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Reconciling agriculture and biodiversity in European public policies: a bio-economic perspective

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Abstract Agriculture has been identified as a major driver of the current significant changes in farmland biodiversity. Taking into account these environmental impacts, agriculture today aims at a more sustainable way of producing that would reconcile its economic and ecological functions. A new approach based on bio-economic modeling has been recently developed to explore different facets of such reconciliation and to understand how to promote sustainable agricultural public policies. In this paper, we review the contributions of such approach. The review shows that it is possible to reconcile agriculture and biodiversity with public policies, since it is possible to increase simultaneously the economic and ecological performances of agricultural landscapes compared to the current trends. However, it is not possible to optimize this reconciliation: The different criteria cannot be maximized simultaneously, and some trade-offs emerge between economic and ecological criteria in optimality. To go further, some bio-economic studies open new perspectives. For example, they suggest studying the society as a whole instead of focusing on the agricultural sector or going beyond the concept of optimality by stressing the idea of viability. In addition to reforming the current agricultural policies, deeper debates on the notion of sustainability have to be held.

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Introduction

Promoting multi-functionality in agriculture constitutes one of the main environmental challenges of the twenty-first century. Past changes in agriculture, such as intensification, mechanization and landscape homogenization have had several negative impacts on the environment, such as the loss of biodiversity (Chamberlain et al. 2000; Tscharntke et al. 2005; Foley et al. 2005). Nevertheless, by combining productive functions (i.e., securing the level of biodiversity insures functional diversity and key functions supporting production) with nonproductive functions (i.e., maintaining the amenity and cultural values of some species), the importance of biodiversity today is clearly established (Swinton et al. 2007). In this context, scientific and policy debates have emerged to take into account ecosystems into agricultural productive landscapes (Wossink et al. 1999; Perfecto and Vandermeer 2010; Kleijn et al. 2011). In this perspective, ecological considerations have been increasingly taken into account when designing agricultural policy. For example, such considerations have been introduced in Europe since the 1990s through the European Common Agricultural Policy (CAP), when agri-environmental schemes were developed to promote protection of biodiversity. However, since they have not exhibited clear effectiveness yet (Vickery et al. 2004; Kleijn et al. 2006; Whittingham 2007; Pe'er et al. 2014), the reconciliation between agriculture and biodiversity in farmlands is still an open question, and designing sustainable agricultural public policies remains an ongoing challenge.

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Such a challenge requires adopting a double viewpoint bringing together ecological conservation with the welfare of human societies. This dual concern notably led to the creation of the International Panel for Biodiversity and Ecosystem Services.[1] In that respect, the development of interdisciplinary scientific researches such as bio-economics or ecological economics is decisive (Thébaud et al. 2013). The aim of this discipline is to understand the control of ecological-economic systems by designing public policies, or management strategies, which take into account both the commodities and the ecosystem services they provide (Doyen et al. 2013). Based on bio-economic models and quantitative methods, it seeks to assess and compare the efficiency of different public policies. For instance, the first historical approach called the cost-benefit method compares monetary costs and benefits of the different scenarios. However, in view of the difficulties of quantifying biodiversity in financial terms (Diamond and Hausman 1994), the cost-effective framework appears as a relevant alternative. Contrary to the cost-benefit method, this framework assesses the public policy scenarios by taking into account the economic and ecological criteria separately within their own units. Based on optimization under constraints, it is possible to define either the least-expensive policy satisfying a biodiversity goal, or the policy with the best biodiversity performance under budgetary constraints. Different strategies of public policies, or more broadly different facets of the question, can be explored by such an approach. In this paper, we propose to provide a review of the main results emerging from bio-economic studies to deal with the reconciliation between agriculture and biodiversity especially in European public policies.

Reconciling agriculture and biodiversity

Farmers' decisions and their impact on biodiversity depend on the farmers' intrinsic preferences and on the exogenous context (such as market settings, price volatilities, environmental uncertainties and public policies). Bio-economic models have investigated these two elements in order to understand the difficulties of reconciling agriculture with biodiversity.

