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THE DESIGN OF ECONOMIC INCENTIVES FOR MORE COST-EFFECTIVE EUROPEAN AGRI-ENVIRONMENTAL MEASURES

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Abstract

From an economic point of view, tendering instruments such as agri-environmental auctions can be viewed as a quasi-market for the production of environmental goods (Latacz-Lohman and Schillizzi, 2005). Since Vickrey's 1961 seminal paper, auction theory (Riley and Samuelson, 1981; Mcafee and McMillan, 1987; Milgrom, 1985; Wilson, 1992; Klemperer, 2004) has been applied to design agri-environmental auctions that use bidding rules and the competition among farmers to mitigate or avoid rent seeking (and the resulting inefficiencies) arising from hidden information about farmers' parameters (i.e. compliance costs, resource setting). The review of the applied policy instruments within the major EU, US and AUS agri-environmental programmes has highlighted the European gap with regards to market-based instruments such as auctions (Vojtech, 2010). While in the last decades there was a growing interest in United States and Australia for these economic policy tools (Latacz-Lohman and Schillizzi, 2006), the European Programs were anchored to instruments that aim to induce environmentally friendly changes in farmers' practices through the provision of uniform payments.

In this work we compare the cost-effectiveness of two simulated auction models (AM1, AM2) with that of classical payment mechanisms as a marginal flat rate payment (MFR) and average flat rate payment (FR). The models follows the one-shot budget constrained auction model first introduced by Latacz-Lohmann and Van Der Hamsvoort (1997), and subsequently by Viaggi et al. (2008) and Glebe (2008). The first model (AM1) deals with one-dimensional bids and it allows farmers to make an offer about a per hectare agri-environmental payment that they would like to receive in order to implement a generic agri-environmental measure on their agricultural land. In AM1, if the proposed payment is accepted, the farmers participate in the agro-environmental measure with their total agricultural area by adopting the agri-environmental prescriptions. In the second auction model (AM2) we further extend the analysis, allowing farmers to offer a combination of payment and a measure of their uptake in the agri-environmental program (i.e. a share of their land to commit under the program). In AM2 each farmer can bid for an agri-environmental payment and for a share of his or her land to be allocated to the agri-environmental scheme.

The models hypothesize that the regulator seeks to purchase multiple units of environmental goods that substitutes traditional cultivation selecting numerous farmers to participate in the agri-environmental auction. Each farmer can choose to produce with a conventional production technology or to comply with some agri-environmental prescription. Assuming that farmers are profit-maximizing agent, they accept to participate to the scheme if through the auction they will receive a payment that must be at least equal to their compliance cost. Farmers' compliance cost have been estimated through a simple methodology, developed by Viaggi et al. (2008), to derive compliance costs from FADN data. Both models assume that farmers differ in the cost of compliance they incur participating in the AEM (i.e. the information that the public regulator is not able to know), and both consider bidders' expectations about the highest acceptable bid as an exogenous variable. This bid cap corresponds at last to the highest accepted bid within the available budget, and representing the reserve price per unit of environmental good/services. According to Lactaz-Lohmann and Schillizzi (2005), we have assumed that the government keeps secretly its value to the potential bidders. Moreover we have assumed that there are no cost in the preparation and implementation of the auction, that the payment is only function of the bid and that farmers are risk neutral.

Once simulated for AM1 and AM2 the optimal bidding behavior of a population of farmer taken from FADN data of E-R 2010 and 2011, assuming a fixed budget level and the sole objective for the public regulator to maximizes

farmers participation to the AEM, we analyzed the total payment, the total cost and the total contracted area in terms of participation comparing the result with MFR and FR payment.

With regard to AM1, considering two-budget hypotheses (i.e. low budget amounting at 0.2 million of euros and a high budget scenario of 2 million of euros) the performance of the auction, evaluated by the percentage of total Utilized Agricultural Area (UAA) of wheat in E-R participating in the hypothetical agri-environmental measure, is 0.26 % of total UAA under the lower budget hypothesis and 1,75 % of total UAA under the higher budget hypothesis. These performances confirm the results of Viaggi et al. (2008) that the auction mechanism is always located between marginal flat rate (i.e. 1.35 % and 3.44 % of total UAA) and flat rate payment results (i.e. 0.13 % and 1.10 % of total UAA). Within the lowest budget hypothesis the maximum UAA up-taken with the MFR is around 5 times the area up-taken with the auction. This difference decreases under the highest budget scenario.

With regard to AM2, maintaining the same budget hypotheses but considering a lower sample of FADN farms and a lower total agricultural area compared to the one considered in AM1 (i.e. the total regional UAA), these results are also confirmed. The performance of the auction (i.e. 7.5 % and 27 % of the total UAA of the sample) is always located halfway between that of FR (i.e. 5% and 21 % of the total UAA of the sample) and that of MFR (i.e. 17% and 100% of the total UAA of the sample). Moreover, in AM2 the farmers offer an average of 30% of their agricultural area, to be committed to the measure, with a maximum acceptable bid cap of 567 euros, equal to the average of the payments for a similar agri-environmental measure in the Rural Development Program of E-R 2000-2006. When the expectation about the maximum bid cap doubles, also the offered share of UAA doubles (i.e. an average 59%), since the optimal share of land increases linearly with the expectation about the maximum bid cap.

According with Schillizzi and Latacz-Lohmann (2007) the analysis of the rate of information rent (i.e. ratio between total payments and total compliance costs) confirms the superiority of AM1 compared to FR. The flat rate option provides an amount of rents that is one and a half the auction's rents with a lower budget and around two times greater with the higher budget level. Thus we find cost savings from AM1 relative to FR. Also the analysis of the rate of information rent in AM2 confirms the results of AM1, we can achieve a reduction of farmers' information rent with AM2 when compared with FR (White and Sadler, 2011; Iho et al., 2014). With a maximum acceptable bid cap of about 567 euros/ha the rate of information rent with FR2 is one and a half larger than the one with AM2.

The results confirm that the auction has the potential to reduce farmers' information rent when compared with uniform policy instruments. Though the scale of saving depends crucially on auction design hypotheses and farmers' expectation about the maximum acceptable bid cap. However, the simulation while reflects a number of plausible assumptions, also remains rather simplified and could be improved in the further research. The results of this research while attempting to provide a useful empirical exploration of auction theory cannot provide a comprehensive solution in most real world settings. However, it can contribute to feed the debate at EU policy level about the role in considering auction design and bidding behaviour so as to limiting the inefficiency related to the actual agri-environmental payments.

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The design of economic incentives for more cost-effective European Agri-environmental measures

Introduction and objectives

Agricultural production causes several impacts on environmental resources affecting air, water and soil quality, as well as biodiversity and the rural landscapes.

While agriculture is a major responsible for water consumption contributing to water pollution and to the production of greenhouse gas emissions, it is a source of carbon sink (OECD, 2008). Many of these environmental effects are recognized as either negative or positive externalities (Vojtech, 2010), for which the market mechanism fails to moderate such impacts or to supply enough environmental benefit. In some cases, the market aligns inadequately the private benefits and costs with the social benefits and costs creating a gap between the private cost of a product (production cost) and the total cost to the environment (including depletion and damage cost). This is due to incorrect market signals deriving from a combination of factor that involve: a) the nature of public goods of natural resources, which are characterized by the absence of secure (and tradable) property rights, b) the extremely costly negotiation process and c) the presence of distortionary subsidies. In other cases, the externalities are caused by the absence of markets for such type of goods. As a consequence producers and consumers are not informed about the true scarcity of the resource they consume or the environmental damage they cause. While agricultural production is sensible to markets signals as individual farmers react to markets changes trying to increase their profit or to decrease their cost, the agro-environmental policies, through the provision of economic incentives, can drive the farmers' adoption of sustainable agri-environmental farming practices (Vojtech, 2010). Where desirable environmental benefit or public goods are undersupplied, a significant role of agricultural policy is to establish procurement contracts and provide incentives to induce the production of such goods, for which the market function inadequately (Moxey et al., 1999). From an economic point of view, such policy instrument can be viewed as a quasi-market for the production of environmental goods (Latacz-Lohmann, 2004).

