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Agglomeration bonus and endogenous group formation

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Abstract

Agglomeration bonus schemes are envisioned to incentivize the connectivity of habitat conservation across landowners. Assuming full cooperation among landowners at the landscape scale, the bulk of the literature theoretically finds that agglomeration bonus schemes are more cost effective in achieving biodiversity conservation than spatially homogenous payments. However, it may be rational for landowners not to cooperate all together but, rather, to cooperate within smaller groups. Here, we analyze the cost effectiveness of agglomeration bonus schemes when such partial cooperation is allowed, that is, when cooperation is endogenously chosen. We introduce a spatially explicit ecological-economic model within a coalition formation game to assess how landowners form stable coalition structures and how this affects biodiversity conservation under a wide range of (i) degrees of spatial cost autocorrelation, (ii) bonuses and flat-rate payments, (iii) species dispersal rates, and (iv) coordination costs. We find that agglomeration bonus schemes are more cost effective than homogenous payments *only* for low public expenditures. This condition is not identified if full cooperation is assumed. We find, however, that full cooperation never emerges and hence that such an assumption leads to an overestimation of the cost effectiveness of agglomeration bonus schemes. Moreover, we find that the cost effectiveness of agglomeration bonus schemes increases when the spatial cost autocorrelation and species dispersal rate decrease. Finally, coordination costs do not affect the cost effectiveness of the agglomeration bonus scheme but they have implications for its design because of their impact on coalition formation.

KEYWORDS
agri-environmental policy, biodiversity conservation, collective incentives, environmental subsidies, green clubs

JEL CLASSIFICATION
H23, Q24, Q57

1 | INTRODUCTION

Habitat connectivity is crucial for the conservation of biodiversity (Eisner et al., 1995). As most habitats are located on private, scattered properties, policy measures have been suggested not only to incentivize conservation efforts but also to favor their agglomeration at the landscape scale (Kerr et al., 2014; Kotchen & Segerson, 2020). Among the proposed mechanisms, the Agglomeration Bonus (AB) has received increasing attention from scientists and policymakers. Initially suggested by Parkhurst et al. (2002), AB is a voluntary collective scheme that consists of a bonus for adjacent conserved plots in addition to a flat-rate per-hectare payment.

The literature has focused on the assessment of the cost effectiveness of AB schemes (in terms of conservation outcomes for a given level of public expenditures)[1] either using lab experiments (Banerjee et al., 2017, 2021; Fooks et al., 2016; Krawczyk et al., 2016; Parkhurst et al., 2002, 2016; Parkhurst & Shogren, 2007; Reeling et al., 2018), field experiments (Liu et al., 2019; Panchalingam et al., 2019), theoretical noncooperative game models (Albers et al., 2008; Arora et al., 2021), or spatially explicit ecological-economic models (Bamière et al., 2013; Bell et al., 2016; Drechsler, 2017a, 2017b; Drechsler et al., 2010, 2016; Wätzold & Drechsler, 2014). These studies find that AB schemes are more cost-effective than traditional spatially homogeneous payments or auction mechanisms. By agglomerating efforts over space, AB schemes are particularly valuable for species experimenting difficulties to disperse over long distances or for heterogeneous, nonclustered landscapes (Wätzold & Drechsler, 2014).

Most of the literature using ecological-economic models assumes that landowners maximize the aggregate profit of exogenously predetermined groups (hereafter coalitions), usually of the grand coalition (GC) in which *all* the landowners within a given landscape cooperate (Bamière et al., 2013; Drechsler, 2017a, 2017b; Drechsler et al., 2010, 2016; Wätzold & Drechsler, 2014). However, as AB are voluntary schemes, there is no reason to assume that landowners will decide to apply within the GC. Indeed, if full cooperation is not profitable for at least one landowner, she will refuse to cooperate, ultimately preventing the GC from emerging. There are two main motives that may disincentivize the emergence of the GC in real settings. First, the costs of conserving habitats can be highly heterogeneous across landowners (Huber et al., 2021). As a result, the maximization of aggregated profits in the GC could lead landowners to conserve plots that are actually costly for their owner. In this case, the outcomes of the GC are individually suboptimal, so that rational landowners would refuse to cooperate in the GC. This is particularly important for the assessment of the cost effectiveness of AB schemes in rural landscapes because the opportunity costs, in addition to being heterogeneous, are often spatially clustered (Drechsler et al., 2010). Second, cooperation among landowners entails significant coordination costs such as the time required for communication (Villamayor-Tomas et al., 2019). If coordination costs increase with the number of people cooperating, a subcoalition of landowners might find it rational, if possible, to exclude participants from the coalition.

Given these issues, it may be rational for landowners to not cooperate or to cooperate within smaller coalitions. For example, Huber et al. (2021) describe the case of the Saas and Matter valleys in Switzerland where eight groups of farmers independently applied to the proposed AB scheme.

[1]Following Drechsler et al. (2010), we define cost-effectiveness as the level of biodiversity for a given level of public expenditures. The public expenditures correspond to the sum of payments to landowners.

Under these conditions, AB scheme cost-effectiveness assessment could be mistaken if the GC is assumed to emerge. As landowners can choose with whom to cooperate, the first issue is to examine how they group together in mutually exclusive coalitions in response to AB schemes. Comparable issues are typically examined by the game theory literature on coalition formation (d'Aspremont et al., 1983; Yi, 2003). This literature addresses the idea that players *choose* to cooperate (or not) so that the formation of coalitions is *endogenously* determined by the set of individual decisions (rather than being *exogenously* assumed). Such games are used to determine the configuration of *stable coalition structures*, that is, the partitions of players where no one has incentives to change coalition membership. This framework has been applied to cartel formation (Bloch, 1995; d'Aspremont et al., 1983) and to the signing of environmental agreements among countries (Barrett, 1994) or firms (Brau & Carraro, 2011). To our knowledge, coalition formation games have never been applied to AB scheme cost-effectiveness assessment, despite its apparent suitability for the problem at stake here.

The main objective of this paper is to theoretically assess the cost effectiveness of AB schemes in cases where the formation of landowners' coalitions is explicitly accounted for. Specifically, we determine which coalition structures are endogenously formed in response to AB schemes and how this affects the conservation outcomes (in terms of plot enrolment and biodiversity levels). We compare these outcomes with those resulting from spatially homogeneous payments to investigate whether AB schemes accounting for endogenous coalition formation lead to *additional* conservation outcomes. We also compare the outcomes with those arising from the GC in identical AB schemes to investigate the extent to which the cost effectiveness of the scheme depends on the assumption of (full) cooperation. Finally, we address the role of (i) landscape structure (as measured by the spatial autocorrelation of the opportunity costs), (ii) payment design, (iii) species dispersal rate, and (iv) coordination costs (as a function of the number of cooperative landowners) on the final outcomes.

The analysis of these elements is valuable for the ongoing debate on the benefits of collective schemes for biodiversity conservation (Kotchen & Segerson, 2020). Indeed, schemes that incentivize the coordination of conservation efforts in rural landscapes have been increasingly implemented, for example, in the Netherlands (Franks, 2010), Switzerland (Huber et al., 2021; Krämer & Wätzold, 2018), France (Limbach & Rozan, 2021), Italy (Gatto et al., 2019), Japan (Shimada, 2020), and the USA (McEvoy et al., 2014). However, contrary to the findings of the literature, these schemes have not succeeded in incentivizing large groups of landowners to collectively apply in practice (Fooks et al., 2016; Gatto et al., 2019; Westerink et al., 2017). There are likely to be many reasons for this mismatch between the reality and the scientific literature. We explore one here: the absence of specification in previous studies of a formal, rational choice to cooperate in AB schemes.

Our methodology relies on the introduction of a spatially explicit ecological-economic model into a coalition formation game. Our coalition formation game models the landowners' response to the AB scheme, in terms of group and plot enrollment in the scheme, ultimately yielding the spatial structure of the conservation efforts and the corresponding biodiversity levels. To assess the stability of the coalition structures, we assume that coalition formation is characterized by exclusive membership and unanimity (Hart & Kurz, 1983; Yi, 2003): a landowner can join a coalition only if the other members accept her, but members are free to move out. We believe that this type of coalition formation best represents the bottom-up approach that characterizes enrollment in a voluntary and collective scheme such as the AB. Given the high levels of heterogeneity and the complex spatially explicit spillovers among landowners, we solve the problem numerically for several fictitious landscapes characterized by different degrees of spatial autocorrelation of conservation opportunity costs.

We contribute to the literature on AB schemes by adding a coalition formation perspective that enables us to highlight several elements that were previously overlooked.[2] First, we find that the GC

[2]On this prospect, we build upon the game theory studies on AB schemes (Albers et al., 2008; Arora et al., 2021) but move away from their noncooperative setting. Our analysis is closer to Ansink and Bouma (2013), Zavalloni et al. (2019), and Bareille et al. (2021), which are among the few studies using coalition formation games for the analysis of conservation policies. Their analyses are, however, applied to minimum-participation rules, a scheme that does not address the spatial dimension of the conservation efforts. These papers also pay particular attention to the impacts of productive spillovers among landowners on the cost effectiveness of such schemes.

is never stable in any AB setting, contrary to the assumption used by a large part of the literature. Second, we find that AB schemes are more cost effective than spatially homogeneous payments to conserve biodiversity *only* for low levels of public expenditures. This condition—which may explain the limited success of AB schemes in practice—does not appear when landowners cooperate in the GC and hence was not previously detected. Third, coordination costs, suggested as an important driver of AB scheme cost effectiveness (Albers et al., 2008; Banerjee et al., 2017; Villamayor-Tomas et al., 2019), could have not been formally evaluated because the GC was assumed. Assuming that coalition formation incurs coordination costs, we find that they have virtually no impact on the cost effectiveness of AB schemes. However, they do have implications for the design of the scheme, because, by reducing the cooperation among landowners, higher coordination costs require higher bonuses to reach any desired biodiversity level.

The paper is structured as follows. We start by presenting our theoretical framework. We then turn to its application in a numerical example. Thereafter, we present our results followed by a discussion of the results and the various policy implications.

2 | MODELING FRAMEWORK

2.1 | Description of the AB scheme

Imagine a landscape subdivided into plots owned by a population of profit-maximizing landowners.[3] A regulator without any budget constraint, conveying the social preferences for biodiversity and ignoring the plot opportunity costs, sets up a voluntary AB scheme that incentivizes both the conservation of habitats and their connectivity. We consider that landowners respond to the AB schemes by formulating conservation projects, where the identity of the applicants and their conservation efforts are indicated.

We assume that the AB scheme that we analyze has three main elements. First, we assume that the AB scheme rewards conservation projects through (i) a flat-rate per-hectare payment for each conserved plot and (ii) a per-border bonus for each adjacent conserved plot (*Assumption 1*). Second, we consider that both individuals and groups can formulate conservation projects in response to the AB scheme, and that the regulator can reward any conservation projects (*Assumption 2*). Third, we assume that payoffs are independent among conservation projects and depend only on the *declared* efforts indicated within each project (*Assumption 3*). In other words, landowners are not rewarded for connections that emerge unintentionally from their participation in different conservation projects.[4]

Assumption 1 is common in the bulk of AB literature since the first study of its kind (Parkhurst et al., 2002).[5] Assumptions 2 and 3 are less common in the existing analyses but come closer to real-world applications of AB schemes, such as the above-referenced one in Switzerland (Huber

[3]We assume that landowners only decide to participate in order to maximize profits, even if previous evidence shows that landowners also join AB schemes for non-monetary benefits (Kuhfuss et al., 2016).

