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**Auctions for biodiversity conservation: what works best? And would a biodiversity offset market work better?**

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Abstract:

How best to incentivise farmers and other land managers to conserve biodiversity on private land is an important policy question. Conservation auctions have been proposed as a tool for providing such incentives in a cost-effective way, but important design problems exist in aliging what encourages farmers to participate in such schemes with what is best for some indicator of biodiversity. This paper reviews the evidence from the lab and the field on how best to design conservation auctions for biodiversity conservation, before outlining an alternative policy instrument – markets for biodiversity offsets – which seems to offer several significant advantages over auctions.

**1.Introduction**

The global biodiversity crisis has prompted a renewed interest in the choice of policy instruments which can help reverse this decline (Dasgupta, 2021). Given the prominent role of private land use in achieving improvements to biodiversity globally, changing the behaviour of those who manage private land in a manner which benefits biodiversity is a key objective (Armsworth et al, 2012). This paper asks the question: how should *conservation auctions* be designed if the policy target is some aspect of biodiversity conservation? We try to answer this by considering findings from the lab, and evidence from the field in real-world applications across the globe. Finally, we ask whether an alternative incentive-based mechanism – tradeable biodiversity offsets – might be a better policy solution.

Conservation auctions are a specific type of Payment for Ecosystem Service (PES) mechanism where a typically-single buyer (the state or a regulatory body) elicits bids from private producers to enter into contracts specified in terms of how land is to be managed over some future time period (Rolfe et al, 2017; Hanley et al, 2012). Each producer is a potential supplier of environmental outputs to the single buyer. Contracts stipulate either the changes in management actions (such as reducing stocking rates) or environmental outcomes (such as reductions in water pollution) which the seller agrees to deliver, along with other relevant details such as the contract duration and monitoring requirements. Each potential supplier can make a bid detailing how much they will accept for agreeing to the terms of the contract. The buyer then orders the bids in terms of either bid price alone, or more often bid price weighted by some environmental metric, and selects the most cost-effective bids until the buyer’s budget is exhausted, or some quantitative programme target is achieved (eg cumulative hectares enrolled), or some maximum reserve price is reached for bids (Hellerstein, 2017).

By encouraging competition between sellers, the buyer hopes to reduce the information rents which sellers can earn, and thus improve the cost-effectiveness of interventions (Stoneham et al, 2003; Wallender et al 2018). This superior cost-effectiveness of conservation auctions over other types of PES scheme, such as uniform payments, has been identified as their major advantage (Stoneham, 2003)[[1]](#footnote-1). Bids also reveal something of the cost type of each producer who bids, since information on the costs to each individual farmer of “producing” the desired environmental outcome is typically hidden from the buyer.

As Rolfe et al (2017,2018) note, there is now much experience with the design and implementation of conservation auctions worldwide, with Australia in particular offering multiple examples of this idea being implemented in practice. Whilst conservation auctions have been used to try to achieve many different types of environmental objective (such as improving water quality, reducing soil erosion, and increasing greenhouse gas mitigation), this paper focusses on auctions targetted at some measure or measures of biodiversity conservation. Such targets could include:

- enhancing the populations of farmland birds

- protecting native vegatation

- or restoring wetlands on farms

Biodiversity gains may be the principal target of schemes (eg Eastern Mount Lofty Ranges, Southern Desert Uplands) or be a side effect of targetting an alternative principal target (such as the Conservation Reserve Program in the US – Dunn et al, 1993, Szentandrasi et al, 1995 – or the English NatureBid auction: Whitely and Johnston, 2020).

To be environmentally effective for biodiversity conservation, there may be a need for an auction design which encourages *spatial coordination* of conservation actions, since succesful realisation of many biodiversity objectives depend on conservation actions occurring on neighbouring sites, across connected networks or along corridors (eg Hodgson et al, 2011; Lamb et al, 2016). Lessons from auctions which encourage such spatial coordination are reviewed below. However, *spatial targetting* – where the regulator targets specific locations of high biodiversity value or potential in the landscape, for example via an environmental benefits index - may be important instead, since in such situations the ecological benefits of switching management to pro-conservation actions vary across space (eg Armsworth et al, 2012). Bid weighting metrics can be used to encourage both coordination and targetting.