In recent decades, many countries have developed a wide ranging of experiences concerning the use of agri-environmental policies providing a fundamental cultural shift amongst rural communities in transition toward more sustainable agriculture (Hajkowicz, 2009). Regulations, agri-environmental payments and taxes, as well as emission/consumption quotas and environmental cross-compliance mechanisms have influenced indirectly or directly and for different objectives the actions of individual and collective group of farmers in order to increase the environmental performance of agriculture. However, each country has developed its own particular mixes of policies. While some OECD countries, such as Australia (AUS) and New Zeland, have placed more emphasis on regulations and economic instrument as tradable quotas and permits through community-based approaches, the focus in Europe (EU) and United States (US) have been on agri-environmental payments within voluntary programmes (Vojtech, 2010). These schemes provide incentives to farmers to adopt farming management practices that increase the environmental benefits.

Despite the rising importance of the developed programmes among the OECD countries, the debate about the design of more effective and efficient measures is still subject to a good deal of discussion. While there are various implementation differences, the national Audit Offices of Europe (EU), Australia (AUS) and United States (US) pointed out in their evaluation of the main national agri-environmental programmes that there are also evidences of common negative aspects.

One of the main concerns regards the unneeded farmers rent generated by the miscalculation of payments due to the lack of information about farmers' compliance costs. The presence of information asymmetries about farmers production technologies and compliance costs, does not allow the public administration to set a proper level and differentiation of payment. Consequently, if the proposed payment is higher than farmers' compliance costs, the difference between payment and cost generates a surplus, for all those farmers that have to cover lower compliance costs, which reduces the cost-effectiveness of the programmes. Other common inefficiencies regard the lack of targeting, the lack of monitoring as well as the lack of evaluating the expenditure.

According with a large pool of economic literature, one key way to reduce farmers' rent is to address the 'information asymmetry', which can give rise to the problems of adverse selection and moral hazard limiting the effectiveness of the schemes and making them expensive to run (Wu and Babcock, 1996; Moxey et al., 1999; White, 2001).

These approaches focus on the procurement of public goods theory (Laffont and Tirole, 1993), aiming to analyse the effects of offering to farmers a well-designed differentiated contract scheme, based on the principles of mechanism design. Other literature analysed the opportunity of designing auction mechanisms to reveal farmer compliance cost in order to reduce information rents and increase policy cost-effectiveness (Stoneham et al., 2003; Latacz-Lohmann and Schilizzi, 2006; Glebe, 2008; Viaggi et al. 2008).

The main objective of this thesis is to evaluate through different economic methods the cost-effectiveness of economic incentives applied to agri-environmental policy tools designed for agri-environmental measures. The analysed economic incentives are based on the modelling approaches developed within procurement contract and auction theory that have been applied within the major agri-environmental programmes in Europe, US and Australia, which are the countries where they have found more diffusion. In order to answer the main research question, we address several sub-objectives:

1. To identify which economic incentives can best deal with information asymmetry problems, such as adverse selection, in order to reduce farmers' information rent. Moreover, we deepen the evolution of agri-environmental auctions and contracts adopted in Europe, United States and Australia and draw a methodological framework of the main design options for more cost-effective agri-environmental policies in real life. Multi-dimensional auctions have been identified as the most applied methodologies for tendering Agri-Environmental measures. Empirical studies (Glebe, 2008; Schillizzi and Latacz-Lhomann, 2007; Stoneham et al., 2003) highlights that cost reductions through conservation auctions can be substantial, though the scale of saving depends crucially on the specific auction design.
2. To develop and test two numerical models of a one-shot agri-environmental auction, of which one provides also a multi-dimensional extension, and compare them with two uniform payment mechanisms in order to obtain an empirical application of the methods and issues resulted from the theoretical analysis. The models are developed with data from Farm Accountancy Data Network 2010 and 2011 (FADN) of the Emilia-Romagna Region (E-R).
3. To provide a comparative evaluation of the performance (budgetary cost-effectiveness) of the simulated mechanisms.

According with the literature review carried on the policy mechanisms designed to reduce farmers' rent, the main instruments are categorized in auction mechanisms and self-selection mechanisms (through contract menus). Empirical studies on agri-environmental auctions (Stoneham et al., 2003; Schillizzi and Latacz-Lhomann, 2007; Glebe, 2008;) reported substantial cost saving through their application and while in the major agri-environmental programmes of US, and AUS, there has been a widespread use of these instruments, the transition from theory to practice in Europe is still in its infancy. The outstanding feature of conservation auctions to reveal, at least partly, farmers' compliance costs (Latacz-Lohman and Schillizzi, 2006) can be a key feature for policy-makers with limited information that needs cost-efficient way of allocating funds for rural areas.

While the main analysis and simulation activity carried out in this thesis focused on the first category, the agri-environmental auctions, this thesis sought also to embrace the second category, dealing with adverse selection through contract menus. Thus, the problem of farmers' rent in agri-environmental policies has been also framed in the context of contract theory, providing a methodological analysis and a theoretical model (i.e. see Chapter 2 and 3), allowing a better understanding and representation of the problem.

The remainder of the thesis is structured as follows. Chapter 2 presents a review of the relevant literature on the background of Contract Theory and Auction Theory applied to Agri-environmental policies in Europe, United States and Australia and it introduces the framework of policy tools and design options for more cost-effective agri-environmental policy in real life. Chapter 3 presents the theoretical auction and contracts model and it describes the benchmarks assumption. The proposed methodologies, the data collection and empirical analysis are presented in chapter 4. While 5 presents and interprets the results of the models providing an analysis of the consistency of the research with previous studies, chapter 6 illustrates the conclusions.

LITERATURE REVIEW

1.1 ADDRESSING ENVIRONMENTAL ISSUES IN AGRICULTURE: THE MEASURES ADOPTED IN EUROPE, UNITED STATES AND AUSTRALIA

In the recent decades, there was an increasing attention about agri-environmental issues in most of the OECD countries (Baylis et al., 2007). The European Union, the United States and Australia (AUS) have placed increasing effort on agri-environmental programmes introducing a large number of policy measures to purchase environmental goods and services from rural landscapes.

Some of these programmes have been specific designed to the agricultural sector, while others have been introduced as a part of broader national environmental programmes. In this thesis, all the policy measures in the context of a single government programme and usually procurement on behalf of the public are broadly categorised as agri-environmental measures, but the analysis is focused only on the measure designed for agricultural issues. Some of the policy measures introduced for non-agricultural issues that may have some environmental outcomes are beyond the scope of this research.

According to Eurostat, the EU annual expenditure on agri-environment measures, under the Common Agricultural Policy (CAP), rose from under 100 million euros in 1993 to over 3 billion euros in 2010. Also in the US there was a progressive increase of agri-environmental payments, but occurred in different steps. Prior to 2002 the majority of payments was devoted to land retirement programmes. After the 2002 a first change occurred with the Farm Security and Rural Investment Act (2002) when the funding for agri-environmental measures were extended on cropped and grazing lands. Then a significant reform took place in 2008 as part of the Food, Conservation and Energy Act (FCEA2) with a second extension of the previous support. The 2008 Farm Act re-authorizes almost all the 2002 conservation programmes increasing the spending by nearly USD 8 billion. After these first policies focus on land retirement programmes, there was a progressive shift toward environmental protection of agricultural land. The main US agri-environment programmes are the Farmland Preservation Program (FPP), the Grassland Preservation Program (GRP), the Environmental Quality Incentive Program (EQIP), the Wetlands Reserve Program (WRP), the Conservation Reserve Program (CRP) and the Conservation Technical Assistance (CTA). The support to these programmes has risen from US$ 2 billion per year in 1997 to almost US$ 4.5 billion per year in 2012 (Congressional Budget Office, 2012; FAO, 2010).