[4]Imagine a landscape with four landowners *a*, *b*, *c*, and *d*, each landowner owning four adjacent plots aggregated in a square. Imagine that each landowner conserves *only* the plot that is the closest to the centroid of the landscape such that the four central plots are conserved. Assume that only landowners *a* and *b* apply to the scheme together, whereas landowners *c* and *d* apply individually. Then, the coalition {*a*,*b*} is rewarded for the connection between their two conserved plots but not for the connections with the conserved plots of *c* and *d*. Landowners *c* and *d* do not receive any bonus—but rather only the flat-rate payment—in this illustrative example.

[5]Few studies analyze other types of AB scheme payoffs. For example, Wätzold and Drechsler (2014) define an agglomeration payment in which a bonus is granted to a conserved plot if the *density* of the conservation efforts in its surrounding area is higher than a given threshold. The main difference with ours is that the conserved plots do not need to be adjacent to each other to receive the bonus. Although further analysis is required to properly assess the implications of the Wätzold and Drechsler (2014) setting, it is likely to further boost cooperation among landowners as it enlarges the potential eligible areas to grant a bonus (see below for the details on coalition formation), but this result probably depends on the spatial autocorrelation of the opportunity costs. In addition, Bell et al. (2016) and Banerjee et al. (2017) analyze the cases in which the bonus depends on the number of landowners applying to the scheme (rather than the area). Although such a setting should foster cooperation among landowners (as it is the only source of reward), it would probably lead landowners to devote less conservation efforts than in our setting.

et al., 2021; Krämer & Wätzold, 2018). Regarding *Assumption 2*, the Swiss case illustrates that collective projects can be presented by several groups of landowners. For example, in the Saas and Matter valleys in the Canton of Valais, eight groups of farmers enrolled 27% of the available parcels in the AB scheme (Huber et al., 2021). Regarding *Assumption 3*, the Swiss case shows that each group of farmers was independently rewarded, based on the declaration of their conservation efforts across the landscape. More generally, the rewarding of conservation efforts based on the declaration of the submitted projects is not specific to AB schemes, as most individual and other collective schemes rely on this setting (e.g., Limbach & Rozan, 2021).[6]

2.2 | Description of the coalition formation game

The landowners' response to the AB scheme described above is a number of implemented conservation projects, each indicating (i) the plots that are enrolled and (ii) the identity of the collaborating landowners. We model such a response using a coalition formation game. Using the coalition formation terminology, the landowners' response to the AB scheme is a coalition structure (e.g., Carraro & Marchiori, 2002), that is, a partition of landowners in mutually exclusive coalitions. The outcome of the coalition formation game is a set of conservation decisions and corresponding profits for all landowners in all the possible coalition structures. Using this information, we can then identify the coalition structures that are *stable*. Such stable coalition structures are defined as the partitions of landowners where no landowner has incentives to change coalition membership. The resolution of the coalition formation game ultimately allows us to determine the configuration of the stable coalition structures and the corresponding conservation efforts.

Following the literature on coalition formation, we frame the game in two stages and solve it by backward induction (Carraro & Marchiori, 2002). In the first stage, landowners decide noncooperatively with whom to engage in the AB scheme given the individual profits they obtained in the different coalition structures (which are determined in the second stage). In the second stage, landowners in a given coalition decide cooperatively on the size and the location of the conserved habitats, with the objective of maximizing the aggregate utility of the coalition members (Barrett, 1994).[7] The outcomes of the second stage are the conservation decisions and the profits for all the landowners in all the coalitions (which are used in the first stage). We assume that the cooperation problem is static and solved in a single period.[8]

[6]Note that *Assumption 3* is irrelevant if GC is assumed to be the only possible conservation project. To our knowledge, Wätzold and Drechsler (2014) is the only spatially-explicit, ecological-economic study that—implicitly—uses *Assumption 3*. In particular, they assume that bonuses are granted to only one conservation project (if the landowners in the project succeed in presenting a higher density of conserved plots than a threshold), the remaining landowners being only rewarded by spatially homogenous payments irrespective of the density of their conservation efforts. Moreover, Parkhurst et al. (2016) assume that landowners only present individual projects and that unintentionally conserved adjacent plots between two landowners are never rewarded. An alternative setting to *Assumption 3* would be to grant the bonus according to the overall landscape structure, implying that the undeclared connections (from different conservation projects) would also be rewarded. This type of payoff can be found in the Kuma Joint Management Program (Shimada, 2020), but the author describes it as an unusual procedure that stands out from other AB schemes where payments are "determined and agreed upon in advance" (Shimada, 2020, p. 2). This alternative setting seems, however, to describe the framework of most of the experimental papers on AB, even if not explicitly mentioned (e.g., Fooks et al., 2016; Parkhurst & Shogren, 2007; Reeling et al., 2018). Indeed, only such a setting implies strategic interactions among players (such as the ones studied in experimental papers). Assuming these alternative payoffs in our model would mean that the rewards for each coalition depend on the other coalitions' conservation choices. In other words, this setting would create intercoalition spillovers. Intuitively (see below for the details on coalition formation), this alternative setting would reduce the relative profitability of the coalitions with respect to singletons and, hence likely lead to smaller coalitions. Indeed, in such a case, landowners would presumably tend to free ride, benefiting from bonuses while not facing the coordination costs that we assume coalitions face.

[7]In our game, players decide on both the amount and *location* of the conservation efforts in the second stage. Although an increasing number of papers are studying local public goods that address similar issues (Alvarado-Quesada & Weikard, 2017; Bareille et al., 2021), the decision on location is a crucial element of our analysis that is seldom addressed in the coalition formation literature. Indeed, as the bulk of this literature studies the signing of International Environmental Agreements relating to global public goods (e.g., climate change), spatially explicit analyses are not common and players in the second stage only choose the amount of efforts.

[8]A dynamic dimension could be introduced to model the diffusion of the cooperation process in the AB enrollment, due to an evolution in the opportunity and coordination costs over time, for example. Coalition formation games can account for these elements to see how coalitions form, collapse, or regroup (Konishi & Ray, 2003).

The resolution of the game depends on several assumptions related to coalition formation. In particular, we assume that each landowner can only be part of a single project (and thus of a single coalition), but we allow the formation of multiple nontrivial coalitions (two players or more) at the landscape scale.[9]

Moreover, key features of coalition formation games are the rules that govern coalition membership, which constrain the way landowners can join or leave a coalition. Here we assume that coalition formation is characterized by *exclusive membership* and *unanimity*: a new coalition member must be *accepted* by *all* the landowners that are already members. Indeed, there is no reason for a coalition to accept a new member in the project if her adhesion decreases the profit of one or of more of the landowners that are already willing to participate (due to a change in the declared conservation efforts, for example). We believe that these rules are the best features to capture the voluntary bottom-up processes that occur when landowners apply to AB schemes.[10]

In addition, we consider that coalition formation entails coordination costs to the members. Coordination costs may represent the time required for communication but can also take on more explicit forms such as the hiring of consultants to help landowners to coordinate their decisions, as is the case in the *Recreation Eggberge* area, for example (Krämer & Wätzold, 2018). In line with the literature, we assume that coordination costs increase with the number of people cooperating (Sylwester, 2001; Villamayor-Tomas et al., 2019). As they only depend on coalition size, coordination costs do not affect the different coalitions' conservation decisions in the second stage but only the decisions to be part of a coalition in the first stage.[11]

Finally, we assume that there are no side payments within the coalitions. Indeed, formal systems of side payments have not been observed in real-world applications of AB schemes so far (Nguyen et al., 2022) and although they are theoretically considered in the literature (Drechsler, 2017b; Wätzold & Drechsler, 2014),[12] their consideration would raise the additional issue of the definition of their distribution within the coalitions and goes beyond the objective of our paper.

Now that we have presented the logic and the assumptions of our model, we turn to its formal mathematical formulation.

[9]To facilitate the analyses, the literature has often assumed one single nontrivial coalition per stable coalition structure, the remaining players acting as singletons (Barrett, 1994). However, this is a major simplification for the problem here at stake, and we relax such an assumption. An alternative modeling approach could also allow landowners to enroll different plots in different coalitions. However, this alternative would lead to a dramatic increase in the number of coalition structures to investigate. For example, consider a landscape made up of four landowners with four plots each. Allowing landowners to be members of a single coalition implies the identification of the stable equilibrium among 15 coalition structures (the Bell number of four; the computation of the number of possible coalition structures is explained afterwards in footnote n°13), whereas allowing landowners to participate in multiple coalitions (one for each plot at maximum) implies determining the stable equilibria among 10,480,142,147 coalition structures (the Bell number of 16).

[10]An alternative specification to *closed membership* is *open membership* (widely used in the International Environmental Agreement literature). Open membership would imply that a landowner can join an existing coalition without any possibility for the members to exclude her. An alternative assumption to *unanimity* is *majority*, where decisions about accepting new members are subject to voting, without any possibility for a landowner opposed to this decision to leave. These alternative specifications would affect the configuration of stable coalition structures (Carraro & Marchiori, 2002). In both cases, stable coalition structures would probably be composed of fewer, but larger, coalitions. The implication of these alternative assumptions on the cost effectiveness of the scheme remains open to further research as we ignore how these alternative stable coalition structures might change their conservation efforts with respect to those with closed membership and unanimity.

[11]Although plausible, alternative functional forms have not been analyzed by the literature (to the best of our knowledge). One could, for example, imagine coordination costs depending on the aggregated conservation efforts within the coalition, such that the second stage would also be affected. The analysis of alternative types of coordination costs for the problem dealt with here remain, however, the subject of future research.

[12]Wätzold and Drechsler (2014) show that side payments could increase the cost effectiveness of AB schemes when they were made by the landowners in the GC. Side payments are compensations among landowners of a single coalition. They are usually modeled as monetary payments but may also take the form of non-monetary transfers (e.g., help with machinery). In our case, with endogenous coalition formation, allowing side payments among landowners within a single coalition would probably lead to fewer but larger coalitions and could thus affect the scheme's cost effectiveness.

2.3 | Mathematical formulation

We consider a fictitious landscape with **I** landowners ($i = 1, \ldots, I$), each one owning **J** plots ($j = 1, \ldots, J$) of equal size, arranged on a regular square grid. Landowners can form coalitions and submit collective conservation projects in response to the AB scheme. Call $\mathbf{S}_m$ a $I \times 1$ vector indicating the composition of a given coalition of size $|\mathbf{S}_m|$, with $m = 1, \ldots, M$. For example, $\mathbf{S}_m = (1, 1, 0, \ldots, 0) = \{1,2\}$ is the coalition of Landowners 1 and 2. Among the population **I**, there are $M = 2$^$I-1$ alternative non-empty coalitions (including the singletons and the GC). We call $x_{ij}^{\mathbf{S}_m}$ the land allocation of landowner i in the coalition $\mathbf{S}_m$ on plot j such that i in $\mathbf{S}_m$ can implement conservation measures ($x_{ij}^{\mathbf{S}_m} = 1$) or produce marketable outputs ($x_{ij}^{\mathbf{S}_m} = 0$). The opportunity cost of carrying out conservation measures on plot j owned by i is c_{ij} and corresponds to the forgone profit (e.g., from agriculture). In such settings, no conservation measures are undertaken without payments.

