparably, a quantitative study that used panel data spanning over 10 years and involving more than 1900 farms in Wisconsin has determined that the presence of neighbours performing organic agriculture positively affected the decision of a landowner to convert to organic agriculture as well (Lewis et al., 2011), while a study dealing with smallholder technology adoption in Madagascar found statistically significant social conformity effects (Moser & Barrett, 2006). Finally, Kuhfuss et al. (2016) demonstrated, based on the stated intentions of 395 French farmers participating in a national agri-environment scheme, that a nudge in the form of social norms could lead to the permanence of the land use practices prescribed by the AES scheme. The authors found that half of the farmers were willing to maintain the land use practices even after the termination of the AES payments, owing to the great influence that social norms had on the decisions of the farmers to retain such land use practices (Kuhfuss et al., 2016).

These findings demonstrate that the effect of social norms carries crucial implications for the outcome of PES schemes, and possibly for their cost-effectiveness. However, the effect of social norms has not received attention from the majority of researchers studying the motives to participate in PES schemes (Jones et al., 2020). In fact, according to a literature review on the factors and motivations to participate in PES schemes in the Global South, only 17% of the reviewed studies assessed the effect of social norms as drivers for the participation in PES schemes, although the studies that did assess the effect of pro-social motivations have generally found a positive relationship between the motivations and the decision to enrol in the schemes (Jones et al., 2020).

2.3. Bounded rationality and other-regarding preferences

The influences of intrinsic motivations and social norms imply a deviation from neoclassical economics and from rational choice theory (Gsottbauer & van den Bergh, 2011). In fact, landowners may enrol or re-enrol in a PES scheme not out of the rational and profit-maximizing choice, purely dictated by unlimited cognitive abilities, unlimited willpower, complete information and self-interest, but rather because they are influenced by the behaviours of others (Chen et al., 2012; Defrancesco et al., 2018). By contrast, neoclassical economic theory assumes that human-beings behave purely according to their self-interest, and excludes any "other-regarding preferences" (Gsottbauer & van den Bergh, 2011). As Gsottbauer and van den Bergh (2011, p. 275) summarised, other-regarding preferences can take two forms: "(1) non-selfish motives or social preferences, such as fairness, reciprocity, altruism and intrinsic motivations; and (2) self-identity concerns, such as reputation, self-respect and status". However, besides exhibiting limited self-interest, landowners may also exhibit bounded rationality, which strictly speaking refers to the fact that choices are constrained by cognitive processes, information availability and limited willpower, meaning that individuals may consequently fail to make optimal decisions (Gsottbauer & van den Bergh, 2011). Bounded rationality theories and other-regarding preferences represent the core of behavioural economics, which emerged as an alternative to neoclassical economics, providing explanations for those human behaviours that systematically deviate from rationality assumptions (Gsottbauer & van den Bergh, 2011).

In his article “A behavioral model of rational choice”, Simon (1955) urged a reconsideration of *homo economicus*, and of the concept that humans have a clear system of preferences and unlimited computation abilities, which would allow them to maximize their utility. Ultimately, Simon (1955) claimed that humans are not fully rational actors, and urged the need to develop models of behaviour that are more realistic and closer to how humans actually behave.

With regard to the field of environmental policy, there has been a steady increase in the consideration of behavioural economic theories in recent times, although the applications are still relatively limited (Gsottbauer & van den Bergh, 2011; Brown & Hagen, 2010; Croson & Treich, 2014). Traditionally, environmental policy has in fact mainly been based on the concept of *homo economicus* (Gsottbauer & van den Bergh, 2011). However, bounded rationality and in particular the acknowledgment that humans deviate from rational choice due to risk and uncertainty, intertemporal choice and other inconsistencies in decision-making, have made their way into environmental policy (Gsottbauer & van den Bergh, 2011). Overall, behavioural economics in environmental policy replaces the model of utility-maximization and full rationality with theories such as hyperbolic discounting, heuristics, status seeking, self-identity, habitual behaviour, prospect theory, and social preferences in general (Gsottbauer & van den Bergh, 2011).

To summarise, the outcomes of PES schemes are influenced also by social norms and social ties (Chen et al., 2012; Kuhfuss et al., 2016; Defrancesco et al., 2018; Rasch et al., 2021), as well as by fairness and distributional aspects (Sommerville et al., 2010), and intrinsic motivations (Rode et al., 2015; Cetas & Yasué, 2017). With respect to the present analysis, bounded rationality and other-regarding preferences are important because the landowners are not expected to enrol in PES schemes merely on the basis of profit-maximization and self-interest, but are also influenced by other aspects such as social norms, which may lead them to enrol or re-enrol in PES schemes even if it does not represent the rational, profit-maximizing choice. That is to say, that landowners might enrol in PES schemes even if the PES payments are below their costs.

3. The model

The model is a conceptual agent-based simulation model comparing static PES schemes with dynamic PES schemes. The model integrates the concepts of bounded rationality and other regarding preferences through the effect of social norms and the selection of non-profit-maximizing land uses.

In addition, the model considers the influence of conversion and reconversion costs. Conversion costs refer to the costs that are incurred by converting from the conventional agricultural land use to the alternative prescribed by the PES schemes, while reconversion costs refer to the costs incurred by switching back from the alternative land use to the conventional land use. The present model is probabilistic and stochastic, given that the land use choices are determined through the estimation of the landowners’ probabilities to switch from one land use to the other, which are then compared to randomly selected thresholds eventually determining the land use choices of the landowners. The landowners’ probabilities of changing land use are calculated based not only on the influences of the payoffs arising from the two possible land uses, but also on the influences of social norms, conversion costs, reconversion costs, and the slope parameter of a logistic probability function.

As to the time span of the PES schemes, a total of 10 decision rounds has been set, in which the landowners choose to change or not to change land use at each of these rounds. In the dynamic PES schemes, the landowners are offered an initial homogenous payment *p1* for the first 5 decision rounds, and a reduced homogenous payment *p2* during the remaining 5 decision rounds. The reason for considering 10 decision rounds and for lowering the payment after 5 decision rounds concerns the fact that on average PES contracts last for 5 years (Ando & Chen, 2011; Drechsler et al., 2017; Pagiola et al., 2020). Hence, 5 decision rounds would correspond indicatively to a period of 25 years, while 10 decision rounds would correspond to about 50 years, which represents a sensible time frame. Comparably, a recent study by Gerling and Wätzold (2021) analysed offset schemes in Germany and considered schemes lasting over a period of 30 years.

3.1. Landscape

The model landscape consists of land parcels arranged in a 10x10 squared grid, meaning that in the landscape there exist 100 land parcels. Furthermore, to each of these grid cells there corresponds an agent, meaning that there exist also 100 landowners. The land parcels (and the agents) are identified in the landscape through the coordinates i

and j, where $i \in \{1, \cdots, 10\}$ and $j \in \{1, \cdots, 10\}$, indicating respectively the row and the column numbers. Each land parcel is considered within its Moore neighbourhood of radius 1 ($r = 1$), meaning that for each land parcel the neighbourhood composed of its eight surrounding land parcels is considered. Moreover, the landscape exhibits periodic boundary conditions to avoid boundary effects, such that e.g. parcels in the corners of the landscape have fewer neighbours than parcels in the interior.

The land parcels can have different land uses, which are determined by the agents' choices. Namely, each land parcel can be used either for agriculture, which represents the conventional economic use, represented by $cons[i, j] = 0$, or it can be enrolled in the PES scheme, which is indicated through $cons[i, j] = 1$. If a land parcel is enrolled in the PES scheme, it is also said to be conserved.