Finally, high rates of *participation* in an auction may achieve both coordination and targetting indirectly, simply by enrolling a larger fraction of land in a policy area, although these indirect benefits will depend on the spatial covariance between opportunity costs and ecological productivity across patches. Moreover, to be economically efficient, we also want producers bidding near cost to keep information rents low, which also means we need enough competitive pressures, which implies in turn the need for high levels of participation, ceteris paribus.[[2]](#footnote-2)

**2. What lessons do we learn from the lab about how best to design a biodiversity auction?**

There has been considerable experimental research on conservation auctions in experimental economics labs. Most of the experiments that can inform efforts towards the conservation of biodiversity deal with auctions which focus on spatial coordination and targeting. These studies evaluate the efficacy of different auction features in promoting cost-effectiveness while maximizing the amount of biodiversity benefits procured. As in all conservation auctions, the design of the auction (for example, in terms of how winning bids are chosen, how winning bids are paid and whether farmers can submit bids to multiple (repeated) rounds, can have important impacts on environmental and economic outcomes

One important desin parameter is whether farmers are allowed to submit repeated auction bids. A study by Reeson et al. (2011) considered auction performance on a spatially explicit landscape with 10 properties arranged on a grid. Given the complexity associated with this setting, the authors adopted a multi-round iterative auction that allowed bidders to re-submit bids over multiple rounds of the auction. Within this setting, they tested the relative performance of providing bidders with upfront information about the number of rounds, and preventing bid revisions by provisionally winning bidders from intervening rounds before the actual winner is determined. The authors find that not providing information about the total number of auction rounds tempers rent seeking, leading to higher levels of coordination and cost-effectiveness. Moreover, the inability of provisional winners to revise and re-submit higher bids during intervening rounds of the auction reduced rent-seeking tendencies, leading to improved efficiency.

Iftekhar and Tisdell (2014), considered a lab experiment in which they evaluated the impact of two bid submission rules varying in the number of bids subjects could submit in the auction, on the effectiveness of an auction to produce wildlife corridors in a simulated landscape. They also considered whether bidder behavior and auction performance is influenced by considering a net benefit versus benefit-cost ratio auction bid selection criteria. The two bid submission rules entailed bidders in some sessions submitting a single bid for corridor formation; while in others they had the option to submit multiple bids for different corridors from which the auctioneer would pick the one with highest net benefit or benefit cost ratio. The results of the study indicate that having the flexibity to submit multiple bids has a negative impact on auction performance, with the project selection criteria having no impact. These findings indicate that while flexibility of bid submission may be an attractive feature for producers as it provides them with more options to win, this might run counter to the policy maker’s objective of enhancing auction efficiency and environmental effectiveness in terms of biodiversity protection.

Banerjee et al. (2015) consider the performance of a repeated auction with a focus on the amount of information provided to the bidders. This is an important issue given the complexity associated with conservation auctions, as well as the likely need of the regulatory agency to maintain transparency with and fairness among the bidders.[[3]](#footnote-3) Six bidders in the auction were arranged on a circular landscape on which neighbors have to coordinate bid submissions in order to increase the likelihood of being accepted in the auction. In some sessions, subjects are informed that the auctioneer values spatial coordination while in others they are not. Results indicate that providing this information leads to lower levels of rent seeking. Additionally, familiarity with the auction (measured by the number of times subjects submit bids across multiple auction periods) lowers auction performance as bidders are able to learn and bid in the auction to retain more information rents.

Fooks et al. (2016) evaluate an auction mechanism which encourages either spatial coordination via network bonus payments or direct spatial targeting or both. For each mechanism they ran lab experiments (and artefactual field experiments) in which four people could submit bids in an iterative auction multiple times. The results indicate that spatial targeting is more effective on its own in achieving spatial coordination relative to when targeting is absent; while network bonuses have the opposite effect. On their own network bonuses led to poorer environmental and social welfare outcomes compared to when such bonuses are not offered. However, bonuses and targeting work together leading to improved auction performance. These result suggest that if spatial targeting can be practiced as part of an auction based policy (as is the case for many biodiversity conservation policies in practice), appending bonus payments for adjacent bids can lead to greater environmental benefits and higher social welfare.

In a similar vein, Banerjee et al. (2021) considered the performance of an auction specifically geared towards spatial coordination by varying the pecuniary rewards associated with neighboring bid submissions. Specifically, their lab experiment investigated the impact of different magntitudes of rewards for joint bidding by neighboring participants on environmental performance and cost-effectiveness, both in the presence and absense of agglomeration bonuses for individual bidding. Their results indicate that if individual bid-level agglomeration bonuses are available, joint bidding has no impact on garnering greater environmental benefits from spatial coordination. However, if these individual bidding rewards for coordination are absent, joint bidding improves environmental performance although this comes at the expense of economic performance. This study indicates that when it comes to spatial coordination, attention needs to be paid to individual strategic incentives related to coordination beyond information rent seeking behavior. Moreover, in keeping with prior research this study also presents that bid revision opportunities improve environmental and economic performance even when joint bidding is present and rewarded.