The agglomeration bonus is composed of a flat-rate per-hectare payment p to every plot with conservation measures (for all $x_{ij}^{\mathbf{S}_m} = 1$), plus a per-border bonus q to every border that the conserved plots have in common with other conserved plots from the same conservation project. Call $\varphi_j^{\mathbf{S}_m}$ a function that counts the number of adjacent conserved plots around plot j and that are in the conservation project submitted by $\mathbf{S}_m$ (within which plot j is enrolled). As in Parkhurst et al. (2002), we assume that $\varphi_j^{\mathbf{S}_m}$ is a rook-type function that only counts the positive elements of the North, South, East, and West borders of j (if they belong to a landowner in $\mathbf{S}_m$). For example, consider a conservation project composed of nine plots arranged in a 3×3 grid (Plot 1 being the south-west plot and Plot 9 being the north-east one) proposed by $\mathbf{S}_m = \{1, 2\}$ and where conservation is undertaken on five plots such that $x_{12}^{\mathbf{S}_m} = x_{14}^{\mathbf{S}_m} = x_{15}^{\mathbf{S}_m} = x_{26}^{\mathbf{S}_m} = x_{28}^{\mathbf{S}_m} = 1$ while $x_{11}^{\mathbf{S}_m} = x_{13}^{\mathbf{S}_m} = x_{27}^{\mathbf{S}_m} = x_{29}^{\mathbf{S}_m} = 0$. In this example, the total number of connections within the conservation project is $\varphi_2^{\mathbf{S}_m} + \varphi_4^{\mathbf{S}_m} + \varphi_5^{\mathbf{S}_m} + \varphi_6^{\mathbf{S}_m} + \varphi_8^{\mathbf{S}_m} = 1 + 1 + 4 + 1 + 1 = 8$, and the total payment for the landowners in $\mathbf{S}_m$ is $5 \times p + 8 \times q$ (i.e., $3 \times p + 6 \times q$ for landowner 1 and $2 \times p + 2 \times q$ for landowner 2).

Coalition formation is costly for the members in $\mathbf{S}_m$. We define $C(|\mathbf{S}_m|) = \mathbf{1}_{|\mathbf{S}_m| \geq 2}[C \cdot |\mathbf{S}_m|]$ as the individual coordination cost for any landowner within a coalition of size $|\mathbf{S}_m| \geq 2$, where $\mathbf{1}_{|\mathbf{S}_m| \geq 2}$ is the indicator function that takes the value 1 if $|\mathbf{S}_m| \geq 2$ and 0 if $|\mathbf{S}_m| = 1$. At the coalition level, the incurred coordination costs are thus quadratic with the coalition size.

Summarizing these elements, the utility of a given landowner in a coalition $\mathbf{S}_m$ is:

$$u_i^{\mathbf{S}_m} = \sum_{j=1}^{J} \left(x_{ij}^{\mathbf{S}_m} \cdot p + \left(1 - x_{ij}^{\mathbf{S}_m}\right) \cdot c_{ij} \right) + \sum_{j=1}^{J} \varphi_j^{\mathbf{S}_m} \cdot x_{ij}^{\mathbf{S}_m} \cdot q - \mathbf{1}_{|\mathbf{S}_m| \geq 2}[C \cdot |\mathbf{S}_m|]. \quad (1)$$

Now that the utility of the landowners has been defined, we turn to the resolution of the two-stage coalition formation game. In the second stage, landowners decide on the land allocation maximizing the aggregate profits of the members of the coalition. Mathematically, landowners in $\mathbf{S}_m$ maximize:

$$\max_{\mathbf{x}_i^{\mathbf{S}_m}} \sum_{i \in \mathbf{S}_m} u_i^{\mathbf{S}_m}. \quad (2)$$

The solution of (2) is the vector $\mathbf{x}_i^{\mathbf{S}_m*} = \left(x_{i1}^{\mathbf{S}_m*}, \ldots, x_{iJ}^{\mathbf{S}_m*}\right)$ for each landowner i belonging to $\mathbf{S}_m$, each element $x_{ij}^{\mathbf{S}_m*}$ being equal to 1 if $p + \varphi_j^{\mathbf{S}_m} \cdot q > c_{ij}$. Putting $\mathbf{x}_i^{\mathbf{S}_m*}$ back into (1), we obtain the vector of individual profits $\mathbf{u}_i^{\mathbf{S}_m*}$ for all the coalitions.

In the first stage, the landowners decide whether and with whom to cooperate. We determine the stability of the coalition structures using the vectors of individual profits $\mathbf{u}_i^{\mathbf{S}_m*}$ for all I landowners in all M coalitions. Formally, a coalition structure $\boldsymbol{\pi}_k$ ($k = 1, \ldots, K$) is a partition of the landowners so that $\boldsymbol{\pi}_k = \{\mathbf{S}_l, \ldots, \mathbf{S}_v\}$ with $\mathbf{S}_l \cap \mathbf{S}_v = \emptyset$ for $(l;v) \epsilon\ [1, \ldots, M]$ and $\bigcup_{\mathbf{S}_m \epsilon \boldsymbol{\pi}_k} \mathbf{S}_m = \mathbf{I}$, that is, a grouping of the landowners into non-empty coalitions, each landowner being included in only one coalition. In population **I**, the number of potential coalition structures K corresponds to the Bell number of I B_I.[13]

To determine the stable coalition structures, we rely on the two stability conditions of *internal* and *external* stability (e.g., Barrett, 1994), adjusted to the exclusive membership case (Carraro & Marchiori, 2002). First, the internal stability principle states that all members of the given coalition $\mathbf{S}_m$ belonging to a stable coalition structure $\boldsymbol{\pi}_k$ have no incentives to secede and create a smaller coalition. In particular, the landowners prefer to remain in $\mathbf{S}_m$ rather than to apply individually to the AB scheme. Formally, this is described by:

$$u_i^{\mathbf{S}_m*} > u_i^{\{i\}*} \wedge u_j^{\mathbf{S}_m*} > u_j^{\mathbf{S}_m \backslash \{i\}*} \forall (i,j) \in \mathbf{S}_m. \tag{3}$$

Second, the external stability principle states that there are no incentives for changes in membership. This implies that either no landowner is willing to join an alternative coalition or that no coalition is willing to accept new member(s) that would like to join it. Formally, the external stability principle states:

$$u_i^{\mathbf{S}_v*} > u_i^{\mathbf{S}_v \cup \{l\}*} \forall i \in \mathbf{S}_v \text{ and} \forall l \notin \mathbf{S}_v \vee u_i^{\mathbf{S}_v*} > u_i^{\mathbf{S}_z \cup \{i\}*} \forall i \in \mathbf{S}_v \text{ and} \forall (\mathbf{S}_v, \mathbf{S}_z) \in \boldsymbol{\pi}_k. \tag{4}$$

Overall, a coalition structure is stable *if and only if* Conditions (3) and (4) are verified (see the online supplementary appendix for an illustrative example with three landowners). In the light of the fact that Conditions (3) and (4) can be met for several partitions, the solution of the analysis is not necessarily unique, and several coalition structures can be stable within any particular fictitious landscape (Grabisch & Funaki, 2012). It is also worth noting that a particular stable coalition structure $\boldsymbol{\pi}_k$ does not necessarily conserve the same plots if the conditions change. For example, if the bonus increases, the coalition structure $\boldsymbol{\pi}_k$ can remain stable albeit enrolling more plots in the scheme.

As the stability conditions depend on landowners' individual profits, any change in the opportunity costs, coordination costs, flat-rate payments, or bonuses influences the stability of coalition structures. From the regulator's perspective, these changes affect the conservation outcomes and eventually the cost effectiveness of the scheme.

2.4 | Cost effectiveness

We evaluate AB schemes in terms of cost effectiveness, which we define as the level of biodiversity per level of public expenditures.

We assume that the biodiversity level $B(\mathbf{x}^{\boldsymbol{\pi}_k})$ depends on the land-use pattern $\mathbf{x}^{\boldsymbol{\pi}_k}$ at the landscape scale, that is, on the number of conserved plots and the distance between them. We define $\mathbf{x}^{\boldsymbol{\pi}_k*}$ as the vector of conservation decisions taken by the individuals within a particular stable coalition structure $\boldsymbol{\pi}_k$. In other words, we have $\mathbf{x}_i^{\mathbf{S}_m*} = \mathbf{x}_i^{\boldsymbol{\pi}_k*}$, $\forall \mathbf{S}_m \in \boldsymbol{\pi}_k$. Inspired by Wätzold and Drechsler (2014), we define the biodiversity level in a stable coalition structure as:

$$B(\mathbf{x}^{\boldsymbol{\pi}_k*}) = \sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij}^{\boldsymbol{\pi}_k*} \cdot \sum_{k=1}^{I} \sum_{\substack{l=1 \\ l \neq j \text{ if } k=i}}^{J} x_{kl}^{\boldsymbol{\pi}_k*} \cdot \exp\left(\frac{-d_{jl}}{D}\right). \tag{5}$$

[13]The Bell number counts the number of possible partitions of a set, that is, the number of groupings of the set's elements into non-empty subsets, each element being included in exactly one subset.

In Equation (5), d_{jl} is the distance between the centroids of the two different plots j and l (owned respectively by i and k), and D is the dispersal rate of the considered species. Specifically, a positive D implies that the considered species benefits from habitat agglomeration (e.g., butterflies), whereas a negative D implies the opposite.[14] Given the problem at stake, we assume that D is positive. Equation (5) shows that biodiversity levels increase with the number of conserved plots. For a similar aggregated conserved area, biodiversity levels increase when the distance between conserved plots reduces, that is, when the conserved habitats are more spatially clustered. Finally, biodiversity levels increase with the dispersal rate. This means that, to reach a given biodiversity level for a similar total conserved area, the conserved habitats need to be more agglomerated as the target species present a low D (because the target species have difficulty dispersing over long distances).

Public expenditures are defined as the sum of the total payments attributed to landowners in the stable coalition structures. Formally, public expenditures for a given stable coalition structure are: $P = \sum_{\mathbf{S}_m \in \boldsymbol{\pi}_k} \sum_{i \in \mathbf{S}_m} \sum_{j=1}^{J} \left(x_{ij}^{\mathbf{S}_m *} \cdot p + \varphi_j^{\mathbf{S}_m} \cdot x_{ij}^{\mathbf{S}_m *} \cdot q \right)$; that is, the sum of the payments attributed to each landowner in each coalition of a stable coalition structure.

3 | NUMERICAL IMPLEMENTATION

With heterogenous landowners (here in terms of opportunity costs and location), the analytical assessment of the stability of the coalition structures is only possible with strong assumptions or with a high degree of simplification (e.g., McGinty, 2007; Osmani & Tol, 2010; Pavlova & de Zeeuw, 2013). We thus examine these effects by numerically solving the problem described by Equations (1) to (5).

We assume that the landscape is composed of $I = 9$ landowners. There are thus $M = 2^9 - 1 = 511$ coalitions and $K = B_9 = 21{,}147$ coalition structures. We construct fictitious grid landscapes where landowners' properties consist of similar plots agglomerated into one piece. Each landowner owns a block of $J = 9$ adjacent plots, of one hectare each, aggregated in a square. We set the distance between the centroids of rook-neighbor plots to one. The cost effectiveness of the scheme is likely to depend on property size, shape, and fragmentation (Huber et al., 2021). However, studying the role of property configuration goes beyond the objective of our analysis, and we maintain the same regular grid configuration over the entire set of simulations.