In the simulations, the landscape is initialized with all land parcels being in agricultural use, i.e. with $cons[i, j] = 0$ for each i, j. In the course of the simulations, the landowners are subsequently able to change the land use of their land parcels multiple times, by making a land use choice at each decision round $t \in \{0, \cdots, tmax\}$, with $tmax = 9$. Practically, it means that 10 decisions are made in every simulation. The land use decisions are based on many factors, including the profits that can be earned by using the land parcels for the conventional agricultural land use.

3.2. Opportunity costs

The landowners' opportunity costs are the loss in profit stemming from not utilizing the land parcel in the conventional agricultural land use, which represents the profit-maximizing use. Hence, by using land parcel i, j for agriculture, its landowner earns the maximum profit, and the difference in profits between the conventional agricultural land use and the alternative land use determine the opportunity costs. Each land parcel is assigned an opportunity costs $OC[i, j]$ given by:

$$(1)\ OC[i,j] = 1 + \sigma\varepsilon_{i,j}$$

where σ represents the standard deviation of agricultural profits and $\varepsilon_{i,j}$ is a random number drawn for each land parcel from a normal distribution with mean 0 and standard deviation 1. Eventually, the agricultural profits $OC[i, j]$ follow a normal distribution with mean 1 and standard deviation σ. We choose a value of $\sigma = 0.15$ throughout the simulations. The agricultural profits of the land parcels are randomly and independently sampled, and thus spatially uncorrelated.

3.3. PES payment

The alternative payoff that the landowners can earn from their land parcels as opposed to the agricultural profits is represented by the PES payment, which the landowners receive upon enrolling their land parcels in the PES scheme. The PES payment is supposed to cover the forgone agricultural profits as well as any additional costs which may be incurred upon enrolling the land parcels in the scheme, such as the conversion costs for switching from one land use to the other. Importantly, the landowners are granted a PES payment for each of the rounds in which they enrol their land parcel in the conservation scheme. In the present model, a spatially homogenous PES payment is been used. Moreover, the model is developed in such a way to systematically allow for variations in the PES payment. We consider PES payments in the range $[1, 1+\sigma]$ with a formal definition of the payoff as:

$$(2)\ \ P_{i,j} = x_{i,j}p = x_{i,j}(1+\beta\sigma)$$

where $P_{i,j}$ is the PES payment received by the landowner of parcel i, j, while p is the spatially homogeneous PES payment defined as $p = 1 + \beta\sigma$, and $x_{i,j}$ reflects the land use of landowner i, j. Namely, $x_{i,j} = 1$ if the landowner enrols in the PES scheme, and $x_{i,j} = 0$ if the landowner employs her land parcel for agriculture. Finally, the factor β is used for systematically varying the size of the PES payment in units of the cost variation σ. The reason for this scaling choice is that a larger σ requires accordingly smaller payments to conserve the least costly land parcels.

To compare static PES schemes (in which the homogeneous payment is unchanged throughout the simulation) with dynamic PES schemes (in which the payment is lowered during the simulation), a range of payments and combinations of payments are tested. For this purpose, the variables $n \in \{1, \cdots, N\}$ and $m \in \{0, \cdots, N-1\}$ with $N = 40$ are introduced to systematically vary the payment level. The variable $p1$, varied according to n such that $\beta = n/N$, represents the amount of the payment of the static PES schemes as well as the initial payment of the dynamic PES schemes. In addition, in the dynamic PES schemes, the variable $p2$ varied according to m is used to determine the value of the payment after it is lowered. Precisely, in each simulation, as many static PES schemes as N are generated, and for each one of these static PES schemes as many dynamic PES schemes as $N-1$ are considered. Thus, for each static PES scheme, a range of dynamic

PES schemes that have the same initial payment *p1* and different lower payments *p2* are generated. Thus, the payments employed in this article are modelled as follows:

$$(3)\ \ p1 = 1 + \left(\frac{n}{N} * \sigma\right)\ \ for\ \ n = (0, \dots, N)$$

$$(4)\ \ p2 = 1 + \left(\frac{m}{N} * \sigma\right)\ \ for\ \ m = (0, \dots, N-1)$$

where N determines the resolution by which the payment is varied, consequently determining the total number of different payments that are considered in each simulation.

Moreover, as introduced earlier, in dynamic PES schemes the payment is lowered after 5 decision rounds. This means that the landowners are offered a payment $p1$ determined by n from round $t = 0$ up to round $t = 4$, while they are offered a payment $p2 < p1$ determined by m from round $t = 5$ up to the last decision round $tmax = 9$. Similarly to the formal definition provided earlier, at every decision round the landowner of parcel i, j receives the payment $p * cons[i, j]$, where p represents either the payment *p1* or the payment *p2* depending on the number of the decision round, and $cons[i, j] = 1$ if the landowner decides to enrol in the PES scheme, while $cons[i, j] = 0$ if the landowner decides not to enrol in the scheme.

3.4. Conversion and reconversion costs

The model includes the effect of conversion costs (incurred upon switching to conservation) and reconversion costs (incurred upon converting back from conservation to the conventional agricultural use). Conversion and reconversion costs are both assumed to be homogenous, meaning that all landowners face the same conversion and reconversion costs. The conversion costs are denoted as $conv_{cons}$, while the reconversion costs are expressed through the parameter $conv_{agr}$. The reason for conceiving the conversion and reconversion costs as being homogenous concerns issues of modelling complexity, as well as of sensitivity analysis. In fact, considering heterogenous conversion costs and reconversion costs would increase the modelling complexity, besides making the sensitivity analysis significantly more elaborate.

Ultimately, the following combinations of conversion and reconversion costs are used:

i. $conv_{cons} = z, \quad conv_{agr} = w$

ii. $conv_{cons} = z, \quad conv_{agr} = 0$

iii. $conv_{cons} = 0, \quad conv_{agr} = w$

iv. $conv_{cost} = 0, \quad conv_{agr} = 0$

Since the PES payments are supposed to cover the foregone profits and other costs, the conversion costs considered are equal to σ and $\frac{\sigma}{2}$, namely to 0.15 and 0.075, so as to allow *p1 and p2* to be larger than $OC[i,j] + conv_{cons}$.

3.5. Land use change choices

Land use change choices are based on the comparison between the possible payoffs, but involve the computation of probabilities and their comparison to random decision thresholds, which determine whether the landowners ultimately change land use or retain their current land use.

Precisely, the probabilistic model entails that at every decision round t the probability of the landowner of parcel i, j to switch from its current land use to the alternative land use is calculated, and such probability is then compared to a random threshold. Overall, at each decision round t, every landowner faces one out of two decision problems. First, landowners with agricultural land parcels decide whether to enrol in the PES scheme or to continue with agriculture, while landowners with conserved land parcels decide whether to convert back to the conventional agricultural land use or to continue with conservation. Therefore, the land use change decisions occur in both directions, and the decision problems that the landowners face at round t depend on the land use choices that they made at round $t-1$, which determined their current land use. However, since all land parcels are initialized as being employed in the conventional agricultural land use, the first land use decision of all landowners concerns necessarily whether to enrol in the PES scheme or to continue with agriculture. By contrast, in subsequent rounds it becomes possible to decide also whether to convert back to agriculture, in case the land parcels have been enrolled in the PES scheme in the previous round. Thus, in order to develop such probabilistic model, a logistic function is used, whose shape is determined by a parameter α. The probability of switching the land use is determined by the payoff difference between the two land uses (see below).