Studying the individual behavior

Individual preferences are captured by the microeconomic parameters. Our review of the literature on bio-economic models in agriculture highlights a special interest for one specific parameter, namely risk aversion (Lien 2002). Risk aversion is a concept used in economics to capture a cautious behavior facing uncertainties. It is related to the preference of an agent for a certain payoff as compared to the same expected but uncertain payoffs. This concept is broadly applied in finance, especially with the portfolio theory (Markowitz 1991).

In the context of agriculture, theoretical studies suggest that an adequate risk aversion is sufficient to bring farmers to adopt sustainable choices (Baumgartner 2007; Quaas et al. 2007). In other words, farmers do not necessarily need to have environmental preferences or to receive monetary benefits from ecosystem services to favor eco-friendly practices. This implies that the strategy of diversification chosen by risk-averse farmers to mitigate economic risk has also positive consequences on biodiversity. Two levels of diversification can be implemented by the farmers: the diversification of genetic species within farming activity (called the agrobiodiversity), and the diversification of farming activities and land-uses. Empirical bio-economic analyses have studied both strategies: (1) the agricultural diversification as an answer to mitigate economic risks has been confirmed for both the agrobiodiversity [in croplands with Di Falco (2012), Mitter et al. (2015) and in grasslands Schläpfer et al. (2002), Kahmen (2005), Lin (2011) and Vogel et al. (2012)] and the land-uses diversity (Mouysset et al. 2013) and (2) its positive impact on biodiversity has been highlighted by Laiolo (2005), Robinson and Sutherland (2002) for the agrobiodiversity within croplands and grasslands, respectively, and by Mouysset et al. (2013) for the land-use diversity.

One way to explain the positive effect of agricultural diversification on wild biodiversity is to look at the heterogeneity of habitats and available resources arising from the agricultural diversification. This coexistence of habitats is essential for biodiversity, as highlighted by Benton et al. (2003). A landscape with more diverse resource niches is able to host a richer ecosystem (Loreau et al. 2001). Moreover, by increasing farmland biodiversity, diversification has a broader effect on the functioning of the agroecosystem since the different species can respond differently to environmental disturbances and occupy more diverse resource niches (Ives et al. 1999; Doak et al. 1998). Thus, communities with high biodiversity are more stable (Lehman and Tilman 2000; Roscher et al. 2009; Haddad et al. 2011) and more productive in the ecological sense (Tilman et al. 2005; Isbell et al. 2011; Cardinale et al. 2012; Hooper et al. 2012) than those with poor biological diversity. In other words, a higher biodiversity acts as a public natural insurance by insuring ecosystems against declines in their functioning caused by environmental fluctuations (Ehrlich and Ehrlich 1981; Yachi and Loreau 1999).

[1] http://www.ipbes.net.

All these bio-economic studies suggest that farming diversification induced by risk-averse farmers could be an efficient way of promoting both private and public values of agriculture, i.e., lower economic risk on the one hand and more stable and productive communities on the other hand (Mouysset et al. 2013; Finger and Buchmann 2015). Individual behavior face to economic risks might be one lever to explore to reconcile agriculture and biodiversity. Other scholars have made similar suggestions to manage another environmental externality of agriculture, the soil degradation (Chavez et al. 2014).

Nevertheless, this conclusion must be challenged in the particular case of agriculture because economic agents are usually regarded as risk averse by the economic theory. Indeed, if the farming agents are risk averse, why do the specialization of agriculture and the consequent decline of wild biodiversity occur today? This can be explained by the fact that other strategies (i.e., excluding agricultural diversification) are mobilized to manage the agricultural economic risk. Firstly, private financial insurances exist to compensate for farming economic risk. Risk-averse farmers adopting this monetary insurance do not have any economic risk anymore and will therefore choose to specialize their activity in the most profitable one. As a result, by promoting specialization, this monetary insurance has detrimental effects on ecological performances (Quaas and Baumgärtner 2008). Secondly, financial insurance can also be backed by public structures, such as the European Common Agricultural Policy. This policy was created to protect farmers against market volatility and price fluctuation by way of economic compensations. Similarly to the private financial insurance, this policy context encourages farmers to specialize their activities and causes a negative impact on biodiversity.