Finally, many studies have shown that the choice of payment rule can impact on auction outcomes. Payment rules include pay-as-bid or discriminatory pricing, where each winning bid is paid the amount which the farmer asks for; and uniform pricing, where each winning bid is paid the same price (equal, for example, to the highest rejected bid). Krawczyk et al (2016) examine the consequences of choice of payment rule for a spatially-connected auction over forest conservation in Poland, in a design where they are also able to analyse the effects on auction performance of allowing participants to communicate with each other prior to bidding. They find that discriminatory pricing yields to greater environmental benefits per dollar of public expenditure, chiefly because it is easier to construct long corridors of conserved plots. Communication also facilitates such coordination but encourages collusion in sustaining high bid prices for the most environmentally attractive plots.

**3. Lessons from the Field**

Lab experiments have proved very useful to economists exploring the properties of alternative designs of conservation auction (Cason and Wu, 2019). However, given that the subjects used within most economic experiments in the lab are students, lab experiments may tell us less than we would like to know about the effects of alternative auction designs in the real world, where land managers are making contextualised choices based on considerable experience with land management. It is thus important to review evidence from lab-in-the-field studies (experiments conducted with farmers as the players) and from actual conservation auction schemes. Table 1 summarises the main case studies considered in this paper.

|  |  |  |  |
| --- | --- | --- | --- |
| **Scheme** | **Location** | **Biodiversity target** | **Reference** |
| Southern Desert Uplands | Queensland, Australia | Native vegetation  | Rolfe et al 2008; Windle et al 2009. |
| Midlands biodiversity hotspot tender, forest conservation fund | Tasmania, Australia | Plants and animals in native forests | Iftekhar et al 2014 |
| Eastern Mount Lofty Ranges | South Australia | Native vegetation | Bond et al 2019 |
| Bush Tender | Victoria | Native vegetation | Stoneham et al 2003 |
| Northeim and Steinburg projects | Germany | Plant species diversity | Groth, 2009; Ulber et al 2011 |
| Forest planting contracts | Sichuan, China | Increase forest cover on operationland | Wang et al 2012 |
| Forest conservation contracts | Sichuan, China | Protect existing forest cover | Liu et al, 2019 |
| Conservation Reserve Programme | USA | Part of an Environmental Benefits Index | Hellerstein 2017 |

**Table 1. Biodiversity conservation auction schemes.**

We now organise evidence on lessons learned from these schemes under the headings of spatial coordination, spatial targetting and participation, since we have argued above that these three factors are particularly important for conservation auctions to deliver successful biodiversity improvement outcomes.

*Spatial coordination:*

Few real-life conservation auctions for biodiversity have deliberately incentivised spatial coordination in the awarding of contracts. Rolfe et al (2008) and Windle et al (2009) report a pilot testing and then a full-scale roll-out for the Southern Desert Uplands auction in Queensland. Rolfe et al (2008) use an “experimental workshop technique” (which we might describe as lab-in-the-field) to obtain bids from producers for realistic but ficticious properties. The policy target was to create E-W corridors of native vegatation which is protected from clearing. Corridors were ideally 120-150km in length, which would likely involve about 12 neighbouring landowers being selected into the group of winning bids for each corridor. This experimental phase was used to guage likely participation and spatial coordination in the full auction; and to assess the transactions costs of running the auction. Two environmental metrics were used for each bid – a biodiversity score and a connectivity score. Two versions of the experimental design were used, aimed at increasing within-property connectivity and between-property connectivity. According to the authors, the dummy auction worked well in generating conserved corridors.

Lessons from this design exercise were then incorporated into a full scale scheme, as reported in Windle et al (2009). Three rounds of bidding were held to improve auction efficiency (bid prices fell by 34% across the three rounds). The metric was used to weight bids which had three components: a connectivity score (which included a bonus for joint bids between neighbouring operations), a biodiversity assessment score, and a land condition score. Of the 112 producers who were eligible to particpate, 26 submitted bids and 15 contracts were awarded. Importantly, 70% of these successful bids formed landscape corridors. Interestingly, the authors found that the auction “generated strong cooperation amongst producers”, and produced a significant improvement in native vegetation conserved. They note that most producers could meet required management standards without large cuts in stocking rates, so that the opportunity costs of agreeing to sign a contract were small.

Liu et al (2019) implemented a lab-in-the-field experiment with farmers in China to test the effects of including an agglomeration bonus (AB) as part of a conservation auction design. An agglomeration bonus pays an additional amount for each winning bid which is located next to another winning bid. Working with the State Forestry Adminsitration, the authors developed an auction in realistic but stylised landscapes of 8 neighbouring farmers where successful bidders who are next door to another successful bidder receive an additional payment (the AB) from the regulator in addition to their bid price. Theoretically, the presence of the AB gives producers an incective to reduce their bids, since the prize to be won (a conservation contract) is more valuable. Expecting other producers to act in the same way produces a further downward pressure on bid prices. The more neighbours a producer has, the bigger these combined effects should be. Using a discriminating price auction, the authors showed that the inclusion of an AB did indeed reduce bid prices. However, inclusion of an AB payment in the auction did *not* increase spatial coordination of forest conservation to a significant degree.