3.5.1. Probability of enrolling in PES

The probability $pr\_cons[i,j]_t$ expresses the probability of landowner i,j at time t to switch from agriculture to conservation, while $pr\_agr[i,j]_t$ expresses the probability of switching from conservation back to agriculture at time t. The decision problems are mutually exclusive, meaning that at round t only one of the two probabilities will be calculated for each landowner, depending on the current land use. That is to say, if land parcel i,j is currently in agricultural use, i.e. if $cons[i,j] = 0$, then $pr\_cons[i,j]_t$ will be calculated. Alternatively, if the land parcel is currently enrolled in the PES scheme, i.e. if $cons[i,j] = 1$, then $pr\_agr[i,j]_t$ will be calculated.

Importantly, also $conv_{cost}$ and $conv_{agr}$ enter the land use change decision-making process, along with the effect of social norms. The introduction of social norms represents the core aspect of this article. First, we calculate the probability of changing land use in the absence of the effect of social norms, and then adjust the probability in order to account for the effect of social norms.

Thus, a landowner's probability of changing land use and enrolling in a PES scheme at decision round t in the absence of the effect of social norms is the partial probability of enrolling in the PES scheme. This partial probability is calculated based on the influence of the PES payment, the agricultural profits, the conversion costs for switching from agriculture to conservation, and the slope parameter α as follows:

$$(5)\ probability_{enrol}[i,j]_t = \frac{1}{1 + e^{-\alpha * [p - (agr_{pi[i,j]} - conv_{cons})]}}$$

where the agricultural profits $agr_{pi}[i,j]$ and the conversion costs $conv_{cost}$ exert a negative effect on $probability_{enrol}[i,j]_t$. The payment p works in the opposite direction compared to the agricultural profits and the conversion costs. The greater the difference between the payment and the agricultural profits together with the conversion costs, the larger will be the probability of enrolling in the PES scheme.

Then, after computing the partial probability $probability_{enrol}[i,j]_t$, the influence of social norms is introduced in the land use decision. Namely, social norms enter the probability calculation through the parameter sns, which stands for "social norms' strength", in the following way:

$$(6)\ pr\_cons[i,j]_t = probability_{enrol}[i,j]_t * \{1 + sns * n_{cons}[i,j]\}$$

where $n_{cons}[i,j] \in \{0, \cdots, 8\}$ and represents the number of land parcels in the Moore neighbourhood of land parcel i,j which are enrolled in the PES scheme. Therefore, each neighbouring landowner enrolled in the PES scheme exerts a positive effect on the probability of landowner i,j to enrol in the scheme, depending on the strength of social norms sns. As to the strength of social norms, $sns \in \{0.01, 0.03, 0.05\}$ have been chosen, meaning that each neighbouring land parcel that is enrolled in the PES scheme increases the probability of landowner i,j to enrol in the scheme by 1%, 3% and 5% respectively, proportionally to the partial probability $probability_{enrol}[i,j]_t$. In fact, the effect of social norms is multiplied by $probability_{enrol}[i,j]_t$, yielding a proportional increase in probability. Eventually, the final probability to enrol in the PES scheme is indicated as $pr\_cons[i,j]_t$.

Note, that Eq. (6) can generate probabilities $pr\_cons[i,j]_t$ which are greater than 1. In practice, these probabilities are truncated to 1. From this perspective, some of the effect of social norms could also result being redundant, especially because for the land use change to occur, it is only sufficient that $pr\_cons[i,j]_t$ tips over the decision threshold. The probability $pr\_cons[i,j]_t$ is compared with a randomly selected threshold between 0 and 1. The manifestation of bounded rationality lies in the fact that in some instances the effect of social norms is able to generate probabilities that exceed the thresholds, whereas they would have been smaller than the thresholds in the absence of social norms. In other words, social norms are able to increase the $probability_{enrol}[i,j]_t$ until it tips over the decision threshold, eventually leading to land use choices that are not dictated merely by the consideration of monetary payoffs and costs. Moreover, if the decision thresholds happen to be particularly low, also very small probabilities can lead to the occurrence of land use changes. Finally, note that the land use changes can occur also at a loss, meaning that a landowner might enrol into the PES scheme even if the payment is below her costs, thus violating the concept of rationality and profit-maximization.

3.5.2. Probability of converting back to the conventional land use

Similar to the probability of switching from agriculture to conservation, the starting point for calculating the probability of converting back from conservation to agriculture at decision round t consists in the calculation of such probability in the absence of social norms. This becomes especially relevant for dynamic PES schemes. Eventually, the partial probability of switching back from conservation to the conventional agricultural land use depends on the influences of the PES payment, the agricultural profits, the reconversion costs and the slope parameter α, as showed below:

$$(7)\ \ probability_{convertback}[i,j]_t = \frac{1}{1+e^{\{-\alpha*(agr_{pi}[i,j]-p-conv_{agr})\}}}$$

where $conv_{agr}$ represents the conversion costs needed for switching from conservation back to the conventional agricultural land use, and the payment p may correspond to either *p1* or *p2* depending on the decision round. In this case, p and $conv_{agr}$ exert a negative effect on $probability_{convertback}[i,j]_t$, while the agricultural profits $agr_{pi}[i,j]$ exert a positive effect on the probabilities. Thus, the PES payment p and the reconversion costs $conv_{agr}$ work in the opposite direction compared to the agricultural profits. Once again, the larger the difference between the two sides, the greater will be the probability of changing land use. Eventually, the final probability of switching back from conservation to agriculture, including the effect of social norms, is indicated as $pr\_agr[i,j]_t$ and is calculated as:

$$(8)\ \ pr\_agr[i,j]_t = \ probability_{convertback}[i,j]_t * \{1+sns*(8-ncons[i,j])\}$$

where in this case every neighbour that is not enrolled in the PES scheme (i.e., $8-ncons[i,j]$) exerts a negative effect on the participation in the PES scheme. In other words, in this case the social norms sns increase the probability of landowner i,j to convert back to the conventional agricultural use depending on the number of neighbouring landowners that use their land parcels for agriculture. Thus, as for $pr\_cons[i,j]_t$, the effect of social norms increases the probability of changing land use but in this case it does so in the opposite direction. Nevertheless, the greater the value of $n_{cons}[i,j]$, the less significant will be the overall effect that social norms have on encouraging landowners to convert back to agriculture. Also, like for the probability of enrolling in a PES scheme, the effect of social norms affects the probability of converting back to agriculture proportionally to the probability of converting back in the absence of social norms, i.e. proportionally to $probability_{convertback}[i,j]_t$. Eventually, the functions for the computations of $pr\_cons[i,j]_t$ and $pr\_cagr[i,j]_t$ are perfectly symmetric. In the next section, the evaluation of the landscape will be presented.

3.6. Evaluation of the landscape

At the end of each simulation scenario, which is represented by the termination of the PES schemes after 10 decision rounds have occurred, the status of the landscapes is evaluated in order to assess the outcome of the different schemes. Thus, the evaluation is done in terms of the shares of conserved land parcels at the end of the PES schemes' lifetimes, calculated as the ratios of conserved land parcels to the total number of land parcels present in the landscape. Similarly, the budgets spent during the whole duration of the schemes are calculated as well, in order to assess the cost-effectiveness of the schemes. This process is performed for each static PES scheme as well as for each dynamic PES scheme, meaning that in each simulation 40 ratios of conserved land parcels and corresponding budgets are calculated for the static PES schemes, as well as

820 ratios of conserved land parcels and corresponding budgets for the dynamic PES schemes.

Then, in order to compare the outcomes of the static PES schemes with the outcomes of the dynamic PES schemes, the percentage changes in the ratios of conserved land parcels as well as in the budgets are calculated. The percentage changes in the budgets and the percentage changes in the ratios of conserved land parcels are subsequently compared to one another, so as to determine the relative sizes. Finally, several graphical representations are created in order to facilitate the understanding of the simulation outcomes, and multiple linear regressions are run in order to assess the significance of the effects of the several parameters. Namely, in order to assess the significance of the effects of social norms, PES payment, agricultural profits, conversion costs and reconversion costs.

