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# On the efficiency of the mitigation hierarchy

Anneliese Krautkraemer\*, Sonia Schwartz†

Preliminary version

## Abstract

This article focuses on the avoid, reduce, compensate (ARC) sequence that accompanies the no net loss policy. It studies the behavior of a developer in the face of this policy. Under perfect information, it appears that this policy is a policy of environmental standards, whose objectives are difficult to transpose into a microeconomic decision model. Moreover, we show that the demand for compensation does not depend on its price. We then assume that the regulator does not share the same information as the developer on the environmental damage of the project. In this case, the developer strategically uses this asymmetric information. Using the backward induction reasoning, he simultaneously defines his demand for offsets and the level of environmental damage reduction based on the offset price. In the end, the project choice is made by also taking into account the price of the offset. This article shows that the mitigation hierarchy is ineffective under asymmetric information, making the safeguarding of biodiversity inefficient.

**Keywords:** biodiversity conservation; avoid reduce compensate sequence; mitigation banking; mitigation hierarchy

**JEL codes** Q57; Q58

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# 1 Introduction

The collapse of biodiversity is a well-documented phenomenon, which is likely to worsen with climate change (Dasgupta, 2021; Díaz et al., 2019; Ruckelshaus et al., 2020). A leading cause of the decline in biodiversity is the loss of various habitats due to land use change (Lewis et al., 2011; Bamière et al., 2013). According to Dasgupta (2021), an estimated 20% of species could become extinct in the next several decades, perhaps twice as many by the end of the century.

One concept that aims to halt biodiversity loss is mitigation banking, the idea behind which started in the context of declining wetland area in the United States, which was often the result of land use shifts to urban development projects and agriculture (Burgin, 2010; Dahl, 1990). Wetlands act as habitat for many species and also provide many environmental services, including water filtration and flood management. The Ramsar Convention in 1971 established an international treaty for the conservation and sustainable use of wetlands, especially as habitat for birds. In order to address the loss of wetland area, the US Clean Water Act of 1972 introduced a permitting program that requires following a mitigation hierarchy to obtain a permit for a development project. The mitigation hierarchy lists the steps to be taken by major development projects to achieve the goal of no net loss of wetland area: avoid, reduce, and compensate (ARC)<sup>1</sup>. Consider a plan for a development project that will damage at least part of a wetland. First, the developer must avoid as much damage as possible, for example by relocating the project or reducing its size. Second, if some damage remains, it should be reduced as much as possible, using pollution abatement technologies or other methods. And finally, if there is any remaining damage, there are two options to compensate for said damage: either re-establish a similar wetland, on site or at another location, or purchase credits from a mitigation bank. A mitigation bank buys credits from restoration projects and sells them to developers who need to offset their residual impacts that could not be avoided or reduced.

In France, the mitigation hierarchy was introduced by the founding law for the Protection of Nature of 1976. The effectiveness of the mitigation hierarchy is measured via impact studies, which are required when obtaining a permit for development projects of a certain nature or size that are likely to affect protected species or habitats (Bigard et al., 2018; Levrel et al., 2018). It applies to projects, plans and programmes subject to environmental assessment as well as to projects subject to various administrative authorization procedures under the Environmental Code, such as environmental authorization, derogations for species protection or Natura 2000 impact assessment. The ARC sequence is widely practiced in European Union environmental policy and EU Directives, such as the Habitats Directive, have been a major driver in the reinforcement of the ARC sequence in France (Quétier et al., 2014). France's Law 2010-788 of July 12, 2010 led to important reforms concerning the mitigation of development impacts on biodiversity, including reforms on the requirements for impact assessments and enforcement capabilities (Quétier et al., 2014). Governmental guidance from 2012 states that compensatory actions should last as long as impacts, but there is little guidance about design, duration, or frequency of monitoring efforts (Quétier et al., 2014). The 2016 Biodiversity Law resulted in compensation becoming mandatory for residual impacts (Levrel et al., 2018) and introduced the use of natural compensation sites to anticipate future compensation demands (Aubry et al., 2021).