We randomize the opportunity costs on the $9 \times 9 = 81$ plots of the landscape. Because neighboring plots are more likely to present similar pedoclimatic conditions (Pasher et al., 2013), agricultural landscapes often present a positive spatial cost autocorrelation. Accordingly, we generate 61 random landscapes such that the Moran's I statistics for the plots' opportunity cost successively takes the value of 0.5 (mean spatial autocorrelation) to 0.8 (high spatial autocorrelation), with steps of 0.005.[15] These levels of Moran's I statistics are consistent with those observed in rural landscapes at a 1 km^2 scale (Pasher et al., 2013). To generate comparable landscapes for the simulations, we proceed in two steps. First, we always attribute (i) the lowest opportunity cost to the bottom left plot (always equal to €110/ha), (ii) the highest opportunity cost to the top right plot (always equal to €250/ha), and (iii) the average opportunity cost across the plots as being equal to €180/ha. The generated landscapes capture a natural degree of spatial autocorrelation due to clustered differences in soil quality among plots. However, the heterogeneity of the opportunity costs also depends on the landowners' characteristics (e.g., different production systems, different levels of capital and labor, differences in skills). In a second step, we thus randomly apply landowner-level shifters of ±€30/ha on the 61 generated landscapes (i.e., between about ±15% of the natural opportunity costs).

[14]Several species respond negatively to habitat agglomeration (Fahrig, 2017). Bamière et al. (2013) showed how the agglomeration bonus can accommodate for these effects by simply designing a negative q.

[15]We used the rook matrix to settle the weights within the Morans' I computation (Moran, 1948).

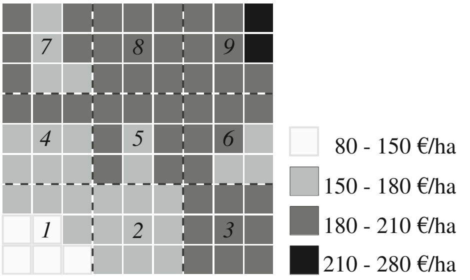

FIGURE 1 Landscape structure and average cost parameters (per plot across the 61 simulated landscapes). The dashed lines are the borders of the landowners' properties

Figure 1 presents the landscape structure and the average opportunity costs over the 61 simulated landscapes. The online supplementary appendix presents similar maps for the subsets of Moran's I statistics comprised between (i) 0.5 and 0.6, (ii) 0.6 and 0.7, and (iii) 0.7 and 0.8. Note that, in addition to differing in opportunity costs, the landowners also differ in terms of location: the landowners at the borders have plots with only two or three neighboring plots (instead of four), limiting their ability to apply to the AB schemes.

In a first set of simulations (hereafter called "benchmark"), we consider the case in which the cooperation does not entail any coordination cost ($C = 0$) and set the dispersal rate at $D = 2$. We analyze the cooperation and conservation outcomes from the AB with bonuses q ranging from €0/border to €100/border, in addition to a flat-rate per-hectare payment of €80/ha. We compare these outcomes with (i) those arising from the GC for identical AB schemes (corresponding to the solution that maximizes Equation (1) with $\mathbf{S}_m = \mathbf{I}$), and (ii) the outcomes for spatially homogeneous payments ranging from €80/ha to €300/ha (corresponding to the solution that maximizes Equation (1) with $q = 0$). We pay particular attention to the relative cost effectiveness of these schemes. We also analyze how the cost effectiveness depends on the spatial autocorrelation of the 61 landscapes.

In a second set of simulations, we examine whether the levels of the flat-rate per-hectare payment p affects the cooperation and conservation outcomes. Indeed, although our first set of simulations focuses on the role of bonuses q, the flat-rate payment p is expected to affect the outcomes as well. For example, increasing p homogeneously covers the opportunity costs for all the landowners such that the bonus should lead to higher conservation. The impact on the cost effectiveness of AB schemes remains, however, an open question, as increasing p also implies higher expenditures from the regulator's side. We thus repeat the benchmark analysis with $p \in \{0; 80; 160\}$.

In a third set of simulations, we examine whether the dispersal rate D affects the cost effectiveness of AB schemes, in particular regarding spatially homogeneous payments. Indeed, even if landowner payments do not depend on the dispersal rate, biodiversity levels do. In particular, the additional biodiversity level of an additional conserved plot increases with D, that is, when the target species can easily disperse over long distances. As AB schemes and homogeneous payments are likely to lead to the conservation of different plots for similar levels of public expenditures, the relative cost effectiveness of the instruments can be affected. We thus repeat the benchmark analysis with $D \in \{1; 2; 5\}$.

In a fourth set of simulations, we consider the case where coalition formation is costly. We repeat the benchmark analysis by setting C equal to 0, 50 or 100, representing on average between 5% and 50% of the individual profits in the absence of the AB scheme (depending on the levels of C and the coalition size). We analyze to what extent coordination costs influence the cost effectiveness of AB schemes, as has been suggested in the literature.

4 | RESULTS

4.1 | Benchmark: Coalition formation

Figure 2 and Table A1 (see the online supplementary appendix) present the configuration and number of the average stable coalition structures over the 61 simulated landscapes according to the bonus levels (when $C = 0$ and $D = 2$). We find that increasing the bonuses affects the configuration of the stable coalition structures, by enlarging average coalition size (Figure 2(a)) and hence decreasing the number of coalitions (Figure 2(b)). Over the whole range of bonuses, cooperation remains rather limited, as the average coalitions are composed of singletons or two or three landowners (Figure 2 (a)). As expected, the average coalition size in a stable coalition structure increases with the bonuses but remains lower than two. In particular, the average coalition size in a stable coalition structure stabilizes at about 1.7 for bonuses higher than €70/border. Indeed, most plots are already conserved at this bonus level, so that any further increase only marginally modifies the coalitions' conservation efforts and thus the stability conditions. Similarly, the average largest coalitions within the stable coalition structures increase from 1.00 landowner ($q =$ €0/border) to 2.00 landowners ($q =$ €100/border), with a maximum of 2.14 at €50/border (the standard deviation in Table A1 indicates some heterogeneity among the simulated landscapes). On the contrary, the average minimum coalition size within the stable coalition structures remains equal to 1.00 (except for bonuses between €50 and €70/border): there is always at least one landowner that prefers to apply individually to the scheme (or alternatively, that is refused by other coalitions). Our results overall suggest that, for bonuses higher than €70/border, the stable coalition structures are mostly composed of one singleton and four two-landowner coalitions. Finally, we find that there is a positive relationship between the bonuses and the number of stable coalition structures per simulated landscape (Figure 2(c)), which increases from a single stable coalition structure at €0/border (the one composed of singletons only) to 22 at €100/border (i.e., less than 0.11% of the 21,147 potential coalition structures are stable).

Figure 3 presents the most frequent stable coalition structures over the 61 landscapes for bonuses of €20/border, €40/border, €60/border, and €80/border. As in Figures 2 and 3 show that the landowners cooperate more and more as the bonuses increase. For €20/border, the most frequent stable coalition structure is a no-cooperation configuration, with landowners only behaving as singletons. Increasing the bonus has two effects: encouraging landowners to cooperate with neighbors and enlarging the habitat area. For €40/border, there are three landowners acting like singletons

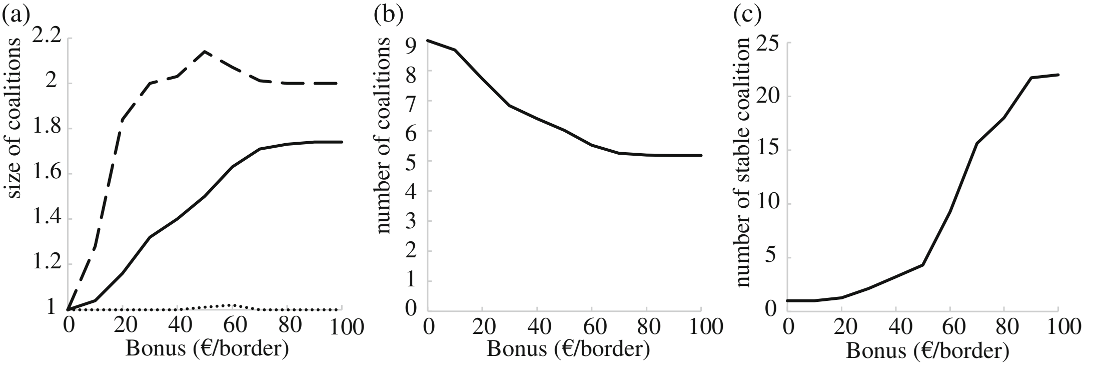

FIGURE 2 Cooperation outcomes according to bonus levels: (a) average (solid line), minimum (dotted line) and maximum (dashed line) number of landowners within an average coalition being part of a stable coalition structure, (b) average number of coalitions per stable coalition structure, (c) average number of stable coalition structures per landscape. The simulations were performed using $p =$ €80/ha, $D = 2$ and $C = 0$. The outcomes are computed as averages over all the stable coalition structures of the 61 simulated landscapes

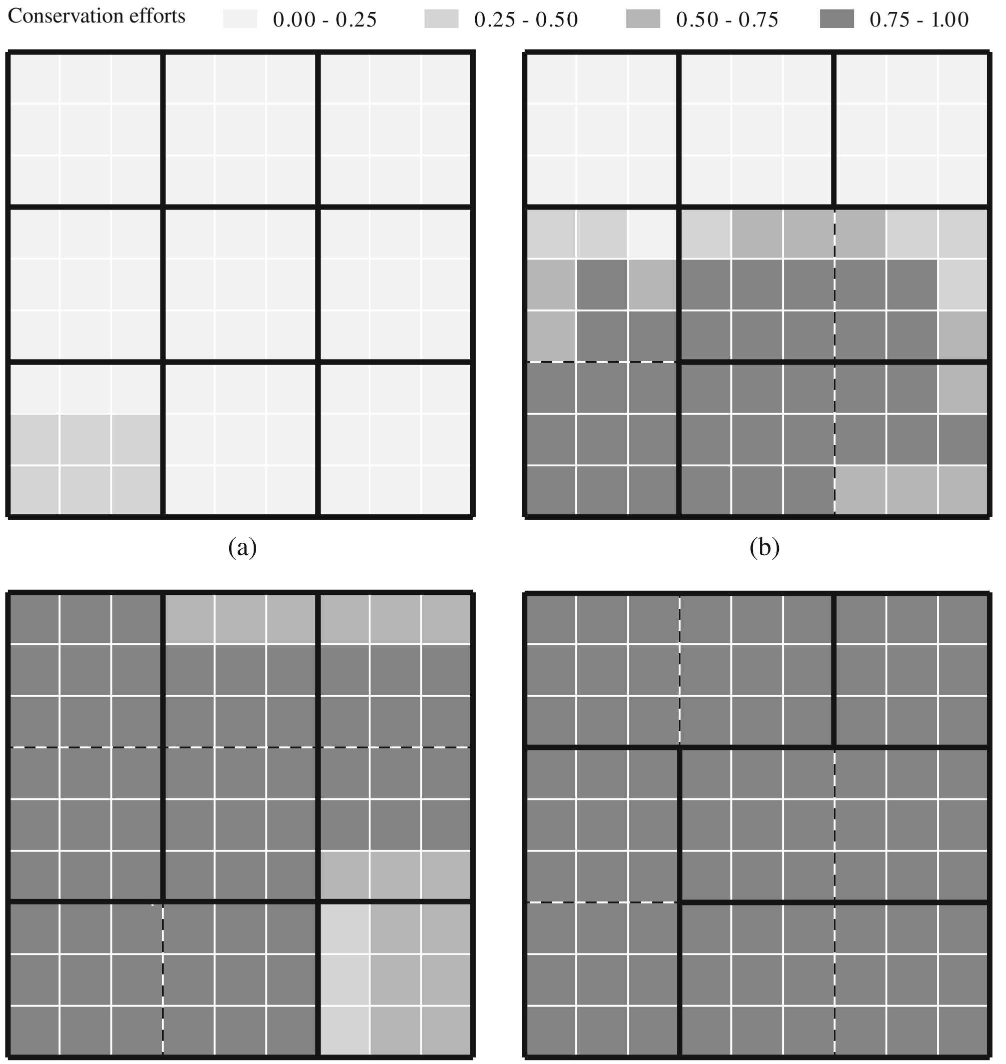

FIGURE 3 Average conservation efforts and most frequent stable coalition structures among the 61 simulated landscapes for (a) $q = €20$/border, (b) $q = €40$/border, (c) $q = €60$/border, and (d) $q = €80$/border. The borders of the coalitions within the most frequent stable coalition structures are indicated by full black lines; borders of landowners' property are indicated by dashed lines. The average plot cover over the whole set of stable coalition structures is shown using a gray scale. The simulations were performed using $p = €80$/ha, $C = 0$ and $D = 2$