To conclude, considering microeconomic parameters such as risk aversion might be an interesting lever to reconcile agriculture and biodiversity. While ecological studies often focus on extensifying the agricultural practices to counter the ongoing biotic homogenization (McKinney and Lockwood 1999; Olden 2006), bio-economic studies highlight the diversification as another leverage to stimulate the farmland ecosystems. With risk-averse economic agents, this lever remains strongly connected to the public policies. Crucially, public policies can play a central role either by promoting directly a diversification or by limiting the negative impacts of private and public financial insurances on ecological performances.

Designing public policies

The question of the efficiency of public policies remains crucial, especially with regard to the budget dedicated to agricultural policies (more than 40 % of the EU's total budget). Although there has been a very recent evolution of agricultural policies toward ecological issues, the efficiency of these policies remains very controversial regarding the effect on biodiversity (Kleijn et al. 2001, 2006; Batary et al. 2011; Pe'er et al. 2014). Our review of bio-economic studies in agriculture shows that we can distinguish two sides of the debate about the effectiveness of public policies. Firstly, it appears that adequate public policies allow to simultaneously improving the economic and the ecological performances of agroecosystems compared to the status quo situation. In this sense, public policies can reconcile agriculture and biodiversity. Secondly, it is not possible to optimize this reconciliation: Even if all the criteria can be improved, it is not possible to optimize all of them with the same public policy. Therefore, one has to make a trade-off between the criteria in terms of optimality. We detail these two aspects.

Based on the comparison of different scenarios of public policies, many bio-economic studies show that adequate public policies can simultaneously improve the economic and ecological performances of agroecosystems compared to the status quo situation. In an overall perspective, Shi and Gill (2005) pointed out the importance of the role of the state to develop a sustainable agriculture. Then, different types of public policies have been investigated by bio-economic models. For example, some studies focus on how to increase the efficiency of the current conservation measures. They have notably pointed out the role of the spatial scale (Hölzkamper and Seppelt 2007; Drechsler et al. 2007; Seppelt et al. 2011). To be efficient, the conservation plans have to be implemented at the landscape scale instead of focusing on small areas of individual fields (Saikkonen et al. 2014). Other studies try to understand how to make the agricultural intensification sustainable. It has been suggested that developing technologies (Fribank et al. 2013; Franks 2014) in strong connection with investing in research (Godfray et al. 2010) is the path toward a sustainable intensification. Other models study how to green current policies by stimulating the development of some specific land-uses [Schuler et al. (2013) in Germany or Mouysset et al. (2011) in France]. For instance, they look at how scenarios based on extensification can reconcile agriculture and biodiversity. This is consistent with the studies in agroecology which have shown the importance of extensive grasslands for biodiversity (Potter and Goodwin 1998; Bignal and McCracken 2000; Laiolo 2005; Batary et al. 2011). These scenarios have also highlighted the importance of combining different policy instruments targeting different land-uses to be able to deal with spatial heterogeneities (heterogeneity in economic contexts, historical agricultural activities, biodiversity communities and dynamics) (Mouysset et al. 2015). Finally, the payments for ecosystem services (PES) have broadly been investigated and especially in agriculture. Based on 25 years of experimentation in the USA, Philip Robertson et al. (2014) showed that citizens appear willing to pay farmers for the delivery of specific services, such as cleaner lakes. This observation suggests that a new paradigm based on ecosystem services seems feasible in US agriculture and could be environmentally significant. A review of European studies (Reed et al. 2013) achieved similar conclusion since spatially targeted and outcome-based payments may be more economically efficient than current approaches. However, implementing PES framework in agriculture raises many challenges, including scientific uncertainty, pricing of ecosystem services, timing of payments, increased risk to land managers, compliance with World Trade Organization regulations, and barriers to cross-boundary collaboration in the management of ecosystem services at habitat, catchment or landscape scales (Reed et al. 2013).