The idea of natural compensation sites first materialized in France with the pilot project

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<sup>1</sup>[https://www.epa.gov/sites/default/files/2015-03/documents/404\\_reg\\_authority\\_fact\\_sheet.pdf](https://www.epa.gov/sites/default/files/2015-03/documents/404_reg_authority_fact_sheet.pdf)

on the Cossure site in the Bouches-du-Rhône department. This site was created in 2009 by the organization CDC Biodiversité, with the support of the Ministry of Ecology and Sustainable Development (MEDD) (Dutoit et al., 2018). The idea behind natural compensation sites is to create a supply of compensation credits by restoring larger connected areas, in order to avoid the time lag between damaging habitats and restoring compensation areas.

The economic literature has examined the efficacy of restoration policies to protect biodiversity. From an ecological point of view, the results of various monitoring studies show that the goal of restoring herbaceous vegetation has been successful so far, and that its maintenance should be upheld thanks to the re-establishment of pastoral practices in the area (Dutoit et al., 2018). However, the final ecological assessment of the restoration actions can only be carried out with a longer time span, as varying weather conditions can lead to different invasive species thriving, as happened in 2014 when a particularly rainy summer allowed an invasive species to proliferate (Dutoit et al., 2018). Campbell et al. (2002) compare natural and created wetlands in the state of Pennsylvania, looking at variables related to soil and plant quality and found that even the oldest created wetlands had few similarities with their natural counterparts. Tillman et al. (2022) looked at wetland mitigation banks that have aged past the required 5-year management and monitoring periods and found that plant communities in wetland banks have greater conservation value than the lowest quality, degraded natural wetlands, but were not close to the same value as high-quality, reference natural wetlands. Reiss et al. (2009) studied wetland mitigation banks in Florida and found that while most banks were deemed successful in terms of permit criteria, the permit criteria were not explicitly tied to ecological criteria, and so the functional performance provided by the wetland banks remains unclear. While the natural compensation site has demonstrated the possibility to restore some parts of a natural habitat, it has also demonstrated the limitations of compensation actions to fully restore lost ecosystems (Dutoit et al., 2018).

Another part of the literature questions the feasibility of the compensation step. There is an issue of finding compensation areas that equate to the damaged areas, which is seen as one of the main challenges of mitigation banking (de Muelenaere, 2011). Often, criteria may be simplified in order to allow for more participation in compensation markets. There is also a potential issue of displacing wetlands or other natural environments from more urban to more rural areas due to differing land prices, making it more cost-effective for restoration projects to occur in more rural areas because of the lower land prices.

While the compensation step of the sequence has arguably received the most attention in the literature, many studies regarding the mitigation hierarchy also highlight that the first step, avoidance, is the most important but is “more often ignored than implemented” (Clare et al., 2011). Avoidance is the most certain and effective way to limit impacts on biodiversity, as it does not engender the same problems as compensation, such as restoration time lags, limitations to what can be offset, and negative social implications from taking away biodiversity in one area and improving it in another (Phalan et al., 2018). A few papers describe different reasons for which the avoidance step is not properly implemented. Clare et al. (2011) identify five key factors that lead decision-makers to fail to prioritize wetland impact avoidance and reduction above compensation in the US and Canada, namely a lack of consensus on what constitutes avoidance, a failure of land-use planning approaches to identify high-priority wetlands in advance of development, an economic undervaluation of wetlands, a “techno-arrogance” associated with wetland creation and restoration that results in wetland loss, and finally inadequate enforcement of compensation requirements. Similarly, Phalan et al. (2018) identify five challenges for effective impact avoidance: political will, legislation

quality and its implementation in practice, process, capacity (informational and transaction costs), and technical knowledge. Finally, Levrel et al. (2018) identify five drifts that undermine the additionality of the ARC sequence in France, which relate to a diversion of resources from existing conservation actions toward compensation measures and the pursuit of rents and cost minimization by different stakeholders.