(the three northern landowners with the highest opportunity costs) and three 2-landowner coalitions. The effect of increasing bonuses on cooperation is thus mainly related to the increase in the number of nontrivial coalitions rather than to their size (that remains limited to a maximum of $|\mathbf{S}_m| = 2$). Moving from €40/border to €60/border entails the creation of an additional nontrivial coalition in the most frequent stable coalition structure (landowners n°7, 8, and 9 start cooperating with their southern neighbors). Further increases in the bonus only affect conservation and not the coalition structure, which is characterized by one singleton and four 2-landowner coalitions (though the configuration of the most frequent stable coalition structure changes at €80/border).

Table 1 presents the frequency with which the different landowners apply collectively to the AB schemes over all the stable coalition structures of the 61 landscapes. It confirms that landowners respond collectively to the AB schemes only when the bonuses are high enough. Overall, location is an important driver of cooperation: as one would expect, the corner landowners (n°1, 3, 7 and 9) are the least frequent members, ceteris paribus. Landowners n°2, 4, 6, and 8 are the most frequent coalition members. These landowners—who share a relatively similar place in the landscapes—are the direct neighbors of both the corner and the central landowners. Due to the structure of the scheme, the only way for the corner and central landowners to cooperate is if the "pivotal" landowners n°2, 4, 6, or 8 agree to be part of the coalition. These pivotal landowners are thus more likely to be members of a coalition.

The opportunity costs are another important driver of cooperation: those landowners that have the lowest opportunity costs are the most frequent coalition members (Table 1). For example, landowner n°8 is the pivotal landowner with the highest average opportunity costs (Figure 1) and is also the one who cooperates the least among them (Table 1 and Figure 3). The differences in terms of cooperation choices between landowners tend to smooth as the bonuses increase. In particular, landowners' cooperation choices become completely symmetrical when $q = 100$€/border (where all the plots are conserved), suggesting that opportunity costs no longer explain the cooperation outcomes for very high bonuses.

4.2 | Benchmark: Conservation outcomes and AB cost effectiveness

Figure 4 displays the conservation outcomes in terms of conserved habitats and biodiversity levels depending on the bonus. As expected, an increase in the bonus increases the area of land devoted to habitats, as higher payments are able to cover more and more costly plots. The change in habitat area is a concave function of the bonus levels and is typically explained by the spatial distribution of the opportunity costs (Figure 4(a)). By comparison, the biodiversity levels follow a more S-shaped curve (see Figure 4(b)). Biodiversity levels increase marginally more than habitat area with the bonuses, confirming that the AB scheme agglomerates conservation efforts over space, even if landowners only partially cooperate.

To analyze the scheme's cost effectiveness, Figure 5 depicts biodiversity levels as a function of public expenditures for three different cases: (i) the endogenous coalition formation response to AB schemes, (ii) the GC response in identical AB schemes, and (iii) the landowners' response to spatially

TABLE 1 Individual frequency of collective enrollment in the AB scheme per bonus level

	€0	€10	€20	€30	€40	€50	€60	€70	€80	€90	€100	Average
Landowner 1	0	9	35	78	129	242	415	658	849	964	976	**396**
Landowner 2	0	7	27	82	137	285	498	861	1110	1263	1281	**505**
Landowner 3	0	2	8	47	90	187	323	612	820	960	976	**366**
Landowner 4	0	6	36	85	145	280	505	844	1091	1263	1281	**503**
Landowner 5	0	4	26	82	146	287	507	826	1061	1203	1220	**487**
Landowner 6	0	3	15	64	114	253	476	862	1098	1264	1281	**494**
Landowner 7	0	2	18	50	86	203	364	653	834	964	976	**377**
Landowner 8	0	3	20	59	110	237	464	829	1100	1264	1281	**488**
Landowner 9	0	1	12	33	59	148	341	649	835	963	976	**365**
Average	**0**	**4**	**22**	**64**	**113**	**236**	**433**	**755**	**978**	**1123**	**1139**	

Note: The simulations were performed using $p =$ €80/ha, $D = 2$ and $C = 0$. The table shows the frequency of collective enrollment in the AB scheme for each landowner over all of the stable coalition structures of the 61 simulated landscapes according to the bonus level (in €/border).

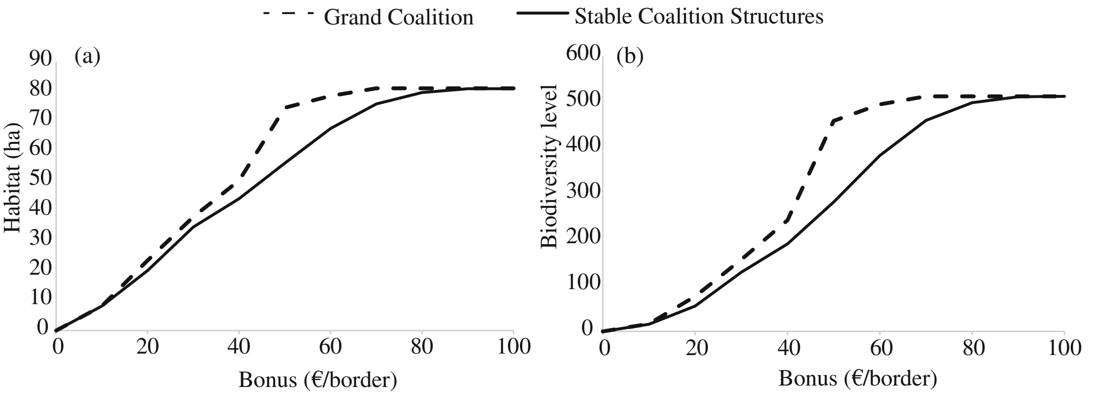

FIGURE 4 (a) Habitat area and (b) biodiversity levels as a function of bonuses in the GC and stable coalition structures. The simulations were performed using $p = €80/\text{ha}$, $C = 0$ and $D = 2$. The outcomes are computed as averages over all the stable coalition structures of the 61 simulated landscapes

homogenous payments. The figure shows that the relative cost effectiveness of an AB scheme with respect to homogenous payments, when considering a coalition formation response, depends on the level of public expenditures (Figure 5(a)). For very low levels of expenditures, the two schemes yield similar results, as payments do not provide enough incentives to convert plots to habitats (nor to connect them). As public expenditures increase, the AB scheme becomes more cost effective than homogenous payments, up to around €17,000. After this threshold, the homogenous payments become more cost effective, until the two schemes once again yield similar results. Indeed, for high levels of expenditures, homogenous payments provide enough incentives for landowners to conserve many plots, to the extent that connections emerge among conserved plots even if the scheme is not explicitly designed to achieve this. For very high levels of expenditures, the whole landscape is converted and there are no differences between the two schemes.[16] Considering the whole range of public expenditures (and in this particular setting), spatially homogenous payments are 1% more cost effective than AB schemes on average over all the stable coalition structures in the 61 landscapes.[17]

These results can be further deepened by disaggregating the cost effectiveness of the scheme according to the spatial autocorrelation of the opportunity costs. Figures 5(b),(d) show that increasing spatial cost autocorrelation has two effects. First, the expenditure range for which the AB is more cost effective than spatially homogenous payments is reduced for high spatial cost autocorrelation. Indeed, the threshold above which homogenous payments become more cost effective than AB decreases with the spatial cost autocorrelation. Second, the biodiversity gains from implementing an AB, in the range in which it is more cost effective, are reduced with higher spatial cost autocorrelation. In other words, the cost effectiveness of AB schemes in comparison to homogeneous payments reduces when landscapes are more spatially clustered. In total, the AB schemes are more cost effective by 0.5% than the homogeneous payments over the whole range of expenditures for low levels of spatial cost autocorrelation (Figure 5(b)). However, for high levels of autocorrelation (Moran's I between 0.7 and 0.8), homogeneous payments are about 2% more cost effective than AB schemes

[16]Figure A2 in the online supplementary Appendix displays the aggregated conserved area in the AB schemes and spatially homogeneous payments depending on public expenditures. It shows that homogeneous payments always provide more conserved habitats for similar expenditures. Together with the results from Figure 5(a), we find that AB schemes lead to smaller conserved areas but with higher spatial contiguity compared to spatially homogeneous payments.

[17]This criterion of cost effectiveness over the whole expenditure range must be interpreted with caution. As highlighted, AB schemes are more cost effective than spatially homogeneous payments over a range of low payments. Hereafter, this criterion is used to help us compare changes in the cost effectiveness of the two schemes when the settings change.

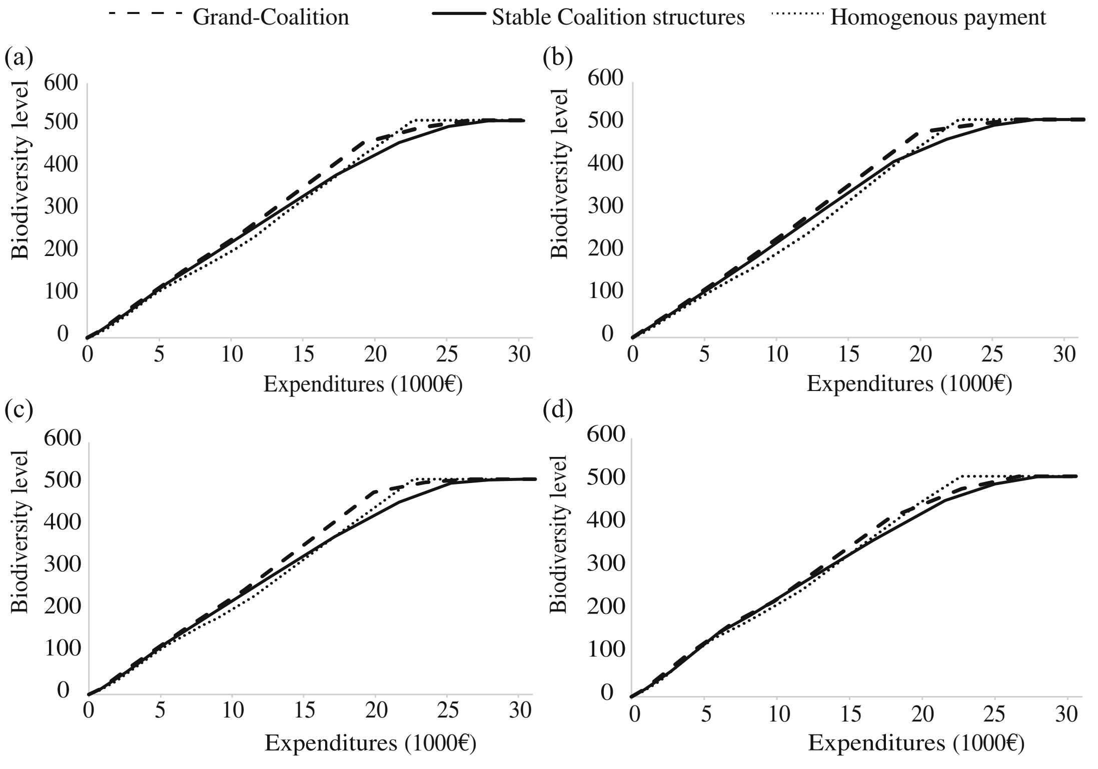

FIGURE 5 Biodiversity levels as a function of aggregated expenditures (in €) under spatially homogeneous payments (dotted line), AB with the GC (dashed line) and AB with endogenous coalition formation (solid line) in (a) the average over all landscapes, (b) the landscapes with Moran's I between 0.5 and 0.6 (b) the landscapes with Moran's I between 0.6 and 0.7 and (d) the landscapes with Moran's I between 0.7 and 0.8. The simulations were performed using $p =$ €80/ha, $C = 0$ and $D = 2$. The outcomes are computed as averages over all of the stable coalition structures of the 61 simulated landscapes

(Figure 5(d)). These figures, though dependent on our specific simulation choices, show that AB schemes are more cost effective when the landscapes have low spatial cost autocorrelation.