Auction schemes which do not specifically encourage spatial coordination of restored/conserved plots may nevertheless result in greater connectedness in a landscape for ecologically-scarce habitats, with associated benefits for species movement and metapopulation stability. Dunn et al (1993) point to woodland planting as a result of the Conservation Reserve Program resulting in closer connections between woodland plots, to the point where wind-blown movement of seeds for species such as green ash and Northern red oak can re-establish indivdual site populations across the landscape*.*

*Spatial targetting:*

Spatial targetting of which bids are succesful can help improve the effectiveness of PES-type schemes for biodiversity conservation. Such targetting in an auction can be achieved using an environmental metric used to weight bids on criteria related to site-specific ecological quality or potential, Such metrics are common in conservation auctions. However, robust evidence on the impact of such metrics auctions on biodiversity outcomes is less common.

Iftekhar et al (2014) report on a range of conservation auction schemes and negotiation-based land covenants for biodiversity conservation in Tasmania. They note that auction mechanisms such as the Midlands Biodiversity Hotspot Tender and Forest Conservation Fund were introduced later in time than land covenants. Auction mechanisms used a metric known as the Conservation Value Index to sort bids relative to the offer price. Both auctions and covenants were spatially targetted on biodiversity hotspots. Using regression analysis, Iftekhar et al find that for the 117 contracts analysed, auctions paid higher prices per hectare on average than covenants (possibly due to the time sequencing of these policies, whereby covenents enrolled low cost, high ecological value land first); and that for either type of scheme, higher prices were associated with better conservation outcomes. Producers with higher ecological value land were more likely to submit higher auction bids than those on lower ecological quality land. However, whether a contract was awarded by auction or not did not in itself affect the ecological outcome.

Bond et al (2019) report on the ecological impacts of a conservation auction scheme in the Eastern Mount Lofty Ranges in Victoria. Producers awarded a contract had to meet certain standards for maximum grazing pressure and weed control. Whilst it is not clear what process was used to select winning bids, the 10-year contracts to those who bid successfully produced significant improvements in native plant species richness, although the gains were “modest”, relative to control sites managed by producers whose bids were not selected or who withdrew before the end of the auction. That the biodiversity gains were “modest” may be explained by the authors’ observation that “in many cases stock management prior to the contract was consistent with that required under the contract”.

Spatial targetting has been a feature of the US Conservation Reserve Program since its inception, with bids being ranked using an Environmental Benefits Index which includes erodibility, water quality improvement potential and the conservation quality of land. The weightings for each of these 3 factors are known to producers before they bid. Bid price is included additively as a 4th factor, but the weight for cost is determined by the buyer (the USDA) once bids have been submitted and is thus not known a priori by the producer.

Several authors have noted evidence that the CRP has led to increases in a number of biodiversity indicators (see Allan and Vandever, 2012), but we are not aware of any work which identifies the effect of the EBI on biodiversity outcomes on enrolled land and on land where bids are rejected (note that a rather high fraction of offered bids have typically been accepted into the CRP). Moreover, as Hellerstein notes, getting the EBI “right” (including its interaction with the bid cap) is a difficult matter. For example, Szentandrasi et al (1995) argue that the EBI is poorly designed to encourage improvements in biodiversity, and that “land currently targetted has relatively few threatened or endangered species”. They investigate alternative designs of the EBI for Oregon, noting that endemic, engangered and game species may each require prioritization via the EBI, relative to other species populations which the CRP could benefit. Work has also shown that sites with higher EBI scores are associated with higher bid mark-ups (Kirwan et al, 2005); and that the encouragement of higher environmental quality (higher biodiversity outputs) bids results in an increase in information rents and thus more expensive bids (Wallender et al, 2018. Jacobs et al (2014) find that allocating a “Conservation Priority Area” score to some operations, in order to encourage high-biodiversity producers to participate, can lead to producers in such areas reducing their bid prices. The key point that emerges from this analysis of the CRP is that the existence and design of the spatial targetting EBI scoring system produces incentives for producers to change how they bid, which in turn affects the environmental outcomes and economic performance of of the policy.

A rather different approach to spatial targetting was taken in the land use change auctions in Sichuan, China (Wang et al, 20120). This involved a prediction at the farm level of changes in water quality, air quality and a biodiversity measure (Shannon-Weaver index) of the land management adjustments implied by winning of a contract. Land management measures included forest planting on farmland. Predicted environmental gains were then converted into monetary values using results from a choice experiment conducted in Shanghai and Chengdu, to allow a monetary environmental benefits index to be used to rank offers in conjunction with bid prices. Once auction bids had been elicited in from 303 farm households in 4 villages, bids were chosen on the basis of this benefit-cost ratio for each farm household. There was a big spatial variation in benefit-cost ratios, both within and between villages, whilst the mean BCR varied from 5.1 to 11.6. No evidence is offered in the paper on the environmental outcomes of this method of bid selection, but clearly there will be potential gains and losses from targetting biodiversity contracts in this manner (converting an ecological metric into an economic metric), compared to either no spatial targetting, or spatial targetting related to a non-monetary ecological metric.