In terms of financial support to natural resource management programmes, Australia is in a different situation comparing to EU and US, due to the lower contribute of agricultural subsidies to the conservation programmes. According to OECD Stat Extracts, in the 2012 Australia had a producer support of 2% of gross farm receipts, which is well under the 20% of the average OECD countries (EU almost 23% and US around 10%). This means that the support of agri-environmental policies in Australia has required redirecting funds from other areas of public expenditure. The Australia's major national standalone natural resource programmes are the National Landcare Program (NLP), the Caring for our Country, as well as the National Action Plan for Salinity and Water Quality (NAPSWQ) and Natural Heritage Trust (NHT). According to Hajkowicz (2009), the total financial support for these programmes has risen from the first starting funding package of A$360 million in the year 1990/1991 to A$ 6.51 billion in 2013. Confirming this trend, the planned expenditure for the continuation of the Caring for our Country program after 2013 is still high, amounting to A$ 2.2 billion over the next five years, from 2013-14 to 2017-18 (Australian Government, 2013).

Despite most of these programmes share the objective of improving the environmental performance of agriculture, they differ both in their specific objectives and in their implementation. On the one hand, there are policies that try to address several specific objectives at the same time in order to reflect the complex interconnection of agri-environmental effects (e.g. improving soil quality, water quality, biodiversity and cultural landscape). On the other hand, there are policies that define easily general objectives but then lack of a precise definition and measurement of the specific outcomes (e.g. the environmental benefits, the economic and social impacts). Many policies focus on specific farming practices on farmland (e.g. input reduction), other focus on land allocation to improve grassland, extensive pasture and green coverage, and other are based on land retirement through more restricted conservation measures.

Several factors influence the nature of policy objectives and priorities, namely: the specific environmental values, the nature of property rights connected to the use of natural resources and the societal concerns related to environmental issues. Consequently, the applied mix of policy instruments reflects the heterogeneity of these factors.

According to Vojtech (2010) the most applied instruments can be classified as economic instruments that focus on cost and benefit of alternative actions open to farmers in order to influence their behaviour and improve the environmental outcomes. Other categories include the regulatory measures, the cross compliance approaches, the community based measures and the advisory and institutional measures (e.g. including research and development, technical assistance/extension).

In the economic pool, there are instruments that aim to motivate farmers to change their farming practices providing agri-environmental payments. The uptake in these measures is, in some cases, enforced by regulations and supported by investment subsidies. Under the economic category there are also other policy instruments, such as tradable rights and quotas generally targeted to specific environmental vulnerability, and environmental taxes and charges applied on the sale of inputs identified as having a potentially adverse impact on the environment (e.g. taxes on pesticides, on fertilizer).

The main types of policy instruments that were adopted to address environmental issues are provided below for the three analysed countries (i.e. Table 1). The information was collected from the OECD Inventory of Policy Measures Addressing Environmental Issues in Agriculture.

Table 1. Measures addressing environmental issues in agriculture in EU, AUS and US

Measure/Country	EU	AUS	US
Regulatory Requirements	+++	+++	+++
Environmental cross-compliance	+++	NA	+++
Payments based on farming practices	+++	+	++
Payments based on land retirement	+	NA	+++
Payment based on farm fixed assets	+	+	+
Environmental taxes/charges	+	NA	+
Tradable rights/permits	NA	+	+
Technical assistance/extension	+	++	++
Community based measure	NA	+	NA

NA not applied; + low importance; ++ medium importance; +++ high importance;

Source: Vojotech (2007) and own elaboration.

EU, US and AUS mostly rely on regulations to address environmental issues in agriculture. Policy and regulatory measures are used to prevent the negative impact of agriculture. Over the time, these requirements have generally been applied more broadly, and as awareness of the environmental risks increased, they have become more restrictive. Most of these regulations are related to the use of agricultural input ranging from outright prohibitions, to input standards and resource-use requirements. These requirements constrain environmentally sensitive areas, or areas with higher environmental values (natural reserves) as well as in those close to densely populated areas.

Besides the regulations, specific environmental issues are addressed mainly through environmental programmes targeting specific areas. These programmes may receive support by short-term financial assistance in order to facilitate the local group initiatives in which farmers and landowners can participate to improve the environmental sustainability and the self-reliance of the agricultural sector. Other financial support to this type of initiatives may also be provided in the form of the technical assistance and extension, in which the support goes to investments to infrastructure and on-farm investments. In this type of policy instrument, greater attention is generally placed towards improving the knowledge base relating to environmental issues in agriculture in order to induce voluntary changes in farming practices and improve the environmental outcomes. For example, most of the US agri-environmental programmes support the technical assistance on farms, offering contracts that range from 1 to 10 years. The US EQIP provides assistance of up to 75% of the cost of nutrient management, manure management, as well as integrated pest management, irrigation water management, and wildlife habitat management (Vojtech, 2010). Similar approaches have been introduced in Australia within the community-base instruments. These measures support collective action to address environmental pollution targeting farmers' mutual self interest in environmental conservation in a specific catchment area and make use of local expertise in solving environmental problems.

Moreover, the European Countries and the United States have implemented measures linking minimum environmental standards to agricultural support programmes such as environmental cross-compliance. Cross-compliance measure requires farmers to fulfil specific environmental practices or environmental performances in order to be eligible for payments from specific agri-environmental programmes. Baylis et al. (2007) consider this instrument as a form of compensation for increased regulation. In such schemes, payments are provided upon the respect of certain environmental constraints or with the provision of a certain environmental outcome. While cross-compliance is a significant condition for the US agri-environmental policy since 1985, the EU cross-compliance principle was first incorporated into the Agenda 2000 reform and then developed under the 2003 Common Agricultural Policy (CAP) reform until it became compulsory from 2005 (Council Regulation No.1782/2003 and Commission Regulation No.796/2004 later replaced by regulation 73/2009). Under the CAP reform, all beneficiaries of Pillar 1 direct payments are obliged to respect specific environmental standards (e.g. respect of maximum permitted volumes of fertilizers per hectare) and to keep land in good agricultural and environmental conditions (e.g. maintenance of soil organic matter and soil structure). Within this horizon, farmers are encouraged to play a positive role in the maintenance of the countryside and the environment, while at the same time, these objectives can only be maintained with enhancing compliance (e.g. recently the full compliance has been introduced) with environmental laws by sanctioning the non-respect of these principle and laws by farmers, even reducing the support payments where it is necessary.

Programmes providing payments for the retirement of agricultural land from production have been implemented mostly in the United States and in the European countries. These programmes provide payments for the conversion of agricultural land to wetlands or forest. The economic rationale is to use these programmes as a trade friendly means to transfer income to farmers encouraging them to remain on the land even though no output is produced (Baylis et al., 2007). The major land retirement programme in the US is the CRP that was introduced under the 1985 Food Security Act. The CRP enrols farmers in 10 to 15-year contracts to retire land from production and provides in return an annual rental payment. Moreover, under the 2008 FCEA reform the land retirement programmes continue, with a focus on wetlands. In the European Union the forestry scheme introduced under Council Regulation No.2080/92, currently regulated by the Rural Development Regulation (No.1305/2013), provide incentives for the afforestation of agricultural land.

In addition to payment for land retirement, the agri-environmental payments have been widely used in the policy mixes of the three countries to induce farmers and other landholders to address environmental problems (e.g. reduce nitrogen pollution, reduce the amount of pesticide used) and/or to promote the provision of environmental goods and services associated with agriculture (i.e. Table 2).

Table 2. Agri-environmental payments applied in EU, US and AUS in 2008

Programme/Country	EU	US	AUS
Land improvement (liming, soil erosion prevention)	X	X	X
Payments for nitrate reduction	X	X	X
Nutrient management plan	X	X	X
Extensive crop production	X		
Organic Farming	X	X	
Integrated production	X		
Reduced Tillage/Mechanic weed control	X		X

Crop rotation	X	X	
Green manure crops			X
Green set aside/fallows	X	X	X
Catch crops, green/winter cover	X	X	
Extensive management of all land	X	X	
Extensive grassland management (pastures/meadows)	X	X	
Conversion of arable land into grassland	X	X	
Grassland/biodiversity/habitat schemes	X	X	X
Biodiversity – local breeds	X		
Biodiversity – local species and varieties of crops	X		
Maintenance of wetlands and ponds	X		X
Protected environmentally sensitive areas	X	X	X
Shelter belts/buffer strips	X	X	X
Landscapes elements/Amenities	X		
Maintaining and improving ground cover		X	X

Source: Vojotech (2007) own elaboration.