3.7. Model analysis

To explore the effects of the several parameters, a sensitivity analysis is performed. As already mentioned throughout the description of the model, the following parameters and constants are used: $\sigma = 0.15$, $\alpha = 1$, $maxcnt = 40$, $sns \in \{1\%, 3\%, 5\%\}$, $conv_{cost}$ as well as $conv_{agr} \in \{0, 0.075, 0.15\}$. These parameters are used in different combinations, eventually leading to several different simulation scenarios. Besides simulating 40 different static PES schemes and 820 dynamic PES schemes in each of the simulation runs, the slope parameter α with a value of 1 has been chosen as the standard value for the simulations. With larger values of α, the logistic function would approach a step function, so we would move more closely towards a rational decision maker who chooses the land use that maximises profit. In order to encompass stochasticity, the averages over 1000 simulation runs are taken. Moreover, concerning the random thresholds, they are automatically drawn from a different lottery in every simulation run.

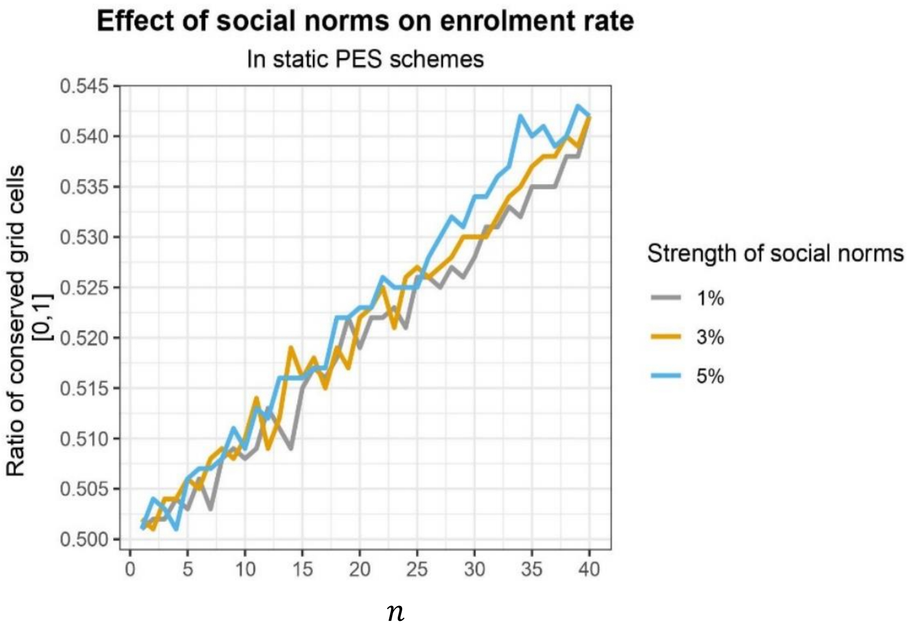
4. Results

In the following sections, first the effects of the different parameters on the ratio of conserved land parcels and respective budgets with regard to static PES schemes will be presented. Then, the comparison between dynamic PES schemes and static PES schemes will be presented. In particular, one section will compare static PES schemes to those dynamic PES schemes in which the initial payment *p1* is equal to the payment of the static PES schemes, besides comparing those dynamic PES schemes whose reduced payment *p2* is equal to the payment of the static PES schemes. The following section will compare all static and dynamic PES schemes, so as to assess whether there exist dynamic PES schemes which are more cost-effective than static PES schemes. Thus, the section will compare the static PES schemes also to those dynamic PES schemes whose both initial payment *p1* and final payment *p2 a*re different from the payment of the static PES schemes. In these sections, the focus will be especially on the effect of social norms.

4.1. The effects of PES payment size, social norms, conversion costs and reconversion costs

Figure 1 shows that for a given PES payment, a higher conservation rate will be achieved under the influence of greater strengths of social norms. Furthermore, the figure also shows that the share of conserved land parcels increases with increasing PES payment size. Such finding provides evidence that stronger social norms lead to a higher number of landowners enrolling their land parcels in PES schemes. Overall, in the absence of conversion and reconversion costs, all combinations of PES payments and social norms' strengths resulted in at least 50% of the land parcels to be conserved at the end of the schemes.

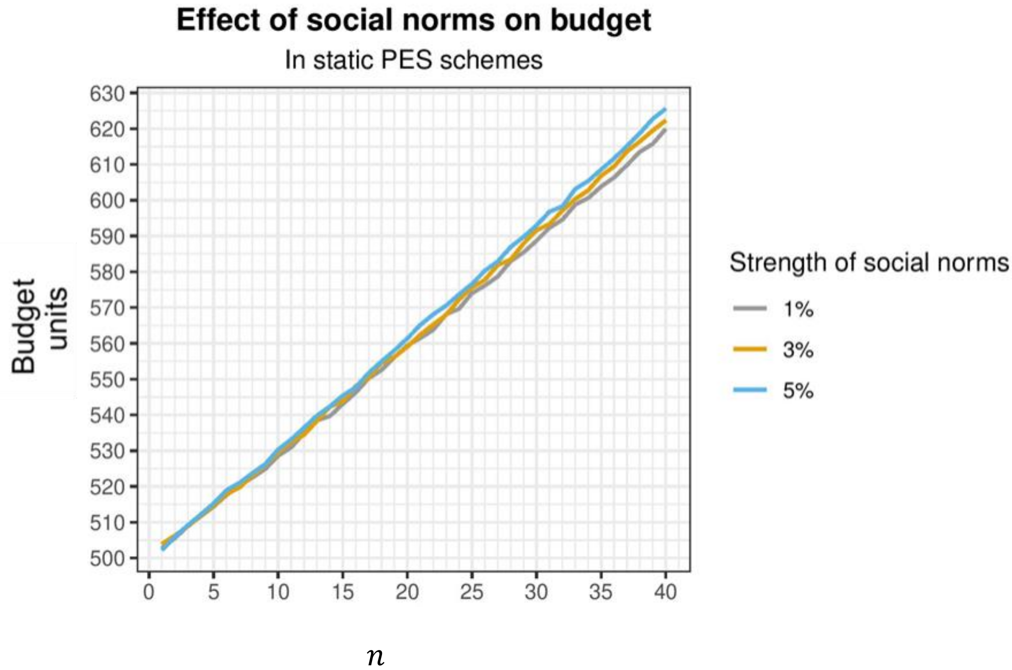
The positive effect of stronger social norms becomes more evident with increasing PES payment size, since the effect of social norms increases the probability to enrol in PES schemes proportionally to the probability of enrolling in the absence of the norms, and larger payments lead to larger probabilities. Therefore, the combined influences of larger values of sns as well as of PES payment tend to lead to larger enrolment probabilities, effectively fostering the enrolment of the land parcels in the PES schemes. To this respect, such positive effects of PES payment size and of social norms on the share of conserved land parcels have been inspected through a linear regression, which confirmed that the two parameters exert a significant effect on the ratio of conserved land parcels. The results of the linear regression showed that both the positive effect of the PES payment size and social norms on the share of conserved land parcels are significant at the 1% significance level. The full results of the linear regression concerning the share of conserved land parcels, which also include the effects of the other parameters, are provided in Table 1 in the Appendix.



$$P = 1 + \beta\sigma, \quad with\ \beta = (\frac{n}{N})$$

Figure 1*: Effect of social norms on enrolment rate in static PES schemes in the absence of conversion and reconversion costs. σ=0.15, α=1.*

Furthermore, as increasing the strength of social norms as well as the size of the PES payment increases the rate of landowners enrolling in the PES schemes, it follows that the required PES budget must increase as well. In fact, as more landowners enrol in the schemes, more PES payments must be awarded. The effects of social norms and PES payment size on the budget are depicted in Figure 2. Compared to those PES schemes in which the social norms have a strength of 1%, the schemes under the influence of social norms which have a strength of 5% can require up to 0.8% more budget.



$$P = 1 + \beta\sigma, \qquad with\ \beta = (\frac{n}{N})$$

Figure 2: *Effect of social norms on budget in static PES schemes in the absence of conversion and reconversion costs. σ=0.15, α=1*

Similar to the positive effects of the PES payment size and of social norms on the ratio of conserved land parcels, the effects of these two parameters on the budget have been confirmed though a linear regression, which showed that both parameters have a significant effect on the ratio of conserved grid cells. Once again, also the effects of all other parameters on the budget were included in the regression. The full results of the linear regression can be found in Table 2 in the Appendix. Finally, Figure 3 combines these results in one figure and shows the ratios of conserved land parcels and the corresponding budgets under the influence of different PES payment sizes and strengths of social norms.