Other bio-economic studies rely on cost-effective framework and analyze more specifically the optimality of public policies. Based on theoretical models (Polasky et al. 2005; Barraquand and Martinet 2011), as well as calibrated models (Lewis et al. 2011; Armsworth et al. 2012), they highlight efficiency frontiers between economic and ecological performances in optimal public policies. These frontiers indicate that the integration of a biodiversity constraint inevitably yields a decrease in the maximum achievable economic performances. In other words, taking into account a biodiversity goal generates an economic loss compared to the public policy built without any biodiversity constraint (i.e., based on only economic perspectives). Thus, there is no optimal win–win public policy which maximizes ecological and economic criteria simultaneously. A trade-off emerges regarding the optimality of the different criteria. It is nevertheless possible to make public policy recommendations by using these trade-off curves. Indeed, most studies conclude that the efficiency frontier is concave such as in Polasky et al. (2008) or Drechsler et al. (2007). A better trade-off strategy can emerge out of this pattern: The public policy at the corner of the concavity exhibits a relatively strong improvement of biodiversity without leading to important economic loss (Polasky et al. 2005; Lewis et al. 2011; Barraquand and Martinet 2011). Even if this shape is the most common in the literature, it cannot be used in every situation, because it actually depends on the ecological indicator (Armsworth et al. 2012; Mouysset et al. 2015). For example, a nonconcave curve has been emphasized for an indicator of special interest, the Farmland Bird Index, which is the official indicator chosen by the European Union to represent the agricultural biodiversity (Balmford et al. 2003). With this pattern, selecting the most adequate policy is no longer obvious. Because of this diversity of efficiency frontiers, the choice of public policies regarding the optimality criteria becomes particularly complex.

The study of the bio-economic literature points to the conclusion that agriculture and biodiversity can be reconciled. Different levers can be investigated, thereby offering a large room of maneuver. Still, the debate remains open since not any arbitration between these different levers has been made yet, especially by taking into account the diversity of ecological impacts. In the perspective of this ongoing debate, some bio-economic studies explore new viewpoints on the agriculture–biodiversity reconciliation. Changing perspectives should provide a better understanding of the question and throw light upon new solutions. More precisely, our review of bio-economic literature pointed out two interesting perspectives.

Changing perspectives

Budget and social welfare

Although the most popular criterion in public economics is social welfare, bio-economics models in agriculture use focusing on the agricultural sector. Indicators are mostly based on the agricultural income costs (Münier et al. 2004; Polasky et al. 2008; Mouysset et al. 2011; Mitter et al. 2015) or the public budget dedicated to agricultural policy (Drechsler et al. 2007; Hölzkamper and Seppelt 2007; Ohl et al. 2008). On the contrary, social welfare has been specified in economics to describe the society as a whole, including producers (here farmers) and consumers. More technically, the social welfare is defined as the sum of consumer and producer surpluses. The consumer surplus is the difference between the consumer's willingness to pay for a good and the amount actually paid. The producer surplus is the difference between the price at which the producer was ready to sell a good and the actual selling price. In the debate on reconciling agriculture and biodiversity, the good exchanged between producers and consumers is the biodiversity (or more generally, the environmental good), and the price can correspond to the level of the incentive in the implemented policy. In the analysis based on social welfare, the arbitration between public policies comes solely from the productive and environmental consequences that they involve. A consequence is that there is not a priori benefit to selecting a subsidy-based policy rather than a tax-based policy.[2] In this context, changing the economic perspective of the debate

[2] Even if we have to keep in mind that tax or subsidy schemes are not 100 % equivalent due to tax distortions with substantial potential effects on welfare emerging in tax schemes (Innes 2016).

on public policies stressing agriculture–biodiversity reconciliation deserves attention.

Mouysset et al. (2015) measured the social welfare of public policies involved in the efficiency frontier between ecological and agricultural sector-based indicators (cf Sect. "Designing public policies"). They highlighted that the social welfare of these policies remains stable, thereby suggesting that increasing biodiversity requirement is not necessarily detrimental with regard to the society at a whole. The underlying mechanism is a redistribution of wealth between producers and consumers due to a switch from subsidies to taxes within optimal public polices: increasing biodiversity requirements requires specific land-use changes, which implies the introduction of taxes. Indeed for high biodiversity goals, it is not sufficient to develop extensive farming activities, whose marginal biodiversity benefit is low; intensive activities, with strong negative marginal impact on the biodiversity state, have also to be taxed to be reduced in acreage.