These instruments combined with a large variety of agri-environmental measures are related to the support of sustainable forms of farming. From one country to another there are differences concerning the type, the level of payments and the mix of policy measures selected to address the environmental concerns. Some authors (Engel et al., 2008; Claassen et al., 2008; Dobbs and Pretty, 2008) referring to the EU agri-environmental payments draw near them to payments for ecosystem services (PES). However, Baylis et al. (2007) highlights that this class of EU policy instruments, including cross-compliance payments, could be broader than the class that meet the requirement of the PES definition made by the Centre for International Forestry Research (CIFOR, 2005). For example, the EU agri-environmental payments are frequently not well defined, while the CIFOR's definition requires that the environmental services be 'well-defined'.

1.2 AN OVERVIEW OF THE MAIN POLICIES TO MANAGE AGRI-ENVIRONMENTAL PAYMENTS

Several factors can have a role in the definition and implementation of the payment schemes under the various policy horizons. From the one hand, some differences might be attributed to different factors endowment, such as land. According with FAOSTAT (2012) and EUROSTAT (2012), the EU has 186 million ha of agricultural land with a population of 504 million, while the US has an agricultural land base of 408 million ha, and a population of 317 million and Australia has 405 million ha of agricultural land with a population of 23 million. However, there is just a little evidence of correlation between the relative scarcity of land, intensive agriculture and the associated environmental problems both in EU, US and in AUS (Baylis et al. 2004). From the other hand, citizens' preferences and farm characteristic, such as the average farm size and the production technologies can have an influence in the type of policies and instrument chosen to address the environmental concerns.

From a policy design perspective, other factors contribute to define the type of payment, namely: policy targeting (e.g. the policy target a specific area or needs), the time duration (e.g. medium, long term), the basis of the payment or the implementation criteria (e.g. based on input use, payment per area/head, resource retirement, non-commodity outputs) and definition (e.g. valuation of a specific project). Payments are generally based on fixed rates for a region. Other bases consider a fixed share of the investment cost or the result of a competitive tender (e.g. the accepted bid in an auction). Many agri-environmental payments tend to be linked to land or to other factors of production, while others focus on farmers' practices. Vojtech (2010) and OECD (2008) classified the various type of payment in three broad categories, namely: payment based on farming practices, payment based on farm fixed assets and payments based on land retirement.

With regard to the payment based on farming practices a description of the major agri-environmental policies is provided in order to identify the main policy characteristics and the fundamental differences between the EU, the US and AUS. These differences can have a direct implication both for how efficiently the agri-environmental programmes through the agri-environmental payments provide environmental services and for their relationship with other policy instruments and other forms of farm subsidies (Baylis et al., 2007). Understanding the policies bargains below these programmes may indicate whether environmental benefits can be achieved in a more efficient manner.

The European agri-environmental policy, is characterized by a predetermined set of management prescriptions (measures) focused on fixed payments to implement more environmentally friendly farming practices going beyond those required by regulation (Engel et al., 2008; Baylis et al., 2007). The agri-environmental measures, based on the subsidiarity principle, were first established in 1985 under the regulation No 797/85. The scope was to reduce the negative impacts of the EU agriculture, to encourage the production of positive externalities and the preservation of the other relevant agricultural function (i.e. Table 3).

Table 3. The function attributed to EU agriculture

Environmental externalities	**Food safety**
Positive	Increasing food availability
Open space preservation	Food security
Landscape conservation	Increasing food quality and health
Reduce city congestion	**Rural Development**
Protection of groundwater	Improvement of farmers' income
Control flood and water damage	Support of rural employment
Control of soil erosion	Preservation of remote areas
Soil conservation	Provision of recreational facilities, agritourism, health and rehabilitation services
Biodiversity conservation	Protection of small business structures
Creating wildlife habitat	Custody of rural traditions
Negative	Preservation of cultural heritage
Production of odours	
Percolation of pesticides, fertilizers and animal manure	**Animal welfare**
Groundwater salinization	
Soil erosion	
Biodiversity Loss	
Genetic pollution	
Toxic gas emission	
Reducing habitat	

Source: Velasquez (2004), Bartolini (2007).

The Regulation No 797/85 was directed to improve the efficiency of agricultural structures and at the same time the Art.19 had provided the possibility for the EU member states to support the introduction of special agricultural regimes in environmentally sensitive areas. Then the Member states basing on various national priorities and environmentally sensitive areas determined the implementation of the agri-environmental practices. Later in 1992, under the MacSharry reform of EU agriculture, the member states were required to implement agri-environmental payment programmes within Pillar 2 of the CAP, under the Agri-environmental Regulation (No 2078/92) providing the over-riding framework within which the subsequent agri-environmental payment programmes have been developed in each member states.

Compared with the previous one, the Regulation No 2078/92 was made mandatory for all member states. The Art.2 conceded the implementation of a greater number of measures than the previous regulation for each Member States subjected on various types of commitments.

The proposed commitments were divided into seven areas of intervention in turn divisible into measures to reduce the negative externalities (A, B, C, D, E) and measure for the creation of positive externalities (D, F, G). Within the Art 3, the regulation asked to each member states to develop Regional programmes with a minimum duration of five years. Then Member states were obliged to implement at national and/or regional level all the proposed commitments. The agri-environmental payments were stated directly in the regulation within a maximum cap, based on the type of crop, on the type of agricultural practice and on the type of action to undertake.

Still in contrast with the previous regulation, the Regulation No 2078/92 increased the EU co-financing share, up to 50% in non-Objective 1 Regions and up to 75% in Objective 1. Moreover, this policy was less targeted than the previous, since it contained measures that are more heterogeneous (Bartolini, 2007).

With Agenda 2000 the agri-environmental measure were definitively considered as a part of the EU Rural Development Policy and integrated under the Rural Development Regulation (No 1257/99). The EU Rural Development Programme (RDP) 2000-2006 aimed to promote structural change of less-favoured regions (Objective 1) and to support measures for the socio-economic conversion of areas facing structural difficulties (Objective 2) within three main thematic Axes:

- Axis 1 improving the competitiveness of the agricultural and forestry sector
- Axis 2 improving the environment and the countryside;
- Axis 3 improving the quality of life in rural areas and encouraging diversification of the rural economy.

The thematic Axes are then developed on five areas of support, namely: support the modernization of the structures, support the environmental practices, support the development of infrastructures and services, support the economic diversification and support the income of underdeveloped farms. The agri-environmental measures were included in the environmental Axis 2 with the objectives to support extensification and incentive more environmentally friendly farming practices that preserve natural resources, provide landscapes services, improve the biodiversity.