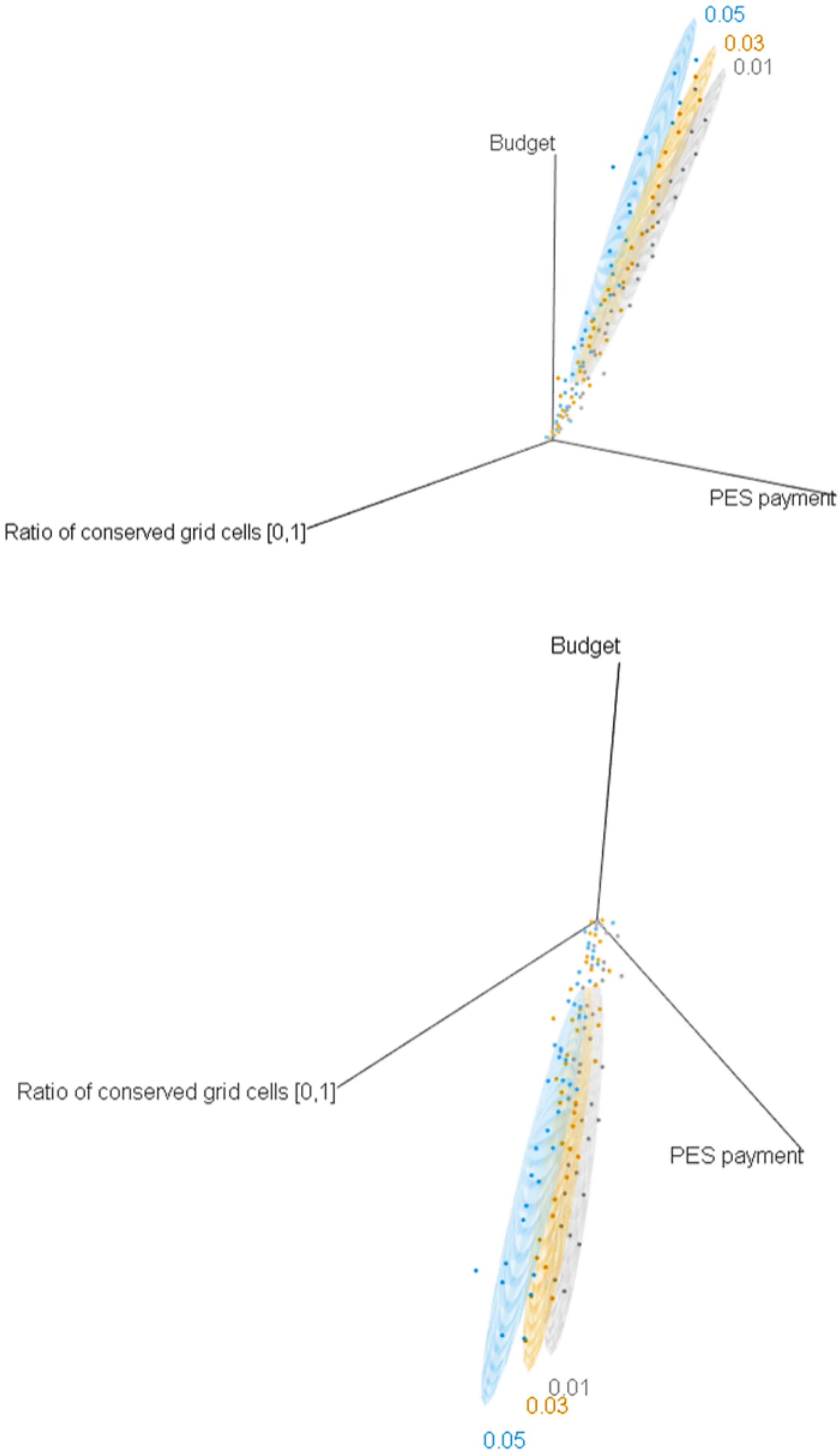
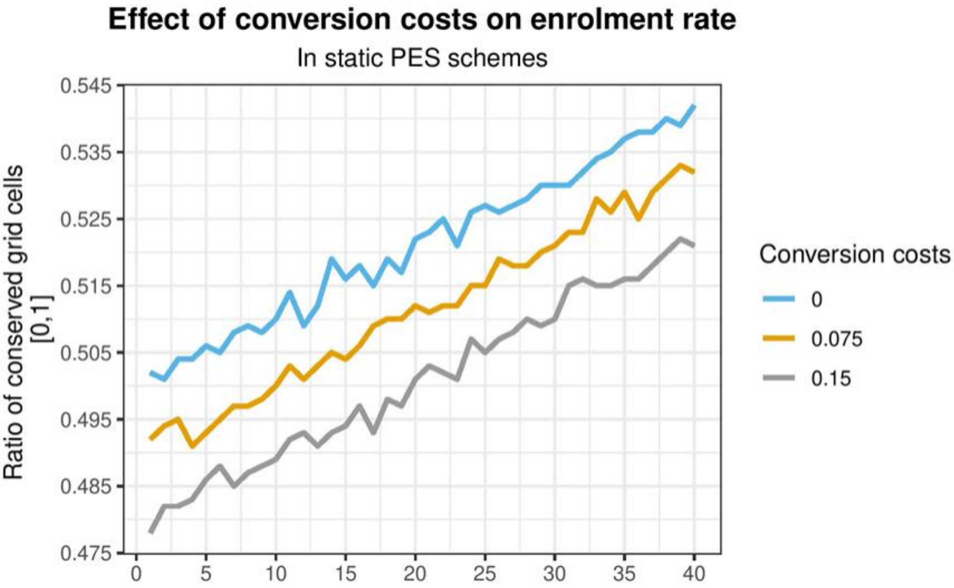


Figure 3: *Influence of increasing PES payment sizes and social norms' strengths on the ratio of conserved land parcels and corresponding budget.* The land parcels are indicated as "grid cells", while the numbers 0.01, 0.03 and 0.05 represent respectively sns= 1%, sns= 3%, and sns= 5%.