*Participation:*

Low participation rates characterise many real world auction schemes (Rolfe et al, 2018). Low participation reduces competition and thus diminishes cost-effectiveness, meaning lower biodiversity benefits from a given budget. For example, Ulber et al (2011) found very low rates of participation in an auction aimed at increasing arable plant species diversity (12 out of 984 producers submitted bids); whilst the CRP in the US has seen historically high (though varying) levels of participation.

But what factors lead to low participation? This question is addressed in Rolfe et al (2018) and Whitten et al (2013). Four factors seem to emerge as being particularly important:

1. that auctions can have higher transactions costs for producers than alternative (non-auction) incentive schemes;
2. monitoring arrangements during the contract lifetime may be more complex and burdensome for the producer than with alternative schemes;
3. that there may be a mis-alignment of producer goals with policy goals; and
4. there may be a mis-alignment of producer knowledge with actions needed to fulfill the contract

Whilst these barriers to participation occur for any type of conservation auction, they may be higher when biodiversity conservation is the goal.

Argument (1) is well-known. Producers must take time to learn the rules of the auction, decide whether they want to bid, decide how much to bid if they do agree to participate, and then register their offer. These steps may simply cost the producer time, and/or they may incur financial costs by paying for advice. In contrast, deciding whether or not to enter a fixed-rate payment scheme will likely involve lower time costs to the producer. If auction payments are a low percentage of total farm income, then it would not be rational to expend large amounts of scarce time resources to try to win these payments. Transactions costs may deter risk averse producers to a greater extent than risk neutral or risk seeking producers (Palm Foster et al, 2016). If biodiversity auction rules are more complex than those for other environmental objectives (such as carbon sequestrion), then this would mean lower participation rates in biodiersity auctions.

Argument (2) suggests that producers may foresee or experience higher monitoring costs for biodiversity conservation contracts in general (whether won though an auction or not). Realisation of policy goals might involve intenstive monitoring of multiple species over time (as compared with , say, checking whether a producer has installed water-saving irrigation technology). Monitoring costs can be shared between regulators, conservation groups and producers, but there is some evidence that asking producers to monitor the results of their actions could deter participation (Tanaka et al, 2021).

With regard to (3), auctions for biodiversity conservation seek to protect species of concern from further decline, or restore habitats and species therein. Producers, in contrast, may be used to thinking about how to improve mean income flows into the operation, or reduce costs, or reduce the volatility of incomes. Unless producers have strong environmental preferences themselves, so that they derive selfish utility from an ecological gain on their own property, then this mis-alignment of objectives could be important in explaining lack of participation (Dessart et al, 2019). Whitten et al (2013) see this as the main reason why participation in the Goulburn-Broken and Queensland Vegetation Incentive Programme auctions was low. In contrast, the environmental objectives of the Southern Desert Uplands scheme were better aligned with producer objectives, boosting particpation rates.

Finally, (4) suggests that lack of understanding of the linkage between changes in management actions and the “production” of biodiversity outcomes upon which payments are based would also deter participation. Producers have high, local knowledge of the production technology linking inputs to marketed outputs, but have had no reason to invest in acquiring the same kind of knowledge to understand the linkage between management actions and, say, the population of a wader species on their land. This makes signing up to outcome based biodiversity contracts riskier than would be the case if such knowledge were greater – whilst the provision of free advice may be an effective means of increasing participation (eg Cortes et al, 2020, for Uruguay).

Length of contract offered in the auction will also affect participation rates. Hellerstein (2017) argues that the 10-15 year contracts offered by the CRP encouraged high rates of participation especially for producers facing more volatile crop returns. Longer contracts are also lilkely to be more ecologically effective than shorter contracts. However, shorter contract lengths may attract some farmers, and also make it easier for the regulator to nake changes to the auction system in the light of new evidence on biodiversity decline or changing land use pressures.