From 2007-2013, the Commission Regulation (Ec) No 1698/2005 provided the EU policy framework for the agri-environmental payments aiming to improve the integration between the Rural Development policies with the sustainable development strategies (Goteborg meeting) and other EU policies for increase the competitiveness (Lisbon meeting). This regulation maintained the same objectives and structure of the previous, but has introduced two elements of novelty (Bartolini, 2007). The first one was a programming period of seven year in order to align the rural development policy with the other agricultural policies. Then it introduced a fourth horizontal Axis, namely the leader. Axis 4 was developed with the scope to improve the agricultural employment and farm diversification within a focus on local strategies. Compared with the previous regulation, the agri-environmental measures (Axis 2) remain in the prevailing form of payments for the production of environmental goods and services covering the environmental dimension of sustainability (FAO, 2010). Currently regulated by the Council Regulation (EC) 1305/2013, these measures are implemented through voluntary schemes largely designed by national/regional governments to address specific local agricultural, natural and cultural issues. Voluntarily, farmers commit themselves for a specific period (e.g. minimum duration of five years except for long-term seat aside, which is for a period of at least 20 years) to adopt agricultural management practices that reduce environmental risks or help maintain the cultivated landscape (Uthes et al., 2010). The agri-environmental payments provide the incentive to participate, which the national/regional administration establish based on the additional costs and income foregone (plus transaction costs) that the farmer bears due to the uptake of the measure. In this scheme, the European Union with EU member states financially supports farmers to provide environmental goods and eco-system services across the EU. The EU member countries developed a wide range of national and regional programmes to support less input-intensive farming practices (i.e. low use of fertilisers and pesticides) including as follows: organic farming, integrated production, extensive management of grassland (i.e. livestock grazing with restricted uses of fertilisers and low stocking densities), biodiversity and the cultural landscapes. The above measures are mostly referred to productive land management measure applied under the rural development programmes 2000-2006 and 2007-2013. However, there are other types of EU agri-environmental payments directed to non-productive land management, such as set aside measures, the maintenance of the countryside and landscape features and measure to preserve biodiversity in most vulnerable sites under the Natura 2000 as well as other linked with the Water Framework Directive (Directive 2000/60/EC).

In the United States, as mentioned above, the first wave of agricultural policies was mostly focused on land retirement. Thus, it was only during the third major shift on land retirement programmes (Claassen et al. 2008), within the CRP, that there has been an evolution towards a multi-objective programme aiming to produce several environmental benefits beyond the main concern for soil erosion and productivity (Feather et al., 1999). Considering just the CRP payments mechanism, the US agri-environmental programmes appear more centralized than the EU counterparts. For example, the CRP assure that bids from farmers being evaluated using an environmental benefits index (EBI) applied across the entire nation (Hajkowicz, 2009). The use of such environmental indices to rank contracts offered by farmers in terms of environmental cost and benefit (Claassen et al. 2008), is much more widespread in US and AUS than in the EU. While in the EU member states the agri-environmental policies have the additional objective to support the Rural Development through the compensation of farmers for the provision of positive services and goods, produced by agriculture, the US agri-environmental payments are linked to agriculture's negative externalities (e.g. soil erosion or nitrogen surplus), based on a cost share and incentive basis. The CRP has begun in the 1930 with a focus on soil protection and to reduce the production of certain crops that were in excess of supply. Likewise, beginning in the 1936, the Agricultural Conservation Plan (ACP) firstly focused on soil conservation structures, then it has been only more recently that it funded a broad range of agri-environmental activities. From the mid-1980 the the US polices have been widened to include the reduction of agriculture water pollution and ensuring that farming does not result in the draining of wetlands and the loss of wildlife habitat (Claassen et al., 2008). From 1996, the ACP was combined with a number of small programmes to form the EQIP, which approaches multiple environmental objectives. Under this scheme, the Conservation Security Program (CSP) established under the 2002 FSRI Act, provide payment for adopting or maintaining several farming practices. CSP focuses on one or more vulnerable area where providing three different tiers of participation based on contract length and total payments. Alongside to the national programmes' evolution, the same emphasis and changes has been posed on conservation programmes at state federal level (i.e. reduction of negative agriculture externalities and provision of public good).

The US programmes attention to the negative externalities is reflected on more targeted policies. While the EU programmes address a wide range of externalities, the US focuses mostly on water quality, wildlife habitat and soil quality. Furthermore within US agri-environmental schemes the agri-environmental payments are generally conditioned to the achievements of environmental outcomes (e.g. in the case of the CRP the environmental outcomes are measured by the EBI index). While the European policy assumes that, less intensive farming reduces input use and therefore the negative externalities, the US policy pays more directly for the achievement of the environmental objectives. The degree of targeting will determine how well a programme meets their objective (Hodge, 2000). The US and AUS policies focus on payments to reach environmental objectives measured by the quantities of environmental services produced. On the opposite, The EU payments are tied to input reduction or technology use. The US CRP and AUS BushTender programme as previously mentioned, uses EBI index, which constituted a detailed targeting instrument. The index is used to impute the environmental services expected from ceasing to farm a certain field (FSA, 1999; Babcock et al., 1997). By contrast, to receive the payment in the EU, it is generally sufficient to commit to use inputs and/or technologies that have been designed as environmentally friendly. The same payment is received either participation are provided in sensitive area or in area where change will have a little environmental impact. However the CRP's higher degree of targeting has a larger information cost, which might raise the problem of the balance between the economic efficiency and environmental achievements. To calculate the EBI index, the US governments requires detailed information on environmental characteristics of the applicant fields, information on the benefits produced and a specific weighting of the objectives. At the same time, there are cases where benefit of one or more action are difficult to quantify and/or measure and it is possible that targeting the externalities may result in fewer environmental services than targeting the input. Environmental cost-effectiveness has been an important criterion in the development of US agri-environmental policies. Osborn (1993) argue that in 1990 the US Congress authorized environmental cost-benefit targeting in CRP and Classeen et al. (2008) that in 1996 the Congress directed the USDA to maximize environmental benefit per dollar of programme expenditure in implementing EQIP. The benefit maximization implies that the payment must be targeted to those combinations of practices and land that yield the greatest environmental benefit per dollar of cost and making those payments in amount necessary to encourage the production of the desired practices on the targeted space of land. To reach this objective the public managers need to identify those combinations of land and practices that would yield the greatest combinations of environmental benefit relative to cost (Babcock et al. 1997; Classeen et al. 2008).

The different views about agriculture externalities in both EU and US influences the different approaches to the agri-environmental payments. Baylis et al. (2007) argue that European perceive the highest environmental value for the land when used for farming, while US policy has demonstrates that land is perceived to attain a higher environmental value when is taken out of farming and returned to its natural state (Dobbs and Pretty, 2004; Hellerstein, 2002). For this reason a significant fraction of the EU agri-environmental payments is targeted at limiting land abandonment in Europe (Baldock et al., 1996), while farmers in the United States are often paid to return farmland to its native state (e.g. within the CRP programme and the Wetlands Reserve Program – WRP). However the Farmland Protection Program, renamed in the 2002 Farm Bill as the Farm and Ranch Lands Protection Program (FRLP), provides financial support for the purchase of conservation measures with the aim of helping farmers and ranchers to maintain productive their land. This programme was created with the purpose of limiting the urban sprawl, thus it has determined an allocation of the land to States focusing on the different pressures on agricultural land. In contrast the EU agri-environmental programmes encourage participation in remote and mountainous areas (Baldock et al., 1996).

The Eu agri-environmental policy focuses on externalities that are by-product of the intensification of farming (i.e. the use of too many non-land inputs per unit of land), whereas the US policy focuses mainly on the by-products of extensification of agriculture on marginal (i.e. use of excessive amounts of environmentally sensitive) land (Baldock et al., 2002). This difference can be stressed comparing the US EQIP programme with the EU RDP. The first subsidizes farmers to install manure storage and fencing system, which allow higher stocking rates, while the second support farmers for decreasing their stocking rates.

Thus, both the EU and the US agri-environmental programmes are characterized for a different focus on supporting extensive and intensive agriculture (Table 4).

Table 4. Support extensive vs. intensive agriculture

Programme target	EU	US
Reduce intensification	Chemical reduction payments; payments for organic farming;	None
Reduce extensification	None; exception for some biodiversity payment;	CRP; CSP; WRP; Sodbuster; Swampbuster;
Support intensification (limiting pollution)	LFA payments for intensive production in Italy and Spain	EQIP (payments for confined animal)
Support extensification	LFA payments; payments for non-abandonment	None
Support move from intensive to extensive	Payments for low stocking rates	None
Support move from extensive to intensive	None	None

Source: Baylis et al., 2004 own elaboration.

Another difference between the analysed countries derived from the differentiation of payments by opportunity cost. In some of the mentioned AUS and US programmes, payments are determined through competitive auctions, which require submitting bids based on EBI index. Contracts are then allocated based on the highest benefits for least cost. Since farmers are unlikely to submit a bid, which is lower than the amount of profit foregone due to the participation to the agri-environmental measures, the opportunity cost is taken into account. However, in the EU, enrolment is voluntary. Thus, farmers are offered an amount per hectare based on the individual member state's calculation of the income foregone and additional cost resulting from the commitments (COM, 2005).