Increasing conversion costs leads to reductions in the ratio of conserved land parcels. In the simulation scenarios in which the strength of the social norms corresponded to 3%, the effect of conversion costs could lead to a reduction in the ratio of conserved land parcels of up to 3%, compared to when the conversion costs were absent. On the other hand, increasing reconversions costs has the opposite effect. The effect of conversion costs on the ratio of conserved land parcels is shown in Figure 4.



n

$$P = 1 + \beta\sigma, \quad with\, \beta = (\frac{n}{N})$$

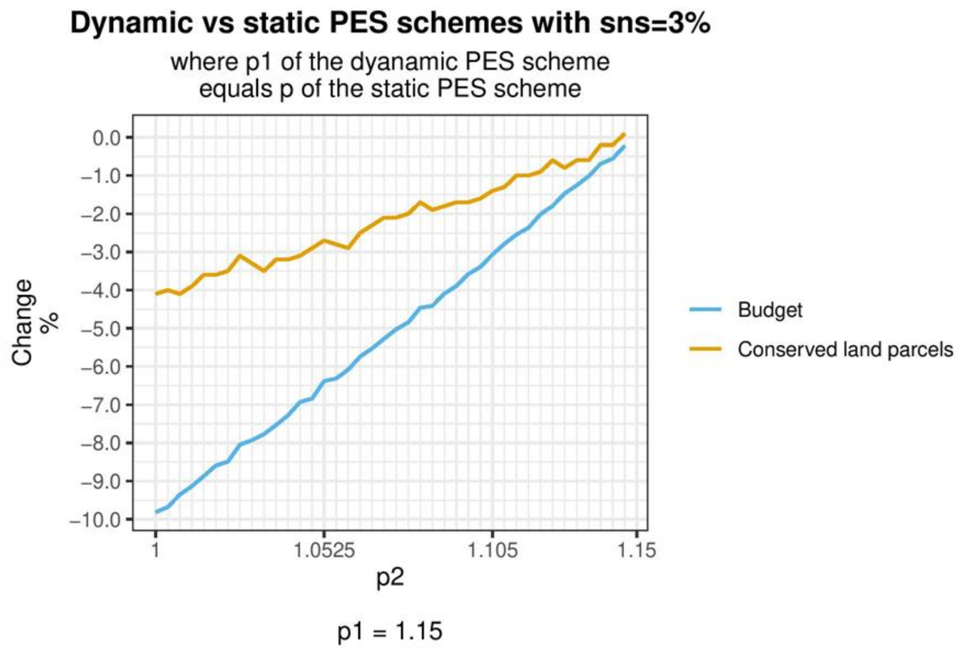
Figure 4: *Effect of conversion costs on enrolment rate in static PES schemes and in the absence of reconversion costs. σ=0.15, α=1, sns=3% .*

4.2. Dynamic vs static PES schemes

4.2.1. 4.2.1 Dynamic PES schemes which have the same initial payment or the same final payment as static PES schemes

As to the results of dynamic PES schemes in which the initial payment *p1* was reduced to a lower payment *p2* after the 5th decision round compared to static PES schemes in which the mentioned payment *p1* was offered throughout the whole period, the results conformed within the expectations. Namely, the results showed that lowering the PES payment from *p1* to *p2* leads to a loss in conservation rate compared to the statics PES schemes in which the homogenous payment *p1* is not reduced. Similarly, in such circumstances, the required budget decreases as well, partly because of the lower payment *p2* and partly because some landowners reconvert back to the conventional land use once the payment is reduced. Interestingly, when comparing the reduction in conservation rate to the reduction in budget, the results showed that the budget decreases more rapidly than the ratio of conserved land parcels. In other words, the savings in budget exceed the losses in conservation rates most of the times. The difference between these two changes appeared to become larger with greater strengths of social norms, as well as with greater sizes of initial payment *p1* and decreasing sizes of final payment *p2* (i.e. with larger differences between the two payments). Also, it appeared that the budget decreases more linearly than the ratio of conserved land parcels.

These findings are partially depicted in Figure 5, which shows the comparison between the static PES scheme with payment p = 1.15 and all dynamic PES schemes with initial payment $p1$ = 1.15 under the influence of sns = 3% and sns= 5%. The difference between the loss in conservation rate and the saving in budget becomes larger with stronger social norms and with larger differences between payment $p1$ and payment $p2$. These effects have been again inspected through a linear regression, whose results are reported in Table 3 in the Appendix. The results showed that the effect of varying the strength of social norms and the conversion as well as reconversion costs are significant. Increasing the conversion costs reduces the difference between the loss in conservation rate and the budget savings, while reconversion costs have the opposite effect. Finally, the simulations showed that a higher conservation rate can be achieved by dynamic PES schemes whose payment $p2$ is equal to the payment of the static PES schemes, representing an evidence of permanence.



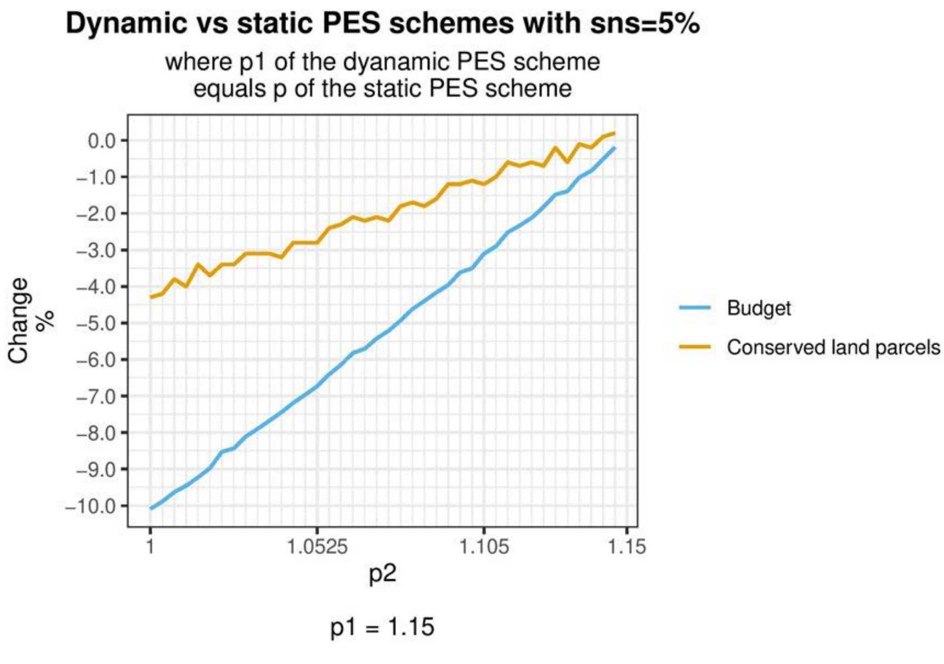


Figure 5: *Comparison of dynamic PES schemes and static PES in the absence of conversion costs and reconversion costs, where initial payments of the staggered PES schemes equal the payment of a static PES scheme.*

4.2.2. Dynamic PES schemes which have different initial payment as well as different final payment than static PES schemes

Although the lowering of the payment in the dynamic PES scheme lowers the budget more strongly than the conservation rate, this requires a rather high payment in the first place, which obviously raises the costs. To compare the cost-effectiveness of dynamic and static PES schemes in a more general manner, all payments must be varied systematically. The result of this analysis is shown in Figure 6, where the black dots represent the conservation rate and corresponding budget achieved through the 40 different static PES schemes, while the green dots represent relevant dynamic PES schemes exhibiting similar or better conservation rates and their corresponding budgets. The figure shows that there could indeed exist dynamic PES schemes which are more cost-effective than static PES schemes. In fact, the green dots which are located at the same height of a black dot but to the left of it, as well as the green dots that are perpendicularly above a black dot, represent dynamic PES schemes that are more cost-effective than static PES schemes. In the former case, the dynamic PES scheme is able to achieve the same conservation rate of the static PES scheme but at a lower budget. In the latter case, the dynamic PES scheme is able to achieve a higher conservation rate than the static PES scheme for a given budget. The cost-effectiveness gain of the staggered scheme increases with increasing strength of the social norm (compare Figs. 6a-c).