Figure 5 also shows the cost effectiveness of AB schemes when it is assumed that landowners cooperate within the GC. Assuming full cooperation among the landowners would lead to an overestimation of the cost effectiveness of the AB scheme. Indeed, in the GC case, the AB scheme always seems to be more cost effective than the spatially homogenous payment (except in a small range of very high expenditures when the spatial autocorrelation is high). This is a common result in the AB literature, but we previously showed that the GC is not stable. In our illustrative example, assuming stability of the GC leads to an overestimation of AB scheme cost effectiveness of about 6%, on average (Figure 5(a)). However, this bias is reduced as spatial autocorrelation increases (Figures 5(b)–(d)). To further deepen the implications of assuming a GC response to AB schemes, recall that Figure 4(b) depicts the biodiversity levels per bonus rate for the GC and for stable coalition structures. It clearly shows that the GC response overestimates the conservation outcomes for the different bonus rates. For example, for a bonus of €50/border, the biodiversity levels are on average 60% higher with the GC compared to those with the stable coalition structures. In other words, the required bonus to reach any given level of biodiversity is much higher with endogenously formed coalitions than in the exogenously assumed GC.

To sum up, our results show that to assume the stability of the GC as a response to an AB scheme leads to a bias in the assessment of AB scheme cost effectiveness. Contrary to the literature, we find that AB schemes do not necessarily lead to higher cost effectiveness than spatially homogenous payments, but this greatly depends on both public expenditures and landscape characteristics.

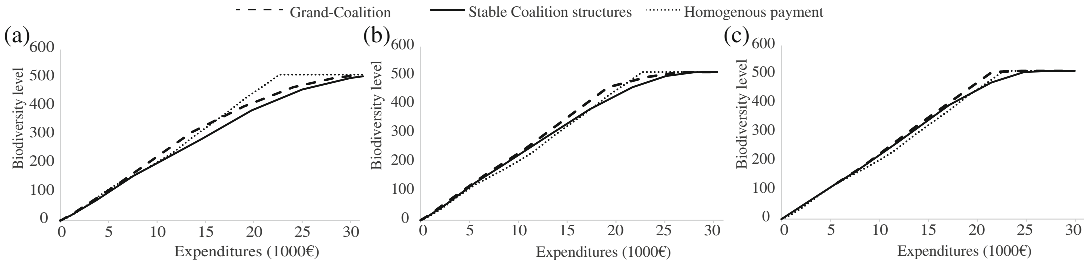

FIGURE 6 Biodiversity levels as a function of the aggregated expenditures (in €) under spatially homogeneous payments (dotted line), AB with the GC (dashed line) and AB with endogenous coalition formation (solid line) for (a) $p = €0/ha$, (b) $p = €80/ha$ and (c) $p = €160/ha$. Figure 6(b) is equivalent to Figure 5(a). The simulations were performed using $C = 0$ and $D = 2$. The outcomes are computed as averages over all of the stable coalition structures of the 61 simulated landscapes

4.3 | Role of flat-rate payments

We previously investigated the role of the bonuses on the cooperation and conservation outcomes. However, AB schemes are defined by both the bonus q and the flat-rate payment p. Figure 6 shows how the level of the flat-rate payments affects AB cost effectiveness. It clearly shows that increasing p increases the cost effectiveness of AB schemes (when coalition formation is accounted for). In particular, for $p = €0/ha$ (Figure 6(a)), the AB scheme with endogenous coalition formation is less cost effective than spatially homogenous payments over the whole range of expenditures. On average over the whole expenditure range, homogenous payments are 12% more cost effective than AB schemes when the latter are coupled with null flat-rate payments. Doubling p from €80/ha to €160/ha does not considerably increase the cost effectiveness of AB, but the threshold above which the homogenous payment becomes more cost effective than the AB scheme is higher. This slight change results in the AB schemes being more cost effective than homogenous payments by about 1% on average over the whole expenditure range.

Our results are thus different from those of Wätzold and Drechsler (2014) who find that AB schemes are more cost effective when the flat-rate payments are removed. This difference is probably due to the specific characteristics of the instrument that they analyze, which stands out from the remaining of the literature by rewarding the density of the conservation plots instead of their adjacency. Nonetheless, the difference is not due to accounting for endogenous coalition formation, because Figure 6 highlights the fact that we depart from Wätzold and Drechsler (2014) even when considering the GC response (which is never stable irrespective of the level of p in our simulations). In addition, it is worth noting that Figure 6 suggests that increasing p from €80/ha to €160/ha reduces the overestimation of the cost effectiveness of AB schemes by half. On the contrary, cutting p to zero leads to overestimation by about 10%.

4.4 | Role of dispersal rate

Figure 7 shows biodiversity levels as a function of public expenditures for $D = \{1; 2; 5\}$. It underlines the fact that the relative cost effectiveness of AB schemes (both in stable coalition structures and with the GC) with respect to spatially homogeneous payments decreases when the dispersal rate increases. Indeed, although the AB scheme is more cost effective than homogenous payments up to around €18,000 for $D = 1$ (i.e., when species have difficulty dispersing over space), the threshold decreases to €17,000 for $D = 2$ (i.e., the benchmark) and to €15,500 for $D = 5$ (i.e., when species can easily disperse). AB schemes are on average more cost effective by 0.5% compared to spatially homogeneous payments over the whole range of public expenditures for $D = 1$ (even if homogeneous payments

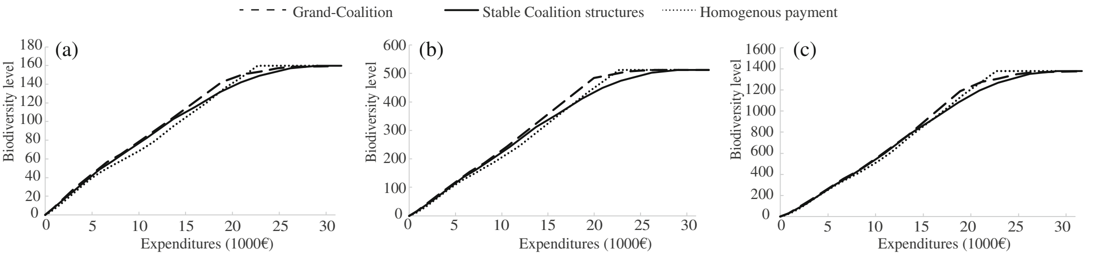

FIGURE 7 Biodiversity levels as a function of aggregated expenditures (in €) under spatially homogeneous payments (dotted line), AB with the GC (dashed line) and AB with endogenous coalition formation (solid line) for (a) $D = 1$, (b) $D = 2$ and (c) $D = 5$. Figure 7(b) is equivalent to Figure 5(a). The simulations were performed using $p =$ €80/ha and $C = 0$. The outcomes are computed as averages over all the stable coalition structures of the 61 simulated landscapes

are still more cost-effective when public expenditures are high). Spatially homogeneous payments become on average relatively more cost effective by 1% (resp. 2%) when $D = 2$ (resp. $D = 5$) over the whole range of public expenditures. Finally, note that the overestimation of the cost effectiveness of AB schemes by assuming the stability of the GC remains stable around 6%, irrespective of the dispersal rate considered.

4.5 | Role of coordination costs

Figure 8 displays the cost-effectiveness of AB schemes and the average AB outcomes in terms of coalition size, biodiversity levels, and conserved habitats depending on the bonus levels for different levels of coordination costs ($C = \{0; 50; 100\}$).

As expected, the average size of the coalitions within the stable coalition structures decreases as the coordination costs increase (Figure 8(a)). The average coalition size is more and more S-shaped as the coordination costs increase. In particular, for high coordination costs, there is almost no cooperation until the bonus reaches the threshold of €70/border: Low payments do not cover the coordination costs incurred in cooperation, and the landowners prefer to apply individually to the scheme. Above this threshold, however, the stable coalition structures are on average composed of one singleton and four 2-landowner coalitions, in a similar way as those without coordination costs (see benchmark). In this case, the biodiversity levels are also similar to those in the benchmark (Figure 8(b)). This suggests that landowners facing coordination costs start formulating similar conservation projects (both in terms of plot and group enrollment) as in the case without coordination costs because bonuses are high enough.

Remarkably, the cost effectiveness of AB schemes is almost identical for the different levels of coordination costs (the threshold for which the AB scheme becomes less cost effective than the spatially homogenous payments remains around €17,000). This result is explained by two mechanisms. First, when the bonuses are high (typically €70/border here), we already highlighted that landowners submit similar conservation projects regardless of coordination cost levels. In this case, the cost effectiveness of AB schemes is obviously unaffected. Second, when bonuses are low (from €0/border to 60€/border), we find that coordination costs (i) reduce land enrollment (Figure 8(c)) and the resulting biodiversity levels (Figure 8(b)) but (ii) also reduce payments to landowners such that (iii) the two combined effects cancel each other out.