However, it is well known that increasing taxes raises several questions as to whether such measures are socially acceptable. According to Mouysset et al. (2015), the balance of wealth between farmers and consumers offers some opportunities to limit this problem. They suggested that high budgets of current policies could be temporarily maintained even though they are not required for the implementation of high-score biodiversity policies. The budgetary surplus could be temporarily redistributed to farmers in order to help their transition toward eco-friendly agricultural policies. This budgetary benefit could be also distributed to other sets of land-uses regarding other environmental issues (erosion, water pollution, etc.). However, we should note that the financial redistribution of the public gain raises other questions such as equity between agents or the spatial scale of redistribution. A more complete analysis of policy opportunities should also take into account the cost of public funds, which has not been considered yet in bio-economic analysis of European agriculture.

Crisis and viability

The creation of the International Panel for Biodiversity and Ecosystem Services (IPBES) showed that managing biodiversity in a sustainable way requires adopting a double viewpoint bringing together ecological conservation and the welfare of human societies. In that respect, a reasonable management of agricultural terrestrial resources calls for the creation of conditions for sustainability from a socioeconomic and environmental viewpoint. Changing perspectives on sustainability and moving forward the notion of optimality by developing a framework based on the concept of viability could thus be fruitful in order to address the challenge of the agriculture–biodiversity reconciliation. The objectives of such a framework are to overcome the apparent antagonism between ecology, often concerned with survival and conservation issues, and economics rather focusing on the pursuit of efficiency and optimality.

The viability (or viable control) framework (Aubin 1990) deals perfectly with these objectives. It focuses on the compatibility of the bio-economic dynamics with constraints or targets representing the good health of systems (Baumgartner and Quaas 2009; Doyen and Martinet 2012). These constraints are ecological thresholds as inspired by the extinction of population viability analysis (Morris and Doak 2002) and socioeconomic benchmarks. More specifically, the viability approach makes it possible to evaluate the bio-economic risks of scenarios of public policy through the probability of satisfying the set of ecological and economic constraints up to time. Taking into account many economic indicators, including sector-based indicators and social welfare, enables to go beyond the bio-economic antagonism. It allows to concile several potentially antagonist economic perspectives and adopt a broader point of view on the society. This is of special interest when a wide range of stakeholders is involved, such as in agroecological issues. Indeed, each of these groups has an interest in particular outcomes, and some outcomes which are considered desirable by one stakeholder may be not crucial to another group.

The viability framework has been broadly applied to environmental resources management especially to the management of fisheries as in Béné et al. (2001), Eisenack et al. (2005), Péreau et al. (2012), Cissé et al. (2013) and Gourguet et al. (2013). Specific viability works on agroecological issues can be found in Tichit et al. (2007) and Sabatier et al. (2012), which combine the productive and ecological goals and in Mouysset et al. (2014) for economic and ecological insights. The latter have identified viable public policies, which can satisfy a set of economic and ecological constraints throughout time within an uncertain context. By considering different constraints through time, the model takes into account intergenerational equity and allows to reconcile the present and the future. Identifying current public policy decisions which forestall future crises without penalizing the current generation puts the viability approach in accordance with the definition of sustainable reconciliation of agriculture and biodiversity.

Moreover, the viability framework allows to go further the intertemporal issue by dealing with the notion of flexibility. For instance, Sabatier et al. (2012) pointed out that the differences in both ecological and productive performances between the habitat-oriented and result-oriented agri-environmental schemes are limited, but that result-oriented schemes offer a higher flexibility of management for farmers. This study advocates a larger use of result-oriented schemes in conservation which may also allow farmers to adapt their management to local conditions and to climatic variations. More generally, taking into consideration multi-scale issue and global changes such as climate change is crucial to avoid crisis and to deal with the more complete notion of sustainability.

Conclusion

The development of interdisciplinary scientific research in the field of bio-economics or ecological economics brings new insights for decision-makers to design sustainable agriculture. The review of existing studies showed that public policies seem to be essential for reconciling the ecological and economic performances of agriculture. Different types of policies—such as the development of diversification, the advancement of new technologies, extensifying agriculture or implementing payment for ecosystem services—and different levers (including the choice of the spatial scale) can be mobilized to develop an agriculture which is more respectful of ecosystems. Nevertheless, the agriculture–biodiversity reconciliation debate does not stop at the bio-economic antagonism and goes further. Especially, multi-temporal, multi-scale and multi-stakeholder issues as well as global change have to be considered in bio-economic analysis. In that respect, the viability framework should offer interesting methodological opportunities.

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