The current major Australian agri-environmental programmes are also developed within a gradual evolution in the regulation and policy design started from the early large federal programmes and directed towards the creation of new regional institutions and direct payment systems for environmental stewardship. Currently the natural management is determined by four-governance level: Federal, State/Territory, Local and Regional. Each level is creating its own policies, plans and legislation resulting in a complex governance environment. According with Hajkowicz (2009), the Australian natural resource programmes associated with agriculture are mainly focus on securing healthy and productive landscapes, which supply multiple environmental goods and services. To address these wide objectives, the various AUS programmes focus on several externalities with an approach that can be close to the EU counterpart and even less targeted than the US ones. However the evolution of such policies starts from the early 1990 with Landcare Program (the first AUS standalone natural management programme) since previous programme, such as the National Soil Conservation Program (NSCP) that run from 1983 to 1989, was mostly a research and advisory programme. The objective of Landcare were to raise the awareness of the community regarding land degradation problems with a focus on creating new partnership, an improved policy environment and contribute to sustainable agriculture (AFFA, 1997). However, despite this early focus on the negative externalities linked with agriculture within a community framework for the implementation of programmes, it has been only after a second phase of the NHT programme that the Australian Government started to trial the potential of market-based instruments towards a direct payment system. A key development occurs in the 2002 within the National Market-Based Instruments (MBIs) Pilot Programme where a wide range of MBIs were explored focusing on devolved rent or auction. Many programmes, such as the Bush Tender programme, the West Australian Conservation Auction, as well as the New South Wales Environmental Services Scheme, The Queensland NatureAssist programme and the Liverpool Plains, involved direct payments to landholders for the provision of agri-environmental goods and services. Auctions have been developed to involve farmers and landowner participation to obtain salinity control, nutrient balance and improve biodiversity (Stoneham et al., 2003). The Australian auction programmes likewise the US CRP and EQIP programmes are based on competitive tendering, where farmers bid for contracts that generally request the provision of environmental outcomes or conservation services. Once all the bids have been received, are then evaluated and measured by a weighted multi-criteria index such as EBI index. Latacz-Lohmann and van der Hoomsvoort (1997) argue that auctioning conservation contracts as a means of creating markets for public goods offers, from the buyer's point of view, significant advantages in terms of cost effectiveness compared to a simple fixed-rate payment scheme. Empirical studies (Glebe, 2008; Schillizzi and Latacz-Lhomann, 2007; Stoneham et al., 2003) highlights that cost reductions through conservation auctions can be substantial, though the scale of saving depends crucially on the specific auction design.

According to Lankester and Greiner (2007), there are also variations to this policy approach. For example, in the Burdekin Dry Tropics of North Queensland under new schemes, farmers can swap debt in exchange for conservation services. These approaches are similar to the previous but are much more targeted and involve a clearer statement of outcomes and more sophisticated means of measuring benefit (Hajkowicz 2009). In Australia, the success of auction schemes has contributed to the development of an Environmental Stewardship service package announced as a separate programme (Australian Government, 2007). This programme has been integrated in the Caring for our Country programme, which amalgamates the NLP and NHT. The Stewardship programme has been applied in a specific region (e.g. the box-gum woodlands mostly within New South Wales) within a more targeted approach in order to obtain more tangible and direct results. It involves direct payment to farmers and landholders under competitive tendering for the provision of a range of environmental and biodiversity conservation measures and social services. Moreover, Land for Wildlife and Trust for Nature, are other examples of Australian schemes that facilitates farmers' commitments to biodiversity conservations (Stoneham et al., 2003).

However, there are also AUS programmes that involve the provision of fixed payments. For example, under the NHT Bushcare programme, payments are offered to farmers on a fixed-price basis, for fencing and management of remnant vegetation.

Despite the wide ranging and increasing experience with the use of agri-environmental payments, according with OECD (2002) the evidences of their cost-effective application and impacts is often quite limited. The Australian National Audit Office in 1997 and 2008 in the evaluation of Landcare and NHT programmes highlights several problems of evaluation regarding the lack of operational objectives that determines difficulties to quantify their intended outcomes and lack of targeting, monitoring and evaluating expenditure. Similar problems have been found in the reviewing of the EU and US agri-environmental policies (GAO, 2006; ECA, 2006; ANAO, 2008). The European Auditor have reported observations about a general lack of effective eligibility condition, selection procedures, as well as a lack of targeting, monitoring and difficulties to obtain reliable information from the evaluation system of the EU RDP 2000-2006. Due to the criticized lack of clear objectives, the new Rural Development regulation requires the explicit definition of clear objectives and an ex ante (before programme), mid-term, and ex post (after programme) evaluation (COM, 2000). Moreover, from the last programming period 2007-2013 a Common Monitoring and Evaluation Framework (CMEF) for monitoring and evaluation of all rural development intervention has been instituted. Similar problems have been found also in the Unites States. The General Accounting Office found several deficiencies regarding the mechanism used in the EQIP to allocate funds amongst States.

The problems of measuring and valuing outcomes and the difficulties to link public expenditure to outcomes that emerged in the three countries, constitute a part of the main debate on the effectiveness and efficiency of agri-environment measures. Other inefficiencies of agri-environment payments (Engel et al., 2008), focusing on the EU level, can be enumerated below: a) limited information about measures; b) high administrative burden; c) absence or lack of monitoring on farmers' commitments; d) lack of information about actual compliance costs and farmers' rent; e) poor spatial targeting.

The first two points may result in difficulties for farmers to access and properly use the funds. The third point, concerning the lack of monitoring, may give rise to cheating with regard to the prescription of the measures (Ohl et al., 2008).

The fourth point regards cases where the public administration has a lack of information about farmers' compliance costs, which can in turn result in a miscalculation of payments and resulting in farmers' rent. When the proposed payment is below the farmers' participation cost, according to Engel et al. (2008), it is insufficient to induce the adoption of the environmentally friendly farming practices. In the opposite cases, when the payment is greater than the actual compliance cost, it can generate a rent for farmers. In these cases, the presence of information asymmetries about compliance costs, between the regulator and the farmers, does not allow the regulator to set a proper level and differentiation of payment, hence generating profits for all those farmers who have to cover compliance costs that are lower than the proposed payment. This problem of farmers' rent, which represents the focus of this research, will be deepened in detail in the next chapters.

Finally, Uthes et al. (2010) identify poor spatial targeting as one of the major cause of the deemed low effectiveness of AEMs. The absence or weakness of spatial targeting can result from a lack of knowledge about the main local needs and environmental vulnerability. Moreover, poor spatial targeting occurs when these measures are applied uniformly throughout the geographical area and farm types. This results in a lack of the programmes to take account of areas where the environmental benefits are higher. It may also reflect cases in which payments are directed to practices that would have been adopted anyway, generating a wasteful use of public resources. Finally, lack of targeting may hinder its potential contribution to cost reduction, as targeting could support an attempt to balance concentration of the support in high environmental and low compliance cost areas to pursue a cost-effective application of the measures. To improve the targeting of these measures by focusing on the main local concerns, the local administration needs to set and identify zoning and target provisions in the policy/measure design. However, this process entails higher public transaction costs and leads to increase the administrative burdens, as compared to a lower targeting effort.

Many factors can have a role in the choice of a particular targeting approach, such as administration costs, budget availability, and spatial variability in terms of benefits and costs. Wünsher et al. (2006) remind us that the limit for each reasonable improvement is given by the amount of transaction costs required by additional data needs and changes in administrative procedures. The literature on targeting issues includes a set of various priority or eligibility criteria applying to the measures, mainly based on population density or the amount of inhabitants of the municipalities. Uthes et al. (2012) distinguish different approaches to targeting mechanisms, which range from relatively simple approaches based on benefit, cost targeting, eligibility criteria only, to more complex and selective targeting mechanisms based on zoning policies, or scoring systems such as the one provided by the EBI index under the CRP and Bush Tender programmes.