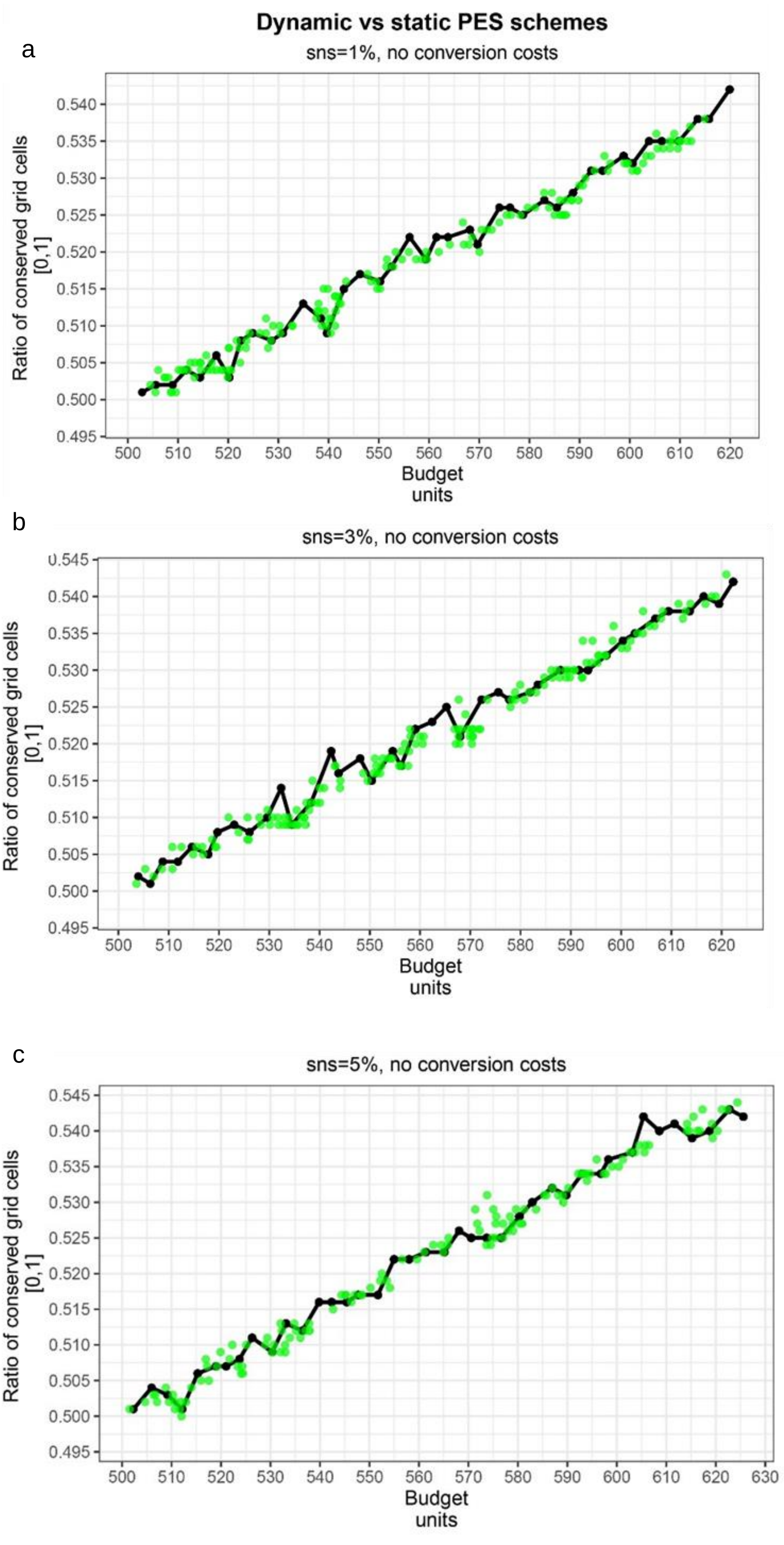


Figure 6: *Dynamic vs static PES schemes in the absence of conversion and reconversion costs and under the influence of different social norms' strengths.* The black dots represent the outcomes achieved by static PES schemes, while the green dots represent the outcome of dynamic PES schemes.

5. Discussion

The result of the model analysis sheds light on the important relationships that exist between some of the elements affecting the outcome of Payments for Ecosystem Services (PES), which represent a prominent incentive-based policy instrument aimed at preserving the environment and human well-being. Namely, the results show that it could be possible to gain cost-effectiveness in PES schemes by harnessing social norms and designing dynamic PES schemes in which a homogeneous PES payment is subsequently lowered sometime after the implementation of the schemes. These dynamic or staggered PES schemes differ from static PES schemes in which the same homogenous PES payment is offered throughout the whole duration of the conservation schemes. In fact, the analysis has estimated that by designing such dynamic PES schemes, budget savings of 0.5% and even beyond 1% could be achieved under the influence of social norms. That is, under the influence of social norms which increase a landowner's probability to enrol or re-enrol in a PES scheme depending on the number of neighbouring landowners that are enrolled in the scheme as well.

However, the actual realization of the mentioned budget savings and of their magnitudes should be further investigated, possibly by developing more accurate and sophisticated models that consider a wider range of elements. In reality, the extent to which budget savings could be achieved by implementing staggered PES schemes as opposed to static PES scheme will be strictly context-dependent and hinge on a large number of factors, including the available funds, the level of political support, the expected time span of the projects and their objectives (Engel et al., 2008). Furthermore, intrinsic motivations (Vatn, 2010, Rode et al., 2015; Cetas & Yasué, 2017), transaction costs (Wätzold & Drechsler, 2005; Mettepenningen et al., 2009) and distributional aspects (Sommerville et al., 2010) have all been found to play a key role in determining the outcome of PES schemes, and should therefore be considered while assessing the opportunities for gaining cost-effectiveness through the implementation of dynamic PES schemes.

Moreover, the results presented showed ratios of conserved land parcels of circa 50%. In reality, the ratio of landowners participating in PES schemes and agri-environment schemes may vary considerably, given that the percentage of participating landowners could vary even between 10% and 70% within a single Country (Cullen et al., 2021) or might not exceed 14% (Zanella et al., 2014). It follows that for future simulations it would be sensible to reduce the lower boundary of the PES payment so as to allow for smaller ratios of conserved land parcels. Namely, instead of considering PES payments within the range $[1, 1+\sigma]$ as it was done in this article, it would be sensible to consider PES payments within a range such as $[1-2\sigma, 1+\sigma]$, which entails a smaller lower boundary and is likely to yield lower ratios of conserved land parcels.

As to the effect of social norms, this article has built on the empirical estimates found in the literature, given that the strengths of social norms used in the model were based on the empirical estimates provided by Chen et al. (2012) and Defrancesco et al. (2018). Eventually, we modestly added to the literature by showing that it could be possible to harness social norms in order to gain cost-effectiveness in conservation schemes through the implementation of dynamic PES schemes. Additionally, this article has estimated that the opportunities for cost-savings are greater in the presence of stronger social norms. Considering that the investments in PES schemes around the world account for billions of US dollars a year (Salzman et al., 2018), and that in practice PES schemes' payments and budgets are determined according to the opportunity costs of the ecosystem service providers rather than the true value of ecosystem services (Engel, 2016), the findings of this article appear to be particularly relevant.

Besides, we developed a conceptual agent-based simulation model which could be exploited for further studies. For instance, the present model could be slightly modified to simulate spatially correlated agricultural profits. Concerning the choice of modelling homogenous PES payments instead of heterogenous PES payments, in some circumstances homogenous PES payments are preferred to heterogenous payments, especially because of the existence of transaction costs (Wätzold & Drechsler, 2005; Lundberg et al., 2018). Yet, a key question to be addressed would be to what extent transaction costs affect dynamic PES schemes offering homogenous PES payments, and by how much could these transaction costs reduce the opportunities for achieving cost-savings through dynamic PES schemes.