**4. An alternative policy instrument for biodiversity conservation: markets for offset credits.**

As we have seen above, there are a number of important design problems in the application of conservation auctions to biodiversity conservation. This raises the question of whether alternative, incentive-based policy options exist which can potentially deliver cost-effective conservation actions by producers. One idea that has attracted increasing recent interest is biodiversity offsetting (Bull and Strange, 2018), and in particular, markets in offset credits (Needham et al, 2019; Simpson et al, 2021a). Biodiversity offsetting aims to provide ‘measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development’ (BBOP 2009). Biodiversity Offset markets are created when multiple buyers and sellers of offset credits interact. Buyers, in many cases, will be developers who are compelled by regulation to offset the impacts of their development plans (eg house building) in a specific location on a particular metric of biodiversity (eg wetland area). This metric (here, wetland area) determines the currency of the offset market. Sellers are land managers who create credits by changing land management in such a way as to increase the supply of this measure of biodiversity at a given location, such as by creating a new wetland. An offset bank facilitates trades between buyers and sellers, typically imposing rules for the overall (aggregate) change in biodiversity in a region which can result. The most commonly applied rule is no net loss of bioidversity (Maron et al 2020) although more countries are applying policies that focus on net gain (Simpson et al, 2021b). Trading ratios are applied to reflect the many sources of heterongenity within the bioidversity metric (Bull et al 2017). Since the location of biodiversity loss (offset demand) is typically different in space from the location of offset creation (biodiversity gain), trading ratios are set to reflect this spatial difference in ecological productivty (Maron et al 2012). Trading ratios also capture the uncertainity associated with the restoration potential of habitats and differences in the timing of delivery of gains versus losses (McKenney & Kiesecker 2010). The offset bank may only issue credits to sellers once expected ecological gains have been realised (Bekessy et al. 2010)

Producers base their decisions over whether to create offset credits on benefit/cost ratios of competing, mutually exclusive land uses (Drechsler, 2021). The demand curve for credits reflects the developers’ decisions on the value of different parcels for development and the expected costs of buying offsets; their maximum willingness to pay. The supply curve reflects the minimum Willingness to Accept (WTA) of producers for creating and then selling offsets, which depends on their opportunity costs (plus any direct costs) for creating the credits by switching current production to more conservation-friendly land management. Given heterogeneity in development benefits and agricultural opportunity costs across space, these maximum WTP and minimum WTA values determine the demand and supply curves in the market. The biodiversity offset bank can match supply and demand offers until the market clears. In equilibrium, only those producers whose WTA is less than the maximum WTP of the marginal buyer will sell credits (Heal, 2005; Simpson et al, 2021b).

A key feature of offset markets is that a regulatory intervention is needed to create demand. In the case of house builders, for example, a planning rule could require each new housing development to offset the predicted impact of construction on a given bird species within a region; or each hectare of wetland that is drained to allow for shopping mall construction must be compensated for by purchase of sufficient credits of new wetland creation. An overall target of no net loss or a specific net gain figure in the metric (bird populations; wetland hectares) lies behind this planning rule. The property right allocation is clear: the state holds the right to protect bird populations/wetlands, and house developers must pay to acquire this right by purchasing an offset in order to be allowed to develop.

But how would this work in the case of agricultural land management which impacts negatively on some aspect of biodiversity? The state would have to set a baseline or reference level of a chosen biodiversity metric. Producers would not be allowed, legally, to reduce the metric below this level on their property without purchasing sufficient offset credits to substitute for the predicted decline in the biodiversity metric, given their desired land use change. Offset suppliers would earn credits by changing land management in a manner which increases the metric above this reference level. The exchange rates between a specific buyer and a specific seller location need to reflect both spatial variation in ecological potential, and the overall biodiversity target (net gain or no net less: Simpson et al, 2021b).

The re-assignment of property rights for land use change on operations would create a demand for offset credits by producers who wish to intensify production (eg by clearing native vegetation). The willingness to pay for credits of such producers creates a market incentive to other producers who can become offset suppliers. We expect those for whom it is relatively low-cost to increase the biodiversity metric on their land to be sellers. Given a large enough number of buyers and sellers, and the facilitation of market-clearing by an offset bank acting as a Walrasian auctioneer, the market clears with an efficient distribution of land between intensification and conservation.

In Table 2, we compare the main features of offset markets and conservation auctions for biodiversity.

**Table 2 – biodiversity conservation under auctions versus offset markets**

|  |  |  |
| --- | --- | --- |
| **Comparison Criteria** | **Conservation Auctions** | **Markets in biodiversity offsets** |
| Competitive pressure | One buyer, many sellers – competition between sellers | Many buyers, many sellers – competition between both buyers and sellers |
| Spatial targetting | Via an Environmental Benefits Index used to weight bids | Via the exchange rates between different sites |
| Spatial coordination | Via an EBI or through Agglomeration Bonus payments (eg Liu et al, 2019) | No specific mechanism, relies on spatial covariance of ecological potential and opportunity cost |
| Participation | Depends on whether expected private benefit of bidding exceeds expected private costs | Demand created by property right assignment; seller participation depends on both opportunity costs and buyer WTP |
| Who pays the budgetary cost? | State  | Private sector – producers or developers, unless state acts as “seller of last resort”. |
| Transactions costs | Likely to mainly fall on the supplier | May be partly absorbed by a state-funded offset bank |
| Certainty over delivery of environmental gain | Uncertain if the contract is for actions rather than outcomes (most likely scenario) | Certain if offset credits are only awarded once environmental benefit is generated |