1.3 AGRI-ENVIRONMENTAL PAYMENTS DESIGN WITH LIMITED INFORMATION: DRAWN LESSONS ABOUT POLICY DESIGN OPTIONS FOR REDUCING INFORMATION RENTS IN REAL LIFE

As emerged in the three analysed countries, agri-environmental schemes face many challenges since it is a complex task to link expenditure to outcomes, measuring environmental effects in practice, selecting the appropriate environmental target and evaluating cost-effectiveness. Implementing a relatively cost effective agri-environmental programme requires a great deal of information on potential environmental benefits and the adequate system of incentives. Two main features are common to agri-environmental schemes in EU, AUS and US. According to Wunder (2005), Ozanne and White (2008), from the one hand there is the voluntary participation of farmers that requires an economic compensation in terms of agri-environmental payments. From the other hand, the participation involves a management agreement or contract between the farmers and the government. Agri-environmental contracts must specify the agricultural practices that the farmers must carry out to produce environmental benefits and the minimum level of payment that farmers would be willing to accept in return for taking action in order to obtain these benefits. The voluntary transaction generates by the agri-environmental schemes must be accompanied with a well-defined environmental service that is being purchased by the government or other public agencies from one or more farmers. This second feature of agri-environmental contracting represents one of the most discussed weaknesses of the approach. The contractual relationships are subject to asymmetric information between farmers and government and can be described by the fact that the farmers know more about on-site costs and local impacts than the government. Information asymmetries cause the major discussed obstacles to designing and implementing more efficient payments schemes and make them expensive to run (i.e. a comprehensive literature review of agri-environmental contracting design in the presence of information asymmetry is provided in chapter 3 of this thesis). Two are the most important information asymmetries in the design of contract. First, the presence of hidden information or adverse selection (Chambers, 1992; Wu and Babcock 1996; Latacz-Lohmann and van der Hamsvoort, 1997; Moxey et al., 1999; White, 2001) arises because individual farmers have more information about their individual cost of compliance than the government (Ozanne and White, 2008). This informational advantage creates the incentive for the farmer to claim compensation payment higher than its own compliance cost. More in detail, farmers use their private information as a source of bargaining power to extract informational rents from governments. Second, the government's difficulties to monitor individual compliance perfectly, can give rise to hidden action or moral hazard (Latacz-Lohmann, 1998; Choe and Fraser, 1998, 1999; Ozanne et al., 2001 and Fraser, 2002), which create the incentive for farmers to seek profit through non-compliance on the prescriptions stated in the contracts. Thus, the question becomes, why these information rents makes measures expansive to run? When governments pay informational rents, they obtain in return less environmental benefit per euros spent than what they could obtain in a contract where the opportunity costs of provide environmental services and goods are observable (Ferraro, 2008).

According to Ferraro (2008), there are three-design approaches to reduce both informational rents. The first rely on costly-to-fake signals to gathering more information on farmers. This approach aims to obtain information on observable farmer's characteristics linked with opportunity costs and uses these attributes to establish the participation price. The soil type, the distance to roads and markets, the forest type and the assessed value are some examples of these attributes that are often correlated with opportunity costs and costly for farmers to fake. Then eligibility criteria can be based on this information reinforcing the distinction of contract types and prices. This approach have been commonly used in EU and US agri-environmental schemes where price have been differentiated on the basis of targeting mechanism or zoning system to reflects regional differences in opportunity cost. Furthermore, minimum eligibility criteria can be also used to exclude the participation of low opportunity cost farmers.

Wätzold and Dreschler (2005) discuss the possibility of spatially heterogeneous compensation payments for biodiversity-enhancing land-use measures. Their results show that the cost-effectiveness of uniform payments may be lower than differentiated payments, depending on the assumption on cost variability, benefit function and the correlation between them. The costs of agri-environmental measures, such as biodiversity-enhancing land-use measures, clearly differ because of the variations in soil quality, opportunity costs for land and the availability of equipment to carry out such measures (Wätzold and Dreschler, 2005). Other works have studied the issue of spatial differentiation of environmental policy instruments (Viaggi et al., 2012) by analyzing the efficiency losses with spatially uniform regulation (see e.g. Kolstad, 1987; Babcock et al., 1997; Ferraro, 2003; Johst et al., 2002). These studies, focusing conservation measures, try to incorporate the ecological and economic knowledge into the evaluation of conservation instruments through an estimation of a biodiversity benefit function. Their findings seem to confirm the presence of efficiency losses with uniform payment policies and the need for alternative payment mechanisms that consider heterogeneous costs. However it is very difficult for the administration to know the different compliance costs and it would be administratively burdensome to attempt to determine such costs. For this reason, the actual payments are designed on the basis of average compliance costs as uniform between different areas and targets. Yet even in this case the regulator does not necessarily know the correct average.

The second approach develops screening contracts to induce farmers to reveal their type by offering a contract for each of the different type of farmers that participates in the scheme. This approach focus on the procurement of public goods theory (Laffont and Tirole, 1993), aiming to analyse the effects of offering to farmers a well-designed differentiated contracts scheme, based on the principles of mechanism design (i.e. for a discussion on the principles of mechanism design within the relevant literature and economic models see the next section). Despite the appeal of screening contracts as policy tools to improve the efficiency of agri-environmental policies, they are rarely used in practice due several constraint that limiting their application. According with Arguedas and van Soest (2011) the main reason for this lack of real-world application depends from the one hand to the difficult of the public regulator to gather information on farmers' activities and types, and from the other hand to the outcomes of such contracts, which are always second best. To design efficient contracts, the public administration needs to acquire a great deal of information about all the relevant economic characteristics and environmental impacts of the various farming activities. These characteristics should include those relevant factor affecting farmers' compliance costs of providing agri-environmental goods and services (i.e. their technology or production function, their land quality, etc.). Without this relevant information, a first best policy can not be implemented, because it will always be not incentive-compatible due to the presence of a certain degree of information asymmetry. Then, if we shift on incentive-compatible mechanism, the extant literature points out that it can provides a compensation payment to the low-cost farmers type larger than the actual compliance cost of this type (i.e. farmers of this type still receive a certain amount of informational rent) and that the level of conservation required to the high type is below the first level (Moxey at al., 1999). Thus, considering these two inefficiencies and adding that this types of instruments deserve a great deal of effort in the sophisticated calculation that require, the net benefits of design incentive-compatible contracts seem to be far from their theoretical potential. Probably for this reason, the attention has shifted towards alternative instruments; one of these is the agri-environmental auction (Ferraro, 2008).

The third approach consider procurement auction in which farmers bids for agri-environmental contracts. Procurement auction, as mentioned above, have been mostly used in the US and AUS conservation programmes. In these countries the Governments increasingly recognise the potential of auctions as a policy tool for allocating public resources (Latacz-Lohman and Schillizzi, 2006). According with Ferraro (2008), procurement auctions use bidding rules and market competition to reduce incentive for farmers (i.e. sellers) to inflate their contract price. In the US, the competition is assured by the limit imposed to the main USDA programmes on budget and acreage enrolment. Through competitive auctions the policy makers can learn what farmers are willing to offer for programme enrolment, which practices they are willing to adopt and what level of payment they are willing to accept in order to reduce information rent (Claassen et al., 2008). Unlike screening contracts, auctions do not require the specification of the distribution of farmers' type, since farmers reveal this distribution through their bids. The major strategy adopted in the auctions performed in the US and AUS, for obtaining cost effective programme outcomes, involves the collection of the relevant farmer's information during application and the use of a benefit-cost indices to select programme participants. As mentioned above, the US CRP, represent an example of a compensation programme based on benefit-cost indexes. This programme remunerates agricultural producers to provide conservation benefit on environmental sensitive land. The participating farmers can choose from a menu of practices that focus on long-term (e.g. the menu include soil conservation measures, measures to improve water quality, air quality, and enhance wildlife habitats). The Farm Service Agency (FSA) of the United Department of Agriculture (USDA) administered the programme. While with regard to the voluntary nature of the CRP, it is comparable to EU agri-environmental measures, for the selection and enrolment procedure and the targeting mechanism, however, is much more selective and competitive (Table 5). Programme application and enrolment follow a screening phase in which eligibility criteria determine which farmers can apply and then with the provision of the agri-environmental payments only the interested farmers are selected.