Bigard et al. (2018) sought to evaluate how the execution of the ARC sequence in France aligned with the definitions and national guidance for each step. They analyzed 42 impact studies for projects between 2006 and 2016 in the territory of the Montpellier metropolis and contiguous municipalities and found that in 60% of the cases, the qualifications of the ARC measures given in the impact study did not correspond to the national reference definitions. For example, the so-called avoidance measures in the impact studies were actually reduction measures according to the national reference definitions. They also found that this confusion had negative consequences on the ecological effectiveness of the ARC hierarchy. As Stevenson & Weber (2020) note, there is a temptation to skip to steps lower in the hierarchy that are easier or cheaper. The aim of this paper is to define the operational contents of the sequence and to identify the cases where the sequence is inoperative.

While the economic literature has focused on the efficiency of the sequence in protecting biodiversity or on the realization of the different stages of the sequence, the essence of the policy is unclear. It appears a confusion between not net loss policies based on the ARC sequence and a market-based biodiversity conservation policy. Mitigation banking can be considered a type of PES scheme, as both instruments involve providing payment for the restoration, preservation, and/or management of biodiversity and ecosystems (Bureau, 2010; Combe, 2020). However, a PES is a market mechanism. The not-net-loss policy is an environmental standard, accompanied by the implementation of three successive standards: avoid, reduce and compensate. However, this possibility of compensation can lead to the development of an offset supply. The simultaneity of norms, prices and the supply of offsets can lead to an amalgam of the ARC sequence with a market instrument. One of the objectives of this article is to clarify this point.

The economic literature has identified various factors contributing to the failure to meet the no net loss objective have been widely discussed. However, to our knowledge, there has not yet been an attempt to model the developer's behavior in the face of various incentives to comply or not with the different steps of the mitigation hierarchy. The objective of this paper is not to analyze the efficiency of the ARC sequence in protecting biodiversity as this question is better suited to biological or ecological analysis. The idea of this article is to analyze how a developer behaves when faced with the ARC sequence.

To answer this question, we will mobilize two informational contexts: perfect information and asymmetric information. Under perfect information, it is assumed that the regulator has all the information about the developer's projects, both on the level of possible damage and the possibilities of damage reduction. Second, we assume that this information is only held by the developer. Under both assumptions, we seek to characterize the behavior of a developer in the face of the ARC sequence and the no net loss policy. We first highlight the difficulties of transposing the sequence into an economic decision model with perfect information. Moreover we show that the demand for compensation does not depend on its price. Under asymmetric information, the developer uses information strategically to achieve the no net loss objective by circumventing the ARC sequence. We show that, using the backward induction reasoning, the developer first defines his demand for offsets based on their price. In the end, the project chosen is the one that is most profitable given the compensation expense. Under asymmetric

information, the price of compensation is therefore a key variable, unlike in the situation of perfect information. The no net loss policy accompanied by the ARC sequence is a policy of environmental standards and not an economic instrument. In the real world, asymmetric information seems the most likely hypothesis. In this case, the ARC sequence is inoperative, with the consequence that it is ineffective in protecting biodiversity. The generalization of the ARC sequence and the creation of a public agency for the preservation of biodiversity may allow the problem of asymmetric information to be overcome, thus making the sequence more operative.

The article is structured as follows. Section 2 outlines the assumptions of our model. Then, Section 3 integrates the ARC sequence into a decision model under perfect information and Section 4 under asymmetric information. Finally, discussion and conclusion are presented in Section 5.

## 2 Assumptions

We assume a developer wants to invest in a project  $v_i$ ,  $i = 0, 1$ . The net economic benefit without taking into account the environmental damages is given by  $B(v_i)$ . Each project causes environmental damages in the amount of  $D(v_i)$ . We assume that the project  $v_1$  generates fewer benefits but less environmental damage than the project  $v_0$ . So we have:  $B(v_1) < B(v_0)$  and  $D(v_1) < D(v_0)$ . The regulator imposes the no net loss principle and the ARC sequence in order to help the developer achieve this environmental policy goal. Thus, each developer must sequentially avoid, reduce and compensate for its environmental losses.