Although not affecting the scheme's cost effectiveness, coordination costs affect the scheme's outcomes. Indeed, the coordination costs affect the conservation outcomes of AB schemes when the public expenditures are low (Figures 8(b),(c)). For example, to reach a biodiversity level of 300 requires bonuses at €50/border when $C = 0$ but bonuses at 60€/border when $C = 100$. Thus,

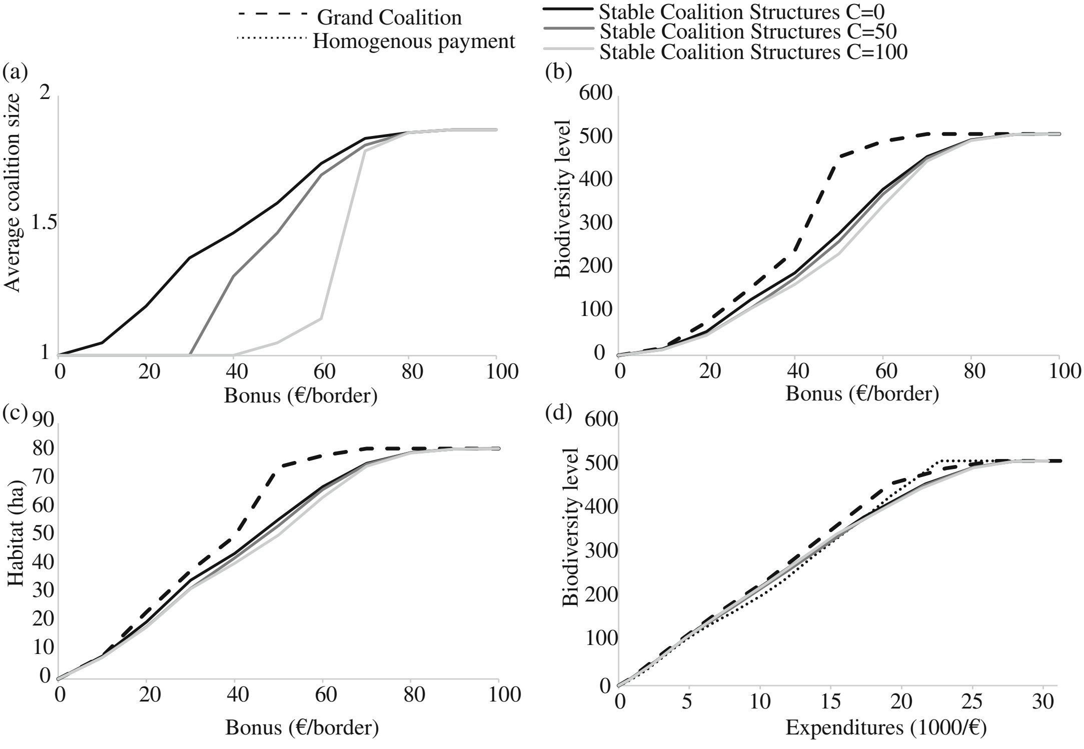

FIGURE 8 Averages for (a) coalition size (b), biodiversity levels, (c) conserved habitats (in hectares) as a function of bonuses (in €/border), and (d) biodiversity levels as a function of aggregated expenditures (in €) under spatially homogeneous payments (dotted lines), AB with the GC (dashed lines) and AB with endogenous coalition formation (solid lines) when the coordination costs depend on the coalition size with $C = 0$, $C = 50$ and $C = 100$. Note that the cost-effectiveness of the homogenous payments and the AB in the GC is not affected by the levels of coordination costs as these only depend on coalition size. The simulations were performed using $p =$ €80/ha and $D = 2$. The outcomes are computed as averages over all of the stable coalition structures of the 61 simulated landscapes

coordination costs do indeed matter in the design of AB schemes. In particular, coordination costs require higher bonuses to reach any given biodiversity target.

Finally, these additional simulations confirm that the GC is never stable for any level of coordination costs. As in the benchmark, we find that assuming the stability of the GC leads to an overestimation of the cost effectiveness of AB schemes by 6% to 7% (Figure 8(d)).

5 | DISCUSSION AND CONCLUDING REMARKS

The literature suggests that AB schemes represent a promising strategy for biodiversity conservation as they explicitly incentivize the connectivity of habitats (Parkhurst & Shogren, 2007). Most of the spatially explicit ecological-economic literature has investigated the cost effectiveness of AB schemes assuming that all the landowners cooperate with each other within the GC (Bamière et al., 2013; Drechsler, 2017a, 2017b; Drechsler et al., 2016; Wätzold & Drechsler, 2014). This assumption, however, ignores the rationality of the landowners' individual decisions to cooperate.

In this paper, we theoretically assess the cost effectiveness of AB schemes in the case where landowners decide on both land use patterns and with whom to cooperate in response to the schemes. In other words, we relax the assumption that landowners respond to AB schemes in the GC and endogenize the landowners' cooperation decisions. Formally, we introduce a spatially explicit ecological-economic model within a coalition formation game that is used to determine which coalition structures are stable. Using numerical examples, we assess the configuration of the stable coalition structures and the associated conservation outcomes in response to the AB schemes, under different conditions in terms of landscape structure, ecological features, payment designs, and coordination costs.

Our results suggest that AB schemes do favor the connectivity of the conservation efforts over space. In particular, for the same amount of public expenditures, we find that AB schemes yield smaller but more clustered conserved areas than spatially homogeneous payments. These results confirm the previous main findings of the literature on AB schemes that assumes full cooperation among landowners (e.g., Drechsler et al., 2010, 2016). However, although previous studies suggest that AB schemes are more cost effective than homogeneous payments irrespectively of the public expenditure levels, our analysis accounting for endogenous coalition formation indicates that this is the case *only* below a certain threshold of public expenditures. Our analysis suggests that this difference is due to coalition formation (and not to any other difference in our settings). Indeed, if we assume a GC response to the scheme, we also find that AB schemes appear to be the most cost-effective solution across the whole range of public expenditures, in line with the literature that shares the same assumption (e.g., Wätzold & Drechsler, 2014). However, our coalition formation game shows that the GC is never a stable coalition structure in response to any AB schemes. We find that landowners do cooperate more and more as the bonuses increase but that they prefer to apply within coalitions of two or three landowners. This has consequences for the assessment of the cost effectiveness of AB schemes as partial cooperation leads to lower area of conserved habitats than full cooperation. Overall, we find that assuming the stability of the GC (instead of explicitly accounting for endogenous coalition formation) leads to an overestimation of the cost effectiveness of AB schemes by 5% to 10%. Such an overestimation explains why the previous literature has not identified the threshold of public expenditures above which spatially homogeneous payments become more cost effective than AB schemes. Disregarding rationality in the choice of who to cooperate with may thus explain why AB schemes have not provided any substantial advantage for biodiversity conservation compared to spatially homogeneous payments in real world conditions (Gatto et al., 2019).

As already highlighted by the literature (e.g., Wätzold & Drechsler, 2014), the cost effectiveness of AB schemes and spatially homogeneous payments is affected by several exogenous factors. We confirm here that the cost effectiveness of AB schemes increases with a reduction in the species dispersal rate and in the spatial cost autocorrelation, even with partial cooperation. However, in previous papers, these elements have only reduced the advantage of AB schemes over spatially homogenous payments, without reversing the ranking of the two instruments. Our results with endogenous coalition formation instead suggest that reducing dispersal rates and spatial cost autocorrelation increases the threshold above which homogeneous payments become more cost effective, ultimately affecting the scope of AB scheme applicability. In particular, when the area of application is spatially clustered in terms of opportunity costs, AB schemes become less attractive as (even small) spatially homogeneous payments could already incentivize neighboring landowners to conserve their plots.

Finally, we contribute to the literature by examining the impacts of coordination costs on the outcomes of AB schemes. Coordination costs are regularly mentioned as being a crucial driver of cooperation failure in AB schemes (Albers et al., 2008; Banerjee et al., 2017), but, to our knowledge, no paper has ever formally examined their impact on the coalition formation process and on the resulting cost effectiveness of the scheme. Contrary to expectations, we find that coordination costs actually have limited impacts on the cost effectiveness of AB schemes. Indeed, coordination costs that depend on the number of people cooperating act like fixed costs: when the bonuses are low, they discourage landowners from cooperating in AB schemes. In this case, coordination costs reduce both land enrollment (and resulting biodiversity levels) and payments to landowners, the two combined effects canceling each other out. When the bonuses are high enough to overcome these coordination costs, landowners are incentivized to collectively participate in AB schemes and, more importantly, to formulate similar conservation projects—in terms of plot and group enrollment—as in the case without coordination costs. These two effects explain why the cost effectiveness of AB schemes is independent of coordination costs. The main effect of the coordination costs rather relates to the design of AB schemes: higher coordination costs require higher bonuses to reach a given biodiversity target.

Our theoretical analysis can inform policymakers on the design of AB schemes and their real-world applications, even though our recommendations are valid within the conditions described by the simplistic assumptions that drive our simulations (profit-maximizing landowners, stylized grid landscapes, no side payments, etc.). First of all, given the rather limited existing conservation budgets, our analysis suggests that AB schemes are likely to be more cost effective than traditional spatially homogenous payments at conserving biodiversity in most situations and should thus be implemented more frequently. This is particularly true when the target species have difficulty dispersing over space (such as butterflies, amphibians or reptiles) or when the landscapes are heterogeneous and non-clustered (similar to those described in Huber et al., 2021). Second, in terms of scheme design, our simulations indicate that the regulator should couple the bonuses with sufficiently high flat-rate per-hectare payments. Indeed, in this case, even small bonuses allow the relative cost effectiveness of AB scheme to be increased with respect to spatially homogenous payments. In comparison, setting up AB schemes that rely only on bonuses (with small or null flat-rate payments) decreases their cost effectiveness. Third, given the time-consuming nature of cooperation among landowners, it has often been recommended that landowner cooperation be facilitated either by subsidizing them in the initial phases of the collaboration process (Banerjee et al., 2017) or by involving third parties such as environmental consultants (Krämer & Wätzold, 2018; Villamayor-Tomas et al., 2019; Westerink et al., 2017). However, our results suggest that if coordination costs do impact landowners' cooperation decisions, setting higher bonuses could already be enough to restore the cost effectiveness of the scheme.

The use of coalition formation games yields results in terms of cooperative outcomes (i.e., partition of landowners with small coalitions) that closely resemble how landowners actually respond to AB schemes. However, drawing more meaningful policy implications with regard to existing AB schemes would require even further realism in the model and notably the relaxation of some assumptions that we set for simplicity. First, we have considered that coalition members do not engage in side payments. Side payments are likely to enlarge the coalitions, especially in case of high heterogeneity of opportunity costs. As our results indicate that greater cooperation increases the cost effectiveness of AB schemes (as illustrated by the fact that the GC is the most cost-effective situation), research into the role of side payments in AB schemes should be prioritized in a setting of coalition formation. Second, we have examined the case in which the coalition formation game is characterized by exclusive membership and unanimity. Even though this setting is probably the most realistic one for the problem at hand, several alternative rules exist and could affect our conclusions (Carraro & Marchiori, 2002). Third, we specify AB schemes as input-orientated schemes where landowners are rewarded for the declared land allocation within each conservation project. This is probably the setting that is the most consistent with reality (Huber et al., 2021). However, a wide range of alternative specifications can be assessed (Kotchen & Segerson, 2020), such as results-based payments (White & Hanley, 2016), where landowners are rewarded according to the actual bidioversity level they generate. Finally, the assessment of bridging institutions that hire public consultants to help landowner coordination could be explicitly introduced into the model to evaluate whether it would diminish (additional transaction costs) or foster (additional conservation efforts) the cost effectiveness of AB schemes (Krämer & Wätzold, 2018; Westerink et al., 2017). Future research should more deeply investigate such design elements to help policymakers improve existing AB schemes. We believe that the coalition formation game that we proposed in this paper could help such research.

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REFERENCES

Alvarado-Quesada, Irene., and Weikard, Hans-Peter. 2017. International cooperation on biodiversity conservation when spatial structures matter. *Spatial Economic Analysis* 12: 27–49.

Albers, Heidi J., Amy W. Ando, and Michael Batz. 2008. "Patterns of Multi-Agent Land Conservation: Crowding in/out, Agglomeration, and Policy." *Resource and Energy Economics* 30: 492–508.

Ansink, Erik, and Jetske Bouma. 2013. "Effective Support for Community Resource Management." *Forest Policy and Economics* 37: 94–103.