Concerning behavioural economics, this article has attempted to represent landowners' bounded rationality and other-regarding preferences by modelling the influence of social norms on the probabilities to change land use and by comparing these probabilities to random thresholds, ultimately determining the land use change decisions. Thus, the model developed for this article attempted to depart from deterministic decision-making processes in which the choices are based purely on self-interest and on the comparison between monetary payoffs, exclusively entailing profit-maximizing choices. By contrast, the model presented in this paper allows also for choices which are not profit-maximizing, besides considering social preferences. In fact, in the present model, the landowners could with some small probability even choose to enrol in PES schemes at a loss. Eventually, the developed model has modestly answered the call for a greater consideration of actual human behaviour in modelling, as opposed to the rationality assumptions of neoclassical economics which have dominated modelling approaches (Fulton et al., 2011; Schlüter et al., 2017).

6. Limitations

The results do not come without significant limitations. One of the main limitations can be considered the conceptual nature of the agent-based model. In fact, the results do not directly apply to real-life settings. However, as for all conceptual models, the aim of this analysis was to explore the relationships between the different elements within the system, and to try to quantify the effects that social norms and other elements could have on the opportunities for achieving cost-effectiveness gains in conservation schemes. Additionally, this paper provides grounds for the development of more sophisticated and applied simulations models, which could assess the opportunities and the conditions for achieving cost-effectiveness gains more accurately. Another limitation linked to the present conceptual agent-based model consists in its overly simplified representation of agents, who exhibit low degrees of heterogeneity. In fact, to increase resemblance with reality, more attributes should be given to the agents other than the foregone agricultural profits. For example, an attribute for the representation of landowners' risk attitude as well as an attribute for the representation of land parcel size could be introduced. Such additions would yield greater degrees of heterogeneity in the landowners, and accomplish a closer match with reality.

Incorporating additional parameters in the present model was out of the scope of the research and would have required greater levels of modelling complexity, besides making the analysis of the results more difficult.

7. Conclusions

The present analysis showed through the development of a conceptual agent-based simulation model that it could be possible to gain cost-effectiveness in conservation schemes by implementing dynamic Payments for Ecosystem Services (PES) schemes, leveraging on the effect of social norms. Namely, dynamic PES schemes in which a homogenous PES payment is subsequently reduced to a lower payment could deliver the same level of conservation at lower budgets than static PES schemes in which the payment remains unchanged for the whole duration of the schemes. Additionally, the opportunities for cost savings were found to increase under the influence of social norms, which positively affect the probability of a landowner to enrol or re-enrol in a PES scheme depending on the behaviour of neighbouring landowners. Lastly, also conversion costs and reconversion costs were shown to significantly affect the outcome of PES schemes.

Overall, we found that approximately 0.5% of conservation budget could be saved in the presence of social norms which increase a landowner’s probability to enrol in a PES scheme by 3% for each of the neighbouring landowners that are enrolled in the scheme as well, proportionally to the probability of enrolment in the absence of such social norms. Similarly, the budget savings could even exceed 1% under the influence of social norms which increase a landowner’s probability to enrol in the PES scheme by 5% for each of the neighbouring landowners that are enrolled in the scheme. Additionally, we found that the budget savings achieved through the subsequent reduction in PES payment exceeded the losses in conservation rates most of the times. Finally, a higher conservation rate could be achieved by dynamic PES schemes in which the initial PES payment is subsequently reduced to a lower payment, compared to those static PES schemes in which the same lower payment had been offered throughout the whole period, providing an evidence of permanence.

To conclude, this analysis has provided an impression of the potential of dynamic PES schemes to achieve cost-effectiveness gains in conservation schemes under the influence of social norms and bounded rationality by developing and applying a conceptual agent-based simulation model. We demonstrated that social norms are crucial for the outcome of Payments for Ecosystem Services. The recommendations for future research include the careful investigation of the conditions under which the mentioned cost-effectiveness gains could materialize, for example by developing models of higher complexity, as well as to investigate the extent to which transaction costs affect dynamic PES schemes offering homogenous PES payments.

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Appendix

Linear Regression Tables

***Table 1**: Results of the linear regression regarding the influences of the different parameters on the enrolment rate of PES schemes ($m\_totcons$).*

Call: lm(formula = m_totcons ~ n + sns + conv_cost + conv_cost_to_agr, data = merged)

Coefficients:	Estimate	Std. Error	t-value	Pr(>|t|)	code
(Intercept)	0.496	0.000	8857.150	<0.000	***
n	0.001	0.000	691.580	<0.00	***
sns	0.087	0.001	96.080	<0.000	***
conv_cost	-0.135	0.000	-536.860	<0.000	***
conv_cost_to_agr	0.151	0.000	547.420	<0.000	***

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’

Residual standard error: 0.002 on 14755 degrees of freedom

Multiple R-squared: 0.985 Adjusted R-squared: 0.985

F-statistic: 2.373e+05 on 4 and 14755 DF p-value: < 0.000

Table 2: Results of the linear regression regarding the influences of the different parameters on the budget of PES schemes $(budget)$**.**

Call: lm(formula = budget ~ n + m_totcons + sns + conv_cost + conv_cost_to_agr, data = merged)

Coefficients:	**Estimate**	**Std. Error**	**t-value**	**Pr(>|t|)**	**code**
(Intercept)	339.670	2.261	150.220	<0.000	***
n	2.771	0.0045	556.210	<0.000	***
m_totcons	312.997	4.550	68.720	<0.000	***
sns	62.433	0.642	97.260	<0.000	***
conv_cost	-121.111	0.633	-191.460	<0.000	***
conv_cost_to_agr	100.257	0.701	142.020	<0.000	***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Residual standard error: 0.999 on 14754 degrees of freedom

Multiple R-squared: 0.999 **Adjusted R-squared:** 0.999

F-statistic: 2.973e+06 on 5 and 14754 DF **p-value:** < 0.000

Table 3: Results of the linear regression regarding the wedge between the percentage loss in conservation rate and the percentage reduction in budget $(difference\_perc)$ following the implementation of dynamic PES schemes.

Call: lm(formula = difference_perc ~ n+ m + sns + m_totcons + m_totcons2 + conv_cost + conv_cost_to_agr, data = merged)[1]

Coefficients:	**Estimate**	**Std. Error**	**t-value**	**Pr(>|t|)**	**code**
(Intercept)	-5.069	0.436	-11.619	<0.000	***
n	-0.241	0.001	-319.962	<0.000	***
m	0.237	0.001	315.752	<0.000	***
m_totcons	94.222	0.686	137.383	<0.000	***
m_totcons2	-84.306	0.685	-123.101	<0.000	***
sns	-2.351	0.096	-24.411	<0.000	***
conv_cost	0.434	0.123	3.539	<0.000	***
conv_cost_to_agr	-1.376	0.132	-10.391	<0.000	***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '

Residual standard error: 0.148 on 14752 degrees of freedom

Multiple R-squared: 0.989 **Adjusted R-squared:** 0.989

F-statistic: 1.838e+05 on 7 and 14752 DF **p-value:** < 0.000

[1] NB: The percentage change in conservation rate and in budget are both negative, given that they both fall when the PES payment is reduced. The difference $difference\_perc$ has been calculated as the reduction in budget minus the reduction in conservation rate. Hence, if the resulting number is negative, it means that the budget saving exceeds the loss in conservation rate. Thus, the parameters that exert a negative effect (i.e., the parameters having negative estimates), actually increase the wedge between the reduction in budget and the loss in conservation rate.