Damage reduction is achieved by choosing a damage level  $D^{\min}(v_i)$  lower than the initial damage, such as:  $r = D(v_i) - D^{\min}(v_i)$ . Damage reduction imposes an additional cost on the company given by  $C(r)$  with  $C'(r) > 0$  and  $C''(r) > 0$ . The remaining environmental damage must be compensated. Offset banks offer offset allowances. The offset allowance market is assumed to be atomistic so that the price of the allowances,  $p$ , is a competitive price.

## 3 Perfect and symmetric Information

We first assume perfect and symmetric information. In this case, the regulator and the developer share the same information about the environmental damages and the different costs of reducing the damages. The regulator can monitor whether the developer follows the ARC procedure. Under this assumption, the developer can only respect, step by step, the sequence. We follow the French definitions from the MEDD for each step of the sequence.

**The avoidance stage** On the avoid stage, the definition of the MEDD underlines that the design of a project "*must first of all seek to avoid impacts on the environment, including the fundamental choices related to the project (the nature of the project, location, even opportunity)*". We interpret this definition as the fact that the developer must avoid the environmental impacts of the project as much as possible. In our framework, he chooses the project  $v_1$ , which causes the least environmental damage ( $D(v_1) < D(v_0)$ ).

**The reduction stage** The MEDD gives the following definition for the stage reduce: "*These impacts must then be sufficiently reduced (...) at a reasonable cost, to constitute only*

*the smallest possible residual negative impacts.*" This step lacks operational content. Indeed, what does *sufficiently reduced* mean? What is a *reasonable cost*? If the level of damage reduction has to be the lowest level achievable by the developer, it is possible that the cost of reduction is such that the developer's profit is negative. Here, we clarify the desired requirement at this stage as keeping the level of damage reduction as high as possible, while remaining consistent with a non-negative profit. If the level of damage chosen is positive, this constraint must include the necessary cost of compensation, which is included in step 3. We note  $D^{\min}(v_1)$  this level of damage. So  $r = D(v_1) - D^{\min}(v_1)$ , with  $D^{\min}(v_1) < D(v_1)$ . So  $D^{\min}(v_1)$  has to solve  $B(v_1) - C(D(v_1) - D^{\min}(v_1)) = 0$ . If there is no damage level satisfying this condition, the developer chooses  $D^{\min}(v_1)$  such as:  $B(v_1) - C(D(v_1) - D^{\min}(v_1)) - pD^{\min}(v_1) = 0$ . Despite the developer's efforts to minimize damage, there may be no possibility of complete damage reduction compatible with the non-negativity profit constraint. In this case, a positive level of damage is implied.

**The compensation stage** The compensation stage only appears if the damage level is positive, i.e.  $D^{\min}(v_1) > 0$ . The not net loss principle imposes a necessary damage compensation. This compensation is only permitted by the regulator if the ARC sequence has been previously scrupulously followed by the developer. The demand for offsets is therefore determined in a residual manner. This observation allows us to make this proposition:

**Proposition 1** *Under perfect information, the offset demand does not depend on the offset price.*

The compensation cost is given by  $pD^{\min}(v_1)$  if  $D^{\min}(v_1) > 0$  and 0 if  $D^{\min}(v_1) = 0$ .

In the end, by applying the rules of the ARC sequence under perfect information, the developer chooses the project  $v_1$ , opts for an environmental reduction level compatible with a non negative profit and compensates for the residual damage. The sequence is respected at each level, which allows for the best protection of biodiversity. The price of compensation does not influence the developer's behavior. The ERC sequence coupled with the no net loss policy is a succession of environmental standards.

## 4 Asymmetric Information

We now assume that only the developer has information about the different projects he wants to carry out, including the environmental damage of each project ( $D(v_i)$ ) and the possibilities of damage reduction given by the function  $C(r)$ . The information between the regulator and the developer is therefore asymmetric. The assumption of asymmetric information leads to two differences compared to the situation of perfect information. On the one hand, the regulator cannot know whether the developer has respected the ARC sequence. On the other hand, the developer - as an homo economicus - will not consider the sequence separately, that is, in a myopic way. The developer can be expected to behave strategically while respecting the no net loss requirement. He will adopt the backward induction reasoning in order to choose the level of reduction and compensation. In the end, the rational developer will choose the project that offers the greatest profit.