With regard to spatial targetting, the offset bank awards more credits for the same conservation action on patches with higher ecological potential: that is, on land which is expected to generate a relatively large increase in the biodiversity metric (eg population of a specific species) from a given land use change (eg reduction in grazing density, or switch from arable to grassland), than if those actions were on land with low potential. Ecological modelling can be used to generate a matrix of exchange rates between all potential buyer and seller locations. This shows how many credits are needed to allow development – or any land use change which takes the biodiversity metric below the reference level – in any specific patch on a grid. It also predicts how many credits are produced by a land patch undertaking conservation actions. See Simpson et al (2021a) for an example of calculations of such an exchange rate matrix.

With regard to spatial coordination, no *explicit* mechanism exists within a biodiversity offset market to incentivise spatial coordination. However, coordination of new offset sites (ie land switched into conservation use) can emerge if low opportunity cost sites are spatially correlated with each other, and/or if high ecological potential sites are spatially correlated (with ecological potential meaning that the same conservation land use generates a relatively large predicted increase in the biodiversity metric). Both kinds of clustering are possible: Figure 1 is taken from Simpson (2021a) and shows that new offset sites – and new development sites – tend to be located close to each other in equilibrium.

In the design of biodiversity offset markets, there will likely be a case-specific optimal trade-off between having a larger spatial scale which increases participation, and a smaller spatial scale which makes the determination of ecological equivalence easier to model and control for via trading ratios. This design problem over the geographic size of the market is shared by designers of conservation auction schemes, where a larger spatial scale enables greater competition between alternative potential suppliers of biodiversity conservation, and indeed with programme designers of alternative economic incentives such as point-non-point trading schemes for water pollution (Fisher-Vanden and Olmstead, 2013; Doyle et al, 2014).

With regard to certainty over delivery of environmental gain, historcially there have been concerns that bioidversity offsetting has failed to secure no net loss of bioidversity (see Maron et al 2012; Maron et al 2018) with ecologists expressing concerns over the effectiveness of restoration; the additionality of offset schemes and the functionality of restored systems compared to natural systems. As recommended in Needham et al (2019), if offset markets are to be developed then the use of “banked credits” should be prioritised where trading can only take place once the credits have been certified as providing an increase in the target species, which seeks to overcome some of the problems associated with uncertainty in restoration.

1. **Discussion and Conclusions**

Based on our review of the evidence, we draw the following conclusions for conservation auction design when the policy target is an improvement in some index of biodiversity. First, the ecological payoff from farmers changing their management to improve biodiversity is often enhanced if those who win a bid are neighbours to other winners, creating spatial connections in conserved land. However, factors which affect the strategic uncertainty associated with coordination incentives need to be addressed. This strategic uncertainty comes from the fact that producers know that their likelihood of selection as an auction is contingent on the neighors’ behavior. However, farmers may not have enough information on their neighbours’ likely actions, or the social connections with this person to be able to coordinate with them effectively. In this regard, informal community social networks through which producers routinely interact and communicate with each other can be a low cost way of promoting spatial coordination (Bodin et al, 2017). At the same time, the iterative (decreasing price) and discriminatory price nature of the auction can ensure that communication does not increase the chance of collusion.

Second, spatial targeting and bonuses may be combined in a policy to not only reward spatial coordination (via agglomeration bonuses) but also convey the point that specific parcels on the landscape have differing ecological values for the policy maker (via targeting). Such targeting, if successful, can also be combined with the regulator holding events to congratulate contract winners who could be labeled as “model” or “demonstration” producers, who in turn can encourage others to participate by increasing transparency about the program. Given the complexity associated with auctions for biodiversity conservation, it seems beneficial to consider iterative, multiple-round formats, rather than one-shot auctions. This would allow bidders to revise and re-submit their bids, giving them the chance to learn from their past bidding mistakes. Such iterative bidding can, additionally, temper collusive tendencies if and when combined with communication. Last but not the least, it is important to keep the bidding procedure as simple as possible to encourage participation. Complex joint bidding setups can reduce participation, although can have merit in settings where the regulator wants to promote additional social goals such as enhanced community social capital (Westerink et al. 2017), or where landscape-level collective actions are needed to generate meaningful changes to biodiversity.