Arora, Gaurav, Hongli Feng, David A. Hennessy, Charles R. Loesch, and Susan Kvas. 2021. "The Impact of Production Network Economies on Spatially-Contiguous Conservation–Theoretical Model with Evidence from the US Prairie Pothole Region." *Journal of Environmental Economics and Management* 107: 102442.

Bamière, Laure, Maia David, and Bruno Vermont. 2013. "Agri-Environmental Policies for Biodiversity when the Spatial Pattern of the Reserve Matters." *Ecological Economics* 85: 97–104.

Banerjee, Simanti, Timothy N. Cason, Frans P. de Vries, and Nick Hanley. 2017. "Transaction Costs, Communication and Spatial Coordination in Payment for Ecosystem Services Schemes." *Journal of Environmental Economics and Management* 83: 68–89.

Banerjee, Simanti, Timothy N. Cason, Frans P. de Vries, and Nick Hanley. 2021. "Spatial Coordination and Joint Bidding in Conservation Auctions." *Journal of the Association of Environmental and Resource Economists* 8: 1013–49.

Bareille, Francois, Matteo Zavalloni, Meri Raggi, and Davide Viaggi. 2021. "Cooperative Management of Ecosystem Services: Coalition Formation, Landscape Structure and Policies." *Environmental and Resource Economics* 79: 323–56.

Barrett, Scott 1994. "Self-Enforcing International Environmental Agreements." *Oxford Economic Papers, New Series* 46: 878–94.

Bell, Andrew, Gregory Parkhurst, Klaus Droppelmann, and Tim G. Benton. 2016. "Scaling up pro-Environmental Agricultural Practice Using Agglomeration Payments: Proof of Concept from an Agent-Based Model." *Ecological Economics* 126: 32–41.

Bloch, Francis 1995. "Endogenous Structures of Association in Oligopolies." *Rand Journal of Economics* 26: 537–56.

Brau, Rinaldo, and Carlo Carraro. 2011. "The Design of Voluntary Agreements in Oligopolistic Markets." *Journal of Regulatory Economics* 39: 111–42.

Carraro, Carlo, and Carmen Marchiori. 2002. *Stable Coalitions*. SSRN Scholarly Paper No. ID 299624. Rochester, NY: Social Science Research Network.

d'Aspremont, Claude, Alexis Jacquemin, Jean J. Gabszewicz, and John A. Weymark. 1983. "On the Stability of Collusive Price Leadership." *Canadian Journal of Economics* 16: 17–25.

Drechsler, Martin 2017a. "Generating Spatially Optimized Habitat in a Trade-Off between Social Optimality and Budget Efficiency." *Conservation Biology* 31: 221–5.

Drechsler, Martin 2017b. "The Impact of Fairness on Side Payments and Cost-Effectiveness in Agglomeration Payments for Biodiversity Conservation." *Ecological Economics* 141: 127–35.

Drechsler, Martin, Henrik. G. Smith, Astrid Sturm, and Frank Wätzold. 2016. "Cost-Effectiveness of Conservation Payment Schemes for Species with Different Range Sizes." *Conservation Biology* 30: 894–9.

Drechsler, Martin, Frank Wätzold, Karin Johst, and Jason F. Shogren. 2010. "An Agglomeration Payment for Cost-Effective Biodiversity Conservation in Spatially Structured Landscapes." *Resource and Energy Economics* 32: 261–75.

Eisner, Thomas, Jane Lubchenco, Edward O. Wilson, David S. Wilcove, and Michael J. Bean. 1995. "Building a Scientifically Sound Policy for Protecting Endangered Species." *Science* 269: 1231–2.

Fahrig, Lenore 2017. "Ecological Responses to Habitat Fragmentation Per Se." *Annual Review of Ecology, Evolution, and Systematics* 48: 1–23.

Fooks, Jacob R., Nathaniel Higgins, Kent D. Messer, Joshua M. Duke, Daniel Hellerstein, and Lori Lynch. 2016. "Conserving Spatially Explicit Benefits in Ecosystem Service Markets: Experimental Tests of Network Bonuses and Spatial Targeting." *American Journal of Agricultural Economics* 98: 468–88.

Franks, Jeremy 2010. "Boundary Organizations for Sustainable Land Management: The Example of Dutch Environmental Co-Operatives." *Ecological Economics* 70: 283–95.

Gatto, Paola, Daniele Mozzato, and Edi Defrancesco. 2019. "Analysing the Role of Factors Affecting farmers' Decisions to Continue with Agri-Environmental Schemes from a Temporal Perspective." *Environmental Science & Policy* 92: 237–44.

Grabisch, Michel, and Yukihiko Funaki. 2012. "A Coalition Formation Value for Games in Partition Function Form." *European Journal of Operational Research* 221: 175–85.

Hart, Sergiu, and Mordecai Kurz. 1983. "Endogenous Formation of Coalitions." *Econometrica: Journal of the Econometric Society* 51: 1047–64.

Huber, Robert, Astrid Zabel, Mirjam Schleiffer, Willemijn Vroege, Julia Brändle, and Robert Finger. 2021. "Conservation Costs Drive Enrolment in Agglomeration Bonus Scheme." *Ecological Economics* 186: 107064.

Kerr, John, Mamta Vardhan, and Rohit Jindal. 2014. "Incentives, Conditionality and Collective Action in Payment for Environmental Services." *International Journal of the Commons* 8: 595–616.

Konishi, Hideo, and Debraj Ray. 2003. "Coalition Formation as a Dynamic Process." *Journal of Economic Theory* 110: 1–41.

Kotchen, Matthew J., and Kathleen Segerson. 2020. "The Use of Group-Level Approaches to Environmental and Natural Resource Policy." *Review of Environmental Economics and Policy* 14: 173–93.

Krämer, Jan E., and Frank Wätzold. 2018. "The Agglomeration Bonus in Practice—An Exploratory Assessment of the Swiss Network Bonus." *Journal for Nature Conservation* 43: 126–35.

Krawczyk, Michał, Anna Bartczak, Nick Hanley, and Anne Stenger. 2016. "Buying Spatially-Coordinated Ecosystem Services: An Experiment on the Role of Auction Format and Communication." *Ecological Economics* 124: 36–48.

Kuhfuss, Laure, Raphaële Préget, Sophie Thoyer, and Nick Hanley. 2016. "Nudging Farmers to Enrol Land into Agri-Environmental Schemes: The Role of a Collective Bonus." *European Review of Agricultural Economics* 43: 609–36.

Limbach, Kristin & Anne Rozan 2021. "Coordinating Farms within Multiple Regions: Collectively Conditional Incentives in Collective Agri-Environmental Schemes." Presented at the 8th FAERE Annual Conference, Grenoble, p. 30.

Liu, Zhaoyang, Jintao Xu, Xiaojun Yang, Qin Tu, Nick Hanley, and Andreas Kontoleon. 2019. "Performance of Agglomeration Bonuses in Conservation Auctions: Lessons from a Framed Field Experiment." *Environmental and Resource Economics* 73: 843–69.

McEvoy, David, Michael Jones, Michael McKee, and John Talberth. 2014. "Incentivizing Cooperative Agreements for Sustainable Forest Management: Experimental Tests of Alternative Structures and Institutional Rules." *Forest Policy and Economics* 44: 34–41.

McGinty, Matthew 2007. "International Environmental Agreements among Asymmetric Nations." *Oxford Economic Papers* 59: 45–62.

Moran, Patrick A. P. 1948. "The Interpretation of Statistical Maps." *Journal of the Royal Statistical Society: Series B (Methodological)* 10: 243–51.

Nguyen, Chi, Uwe Latacz-Lohmann, Nick Hanley, Steven Schilizzi, and Sayed Iftekhar. 2022. "Spatial Coordination Incentives for Landscape-Scale Environmental Management: A Systematic Review." *Land Use Policy* 114: 105936.

Osmani, Dritan, and Richard S. J. Tol. 2010. "The Case of Two Self-Enforcing International Agreements for Environmental Protection with Asymmetric Countries." *Computational Economics* 36: 93–119.

Panchalingam, Thadchaigeni, Chian Jones Ritten, Jason F. Shogren, Mariah D. Ehmke, Christopher T. Bastian, and Gregory M. Parkhurst. 2019. "Adding Realism to the Agglomeration Bonus: How Endogenous Land Returns Affect Habitat Fragmentation." *Ecological Economics* 164: 106371.

Parkhurst, Gregory M., and Jason F. Shogren. 2007. "Spatial Incentives to Coordinate Contiguous Habitat." *Ecological Economics* 64: 344–55.

Parkhurst, Gregory M., Jason F. Shogren, Chris Bastian, Paul Kivi, Jennifer Donner, and Rodney B. W. Smith. 2002. "Agglomeration Bonus: An Incentive Mechanism to Reunite Fragmented Habitat for Biodiversity Conservation." *Ecological Economics* 41: 305–28.

Parkhurst, Gregory M., Jason F. Shogren, and Thomas Crocker. 2016. "Tradable Set-Aside Requirements (TSARs): Conserving Spatially Dependent Environmental Amenities." *Environmental and Resource Economics* 63: 719–44.

Pasher, Jon, Scott W. Mitchell, Douglas J. King, Lenore Fahrig, Adam C. Smith, and Kathryn E. Lindsay. 2013. "Optimizing Landscape Selection for Estimating Relative Effects of Landscape Variables on Ecological Responses." *Landscape Ecology* 28: 371–83.

Pavlova, Yulia, and Aart de Zeeuw. 2013. "Asymmetries in International Environmental Agreements." *Environment and Development Economics* 18: 51–68.

Reeling, Carson, Leah H. Palm-Forster, and Richard T. Melstrom. 2018. "Policy Instruments and Incentives for Coordinated Habitat Conservation." *Environmental and Resource Economics* 73: 791–813.

Shimada, Hideki 2020. "Do Monetary Rewards for Spatial Coordination Enhance Participation in a Forest Incentive Program?" *Ecological Economics* 177: 106789.

Sylwester, Kevin 2001. "A Model of Institutional Formation within a Rent Seeking Environment." *Journal of Economic Behavior & Organization* 44: 169–76.

Villamayor-Tomas, Sergio, Julian Sagebiel, and Roland Olschewski. 2019. "Bringing the Neighbors In: A Choice Experiment on the Influence of Coordination and Social Norms on farmers' Willingness to Accept Agro-Environmental Schemes across Europe." *Land Use Policy* 84: 200–15.

Wätzold, F., and M. Drechsler. 2014. "Agglomeration Payment, Agglomeration Bonus or Homogeneous Payment?" *Resource and Energy Economics* 37: 85–101.

Westerink, Judith, Roel Jongeneel, Nico Polman, Katrin Prager, Jeremy Franks, Pierre Dupraz, and Evy Mettepenningen. 2017. "Collaborative Governance Arrangements to Deliver Spatially Coordinated Agri-Environmental Management." *Land Use Policy* 69: 176–92.

White, Ben, and Nick Hanley. 2016. "Should we Pay for Ecosystem Service Outputs, Inputs or Both?" *Environmental and Resource Economics* 63: 765–87.

Yi, Sang-Seung 2003. "Endogenous Formation of Economic Coalitions: A Survey of the Partition Function Approach." In *The Endogenous Formation of Economic Coalitions*. Edited by Carlo Carraro, 80–127. Cheltenham: Edward Elgar Publishing.

Zavalloni, Matteo, Meri Raggi, and Davide Viaggi. 2019. "Agri-Environmental Policies and Public Goods: An Assessment of Coalition Incentives and Minimum Participation Rules." *Environmental and Resource Economics* 72: 1023–40.

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