Assuming that the developer chooses the project  $v_i$ , he decides the amount of reduction and so the level of compensation by minimizing the total environmental conformity cost:

$$\begin{aligned} \text{Min } TC_{D\tilde{v}_i} &= C(Dv_i - D\tilde{v}_i) + pD\tilde{v}_i \\ &-C'(Dv_i - D\tilde{v}_i) + p = 0 \end{aligned} \quad (1)$$

According to Equation (1), the developer chooses the level of damage reduction  $[Dv_i - D\tilde{v}_i]$  such that the marginal cost of environmental damage reduction is equal to the offset price. If  $D\tilde{v}_i$  is equal to zero, there is not damage and no need for compensation. If  $D\tilde{v}_i > 0$ , the developer has to buy offset credits in order to compensate for the environmental damage at a cost  $pD\tilde{v}_i$ .

Therefore, what will explain the compensation level is the shape and limits of the damage reduction curves and the price of the compensation credits. Compensation occurs if  $C'(Dv_i)$  has a finite limit in  $D\tilde{v}_i = 0$  such that the offset price is lower than this limit or if  $C'(Dv_i)$  satisfies Inada's condition in  $D\tilde{v}_i = 0$ . However, there is never compensation if  $C'(Dv_i)$  has a finite limit in  $D\tilde{v}_i = 0$  such that the offset price is higher than this limit.

**Proposition 2** *Under asymmetric information, the demand for compensation is based on the offset price.*

Thus, the level of compensation is no more residual as required by law (step 2 of the ARC sequence), but results from an economic calculation. Homo economicus uses the asymmetric information to maximize its profit. Finally, the profit obtained with the project  $v_i$  is written as:

$$\Pi(v_i) = B(v_i) - C(D(v_i) - D(\tilde{v}_i)) - pD(\tilde{v}_i)$$

In the end, the developer chooses the project that gives the higher level of profit. He will choose the project  $v_1$  if:

$$\Pi(v_1) > \Pi(v_0)$$

Which can also be written as:

$$B(v_1) - C(D(v_1) - D(\tilde{v}_1)) - pD(\tilde{v}_1) > B(v_0) - C(D(v_0) - D(\tilde{v}_0)) - pD(\tilde{v}_0) \quad (2)$$

As  $C'(Dv_0 - D\tilde{v}_0) = p = C'(Dv_1 - D\tilde{v}_1)$ , we have:  $Dv_0 - D\tilde{v}_0 = Dv_1 - D\tilde{v}_1$ , and  $C(D(v_1) - D(\tilde{v}_1)) = C(D(v_0) - D(\tilde{v}_0))$ . Replacing in (2), we obtain:

$$B(v_1) - B(v_0) > p[D(\tilde{v}_1) - D(\tilde{v}_0)]$$

A project  $v_1$  is chosen if the difference in benefit between projects  $v_1$  and  $v_0$  is greater than the difference in expenditure between the projects on compensation.

**Proposition 3** *The project choice only depends on the project benefit and on the offset price.*

Thus, the offset price determines the compensation level and thus the level of the environmental damage reduction. The offset price is also the determining factor in the choice of project. At no point does the avoidance stage play a role in the behavior of homo economicus. The reduce and compensate stages are not sequential but simultaneous. In the end, the ARC sequence is inoperative under asymmetric information. The developer makes decisions based on the compensation price. In this case, the not net loss policy can be considered as a market-based instrument.



## 5 Discussion and conclusion

The ARC sequence appeared in the United States in 1972, then in 1976 in French law. In France, the definitions of the Avoidance, Reduction, and Compensation measures were introduced in 2012, followed by the not net loss of biodiversity objective in its Biodiversity Law of 2016. The study of this sequence in the economic literature is most often done by taking into account its impact on biodiversity conservation (Brown & Land, 1999; Quétier et al., 2014; Calvet et al., 2019). Some studies, such as Bigard et al. (2018), highlight the difficulties of translating the concepts of the ARC sequence into practice. According to the authors, the qualifications given in the impact studies often do not correspond to the national reference definitions. In particular, they note a confusion between avoidance and reduction measures.