Nevertheless, evidence from the real world suggests that conservation auctions have been succesful in improving specific measures of biodiversity. Examples include the Southern Desert Uplands scheme, which managed to incentivise the creation of corridors of protected native vegetation and the Eastern Mount Lofty scheme. Auction schemes which are not principally targetted at biodiversity conservation can also achieve significant biodiversity benefits. For example, the CRP is argued to have reduced landscape fragmentation and created new wildife habitats such as riparian buffer strips and new farm woodlands, even though its primary target when introduced in 1986 was a reduction in soil erosion[[4]](#footnote-4) (Allen and Vandever, 2012; Dunn et al, 1993). The new NatureBid auction in Somerset, England aims mainly to reduce flood risks, but can include the creation of new farm woodland and hedge planting.

We set out three features of conservation auctions that were likely to be crucial for the use of such a policy to achive biodiversity conservation targets: spatial coordination, spatial targetting and participation. Looking at the range of schemes implemented in practice, it would seem that spatial coordination is something which few schemes have either specifically encouraged or managed to achieve. We speculated in section 2 that social capital considerations may be key to getting coordination incentives to work, since the strategic uncertainty involved in Agglomeration Bonus-type contracts depends on uncertainty over what neighbours are likely to do. Strategies to enhance communication between producers, and the history of cooperative behaviour in a neighbourhood are thus both likely to be important.

Targetting is much more widespread within biodiversity auctions, although we noted the importance of producers being able to understand how an Environmental Benefit Index weighting system is arrived at. We also noted evidence that the way in which an EBI is set up has been shown to influence bidding behaviour, and thus will affect cost-efficiency. Participation has been recognised as a key feature in the performance of all conservation auctions, as noted recently by Rolfe et al. (2018). It may be that the barriers to improving participation rates are greater for biodiversity auctions than in other types of conservation auction (for example, for reductions in water pollution). One reason is the information asymmetry about the means of producing biodiversity increases on operationland between producers and regulators. Another is the potentially greater complexity of biodiversity auctions, leading to higher transactions costs. Since it is the expected costs of meeting contract requirements which affects producers’ minimum willingness to accept compensation (and thus the bid they submit), it might appear desirable to offer “low hanging fruit” changes in land management associated with positive effects on biodiversity, since this keeps expected costs of participating low. Bond et al (2019) found that many of the contracted actions in the Eastern Mt Lofty scheme were already being partly undertaken by producers prior to payment via winning a contract, stressing the need to make sure that additionality (an increase in biodiversity relative to the business-as-usual baseline) is a key criterion for awarding contracts.

Finally, we discussed the idea of tradeable biodiversity offset credits as an alternative policy instrument to conservation auctions. The type of property right re-assignment needed to implement such a market which could achieve the same kinds of targets as a conservation auction is consderable, and probably politically infeasible at the time of writing in Australia, the US and Europe.[[5]](#footnote-5) However, there may be a sub-set of designated producer actions which generate biodiversity benefits which are site independent (such as woodland clearance) or a sub-set of farm locations (such as farms within national parks in the UK) which could be placed under an offset requirement in order to generate a market demand for offset credits. This market creation, while limited in scope, could provide a proof of concept regarding the feasibility as well as a socio-political acceptance of the mechanism amongst producers and policy-makers alike, in addition to partly transferring the financial burden of paying for biodiversity conservation schemes away from the taxpayer and towards the private sector.

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Figure 1 – spatial clustering in market equilibrium of new offset sites (blue) and developed sites (brown) in the Tees Estuary, England. Source:Simpson et al, 2021a.

1. It is important to note here that the empirical evidence about auction cost effectiveness especially under repeated implementation is mixed. Evaluation of actual data from CRP signups by Kirwan et al. (2005) indicates significant rent seeking over repeated interaction while lab evidence by Banerjee et al. (2021) suggests that auction cost-effectiveness increases with repetition. [↑](#footnote-ref-1)
2. Bingham et al. (2021) provides a systematic review of conservation auctions highlighting issues which need greater attention. Two of the issues relevant to this paper is the need to pay attention to spatial coordination and the importance of factors which influence participation rates. [↑](#footnote-ref-2)
3. In a survey of conservation professionals by Messer et al. (2016) and Grand et al. (2017), respondents indicated that while cost-effectiveness is important for program implementation, the main focus is on transparency and to ensure that producers perceive the program as being fair. However, they are indeed willing to focus on cost-effectiveness if provided with sufficient information resources and personnel training is available. [↑](#footnote-ref-3)
4. Although from 1990 onwards, the importance of other objectives such as wildlife enhancement and water quality improvement was explicitly recognised under the Food Agriculture Conservation and Trade Act. [↑](#footnote-ref-4)
5. As of June 16th 2021, the USDA has committed to investing upto US$ 5 million in their Wetland Mitigation Banking Program. While targeted specifically towards using offsets for wetland creation, enhancement and restoration, the postive impact on biodiversity conservation as a result of this program cannot be ignored. (NRCS 2021). [↑](#footnote-ref-5)