Following Bigard et al. (2018), our work sought to analyze the operational dimension of the ARC sequence, but mobilizing another angle of study. We sought to incorporate the ARC sequence into an economic decision model. The objective of this paper is to investigate the rationality of the ARC sequence. To do so, we assumed the hypotheses of perfect and asymmetric information.

Using the perfect information hypothesis, we first highlighted the difficulties of transposing the imperatives of the sequence into an economic decision model. The ARC sequence corresponds to the implementation of three standards: avoid, reduce and compensate. We selected the project that caused the least environmental damage, at the avoidance stage, which implies the existence of several projects or project modalities. The reduction stage raises the question of the meaning of "sufficiently reduced" (...) at "a reasonable cost". This point is difficult to transpose into an economic model. Here we have chosen the highest level of damage reduction that can be accounted for with a non-negative profit. We have shown that when the sequence is respected, the demand for compensation does not depend on its price. Under symmetric information, the ARC sequence is an environmental standard.

The environmental economics literature notes the importance of information in the implementation of environmental standards as a means of pollution control. However, the sequence goes even further in requiring information than pollution standards because it involves sequential implementation. So, we then lift this assumption of perfect information by assuming that the regulator does not have all the information about the projects. In this case, we showed the information is used strategically by the developer and that the ARC sequence is inoperative. The developer will not behave in a myopic way, considering the different steps independently of each other. As an *homo economicus*, he will reason backwards in order to choose the most profitable project, under constraint of the no net loss policy. We show that the developer will simultaneously decide on the amount of the damage reduction and the compensation based on the offset price and that, in the end, the choice of project is established in particular on the offset price. In other words, establishing this sequence in the law involving the no net loss policy is inefficient when the information is asymmetric. Therefore, under asymmetric information, the no net loss policy is a market-based instrument.

However, our article has not taken into account the existence of another operator, the auditors. In fact, the ARC sequence is carried out through impact studies. The developer is responsible for the study, and can call on the services of consulting firms to draw up this document. The company pays for these services. In the face of the operational vagueness of the ARC sequence, one can imagine that the company can draft the impact study by evading certain information or minimizing certain impacts, which justifies our hypothesis of

asymmetric information. One way to overcome this information problem would be to create a specialized public agency whose mission would be to conduct all these impact studies. This agency would benefit from the experience gained from one study to another and would be better able to apply the same interpretation of the ARC sequence to each project. The generalization of the sequence in France to all projects regardless of their location and size would allow for these economies of scale. In our article, we have considered several possible projects with different levels of damage. In reality, developers consider a single project, hence the difficulties in interpreting the avoidance stage. One could imagine that the developer would be obliged to communicate to this agency his different projects so that the ARC sequence is applied upstream of the decisions. In the end, the creation of this agency would tend to remove the asymmetry of information concerning the environmental damage of the project, thus allowing the ARC sequence to be implemented. The sequence would be a standards approach, not a market-based approach. The objective of no net loss is thus achieved, but not at the lowest cost.

In fact, our work highlights the different objectives of a biodiversity conservation policy, either strictly protecting biodiversity or implementing the least cost criterion. The ARC sequence coupled with the not net loss objective is a sequence of norms aimed at preserving biodiversity. The offset mechanism, by putting a price on the offset, can be seen as an economic incentive to compensate. If each developer reduces his damage by equating the marginal cost of reducing the damage to the price of the offset, biodiversity will be saved at lower costs. This result is not possible by applying the ARC sequence, but perhaps this is the price to pay for taking into account a very particular and difficult to measure good, biodiversity.

In this article, we have assumed an exogenous price for offsets. When the supply of offsets is not well developed, this assumption can be challenged. This work will have to be continued by taking into account the sequence when the price of the offset is established on an over-the-counter market.

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