Table 5. Screening application and eligibility criteria in the EU, US and AUS agri-environmental programmes

Payment programme	Regulated by	Eligibility criteria	Additional selection criteria
EU agri-environmental payments	EU RDP regulation and regional rural development plans	First, eligibility is determined by the objective of the specific regional rural development plans refined through the specific objectives of the single measure. Second criteria of RDP measures generally answered to the "who"-question, defining who is a candidate participant (e.g. based on the type of business, farming orientation, age or other factors). Then there is the "where" criteria responding to the designation or exclusion of zones with specific characteristics. Then there are criteria that define "When" (e.g. indicating starting date or cutting after a certain date) and for "how long".	Different rural priorities scheme can administered the measure, ranging across each EU region from a competitive process based on a scoring system and zoning policies to relatively simple criteria based on "First come, first serve principle".
US CRP	FSA – USDA	Is focused on highly erodible land. Annual sign-ups and offers where ranked according to the EBI index, which is comprised of five environmental factors plus cost. Each of the environmental factors and the cost factor consist of sub-factors related to specific practices offered by farmers and physical site factors. The points achieved for each sub-factor are added up to calculate the final EBI. Bids with EBI scores above a cutoff level are accepted. The FSA determines the offer acceptability (cutoff level) based on the ranking results.	If different types of land usage occur an area-wighted average is calculated. Land that meet more stringent guidelines can also be enrolled through continuous sign-up.
AUS Bush Tender	Victorian Department of Primary Industries	The first version was a field trial that focused on biodiversity through the improvement of bush vegetation. After that trial, the Victorian Government have been run the Bush Tender 1, the Bush Tender 2, River Tender Auction, Plains Tender and EcoTender. Pre-negotiated contracts were evaluated according to	

		the Biodiversity Benefit Index (BBI) defined as the ratio between the product of the conservation value score (define the value of the site) and the habitat amelioration score (value of farmer's effort) and the cost announced by farmers. Bids were ranked according to the BBI ratio, from highest value per dollar bid down, until the budget limit.

Source: own elaboration.

Producers who are interested in participating offer a bid that indicate what land will be enrolled, what practices will be adopted and the desired payment. Once all bid are collected the FSA is in charge to assess the potential benefits and provide a rank of selected bidders. Famers were ranked according to their ability to deliver environmental benefit per dollar of programme expenditure (Claassen et al., 2008). Then the applications are accepted in the rank order until the budget is exhausted or the acreage cap is reached. However the selection is conditioned by the contract term of the programme. In long-term programme, as CRP, public managers may decide to reject some current application in order to receive in the future better applications in term of delivery of agri-environmental outcomes. In Victoria (AUS), the Bush Tender trial was carried out in 2001-2003 for biodiversity conservation contracts through the improved bush (i.e. native vegetation) management. In this pilot auction, ecological data and expression of interest were first collected and then government officers visited the farm and the land areas discussing management options with farmers. Farmers then submitted sealed proposal including their proposed conservation activities and their required payments (Ferraro, 2008). Bids were ranked according with the Biodiversity Benefit Index (BBI), from highest value per dollar bid down, until the budget constraint was hit. Other two conservation auction was performed in Australia, namely: EcoTender and the Auction for Landscape Recovery (ALR). Ecotender was an offshoot of BushTender and the Western Australia ALR presented similar intent aiming to achieve multiple environmental benefits (e.g. salinity control, biodiversity enhancement and water quality).

Since an auction is no more than a set of rules for determining the allocation of resources, unfortunately many of the design features described for agri-environmental auctions (i.e. the bidder asymmetry and multi units of environmental benefit) violate the standard assumption in auction theory (Ferraro, 2008) leading the auction mechanism to a less efficient result than the one predicted by the theory. However auction theory still does not provide clear answers about the appropriate rules for agri-environmental auctions. Policy designers and scientists are researching with experimental economics and agent-based modelling (simulations) the performances of alternative auction environments. Reducing rents is an important task for the public agents who aim to maximize the environmental services obtained from their limited budget. Competitive bidding compared to a simple fixed-rate payment scheme (which is the norm in the EU RDP, though the option of competitive allocation allowed by the regulation) is a more complex incentive mechanism that can be a powerful approach to increase the efficiency and potentially effectiveness (assuming a given budget) of public spending for purchasing countryside goods and services (Table 6). On one side the outstanding feature of conservation auctions is their potential to reveal, at least partly, farmers compliance costs (i.e. uniform price auction). On the other side there are an increase interest from regulators to seek information about compliance cost. From the policy design experiences analysed, several information about the potential approaches to reduce information rents can be drawn (Table 6). These approaches will be further analysed in depth in the next chapters, from a theoretical point of view and through the analysis of simulation, in order to draw more targeted information on the design features and on the relative cost effectiveness of such schemes.

Table 6. Approaches to reduce information rent in agri-environmental contracts

Approach	Institutional Complexity	Informational Complexity	Technical Complexity	Rent reduction	Distortion to contracted services	Comments
Target based on costly-to-fake signals	+	++	+	+	++	Good when correlations between signals and farmers are strong; information acquisition can be costly; field examples.
Screening contracts	++	+++	+++	++	+++	Powerful theoretically; Technically challenging; No field examples.
Procurement auctions	+++	+	++	++	+	Requires competition to achieve rent reduction; uncertainty with repeated format; field examples.

+Low; ++Medium; +++High

Source: Ferraro (2008).

THE THEORETICAL AUCTION AND CONTRACT MODELS

1.4 OVERVIEW OF THE ANALYSED METHODOLOGIES

Chapter 2.2 highlighted different types of incentive problems in agri-environmental contracting. Most of these are mainly caused by the asymmetric distribution of information between government and farmers. Since the latter know best the management techniques and the site-specific production costs, they are considered to have an informational advantage over the government. Farmers can use their private information about compliance costs in order to gain an economic rent through the agri-environmental payment established by the contract, which reduces the cost-effectiveness of the measures.

According to Nicita and Scoppa (2005) the explicit consideration of information asymmetries between the parties involved in the agri-environment contract refers to the approach of information economics, in which authors like William Vickrey, George Akerlof, Michael Spence and Joseph Stiglitz, have created the foundations since the 90s. Following the approach adopted in these theories, one of the parties of the contractual relationship, defined as agent (the farmer) has more or better information than the other, defined as the principal (the government), with respect to his/her specific characteristics or other external environmental conditions (hidden information), typically before the contractual relationship (adverse selection).

When the agent has also an informational advantage on the actions taken (hidden action), which occurs after the conclusion of the contract, we are talking about moral hazard. Since usually the utility of the agent differs from the utility of the principal, it is argued that the agent may exploit the information asymmetry behaving opportunistically. The fundamental assumption behind this theory is that the results of the transactions cannot be traced back to the actions chosen by individuals or through their characteristics. Uncertainty enables opportunistic agents to conceal information about their behaviour and characteristics.

With regard to the agri-environmental contracts, Latacz-Lohmann and Schillizzi (2006) argue that the adverse selection arise when the agency, which is unable to observe the individual farmers' compliance costs, provides to those farmers with low potential for producing high quality environmental output, an agri-environmental payment that is higher than their compliance cost. In economic terms, the difference between payments and compliance cost generates an economic surplus for these farmers, while for the other that have to cover greater compliance costs, it becomes unprofitable to participate to the measure, but these farmers might have the potential to deliver the greater environmental benefit. Adverse selection occurs also when payments are directed to those farmers who have to make less severe changes to current agricultural practices resulting in lower compliance costs, like farmers who have already managed their land in an environmental friendly way. Fraser (1995) and Wu and Babcok (1996) demonstrate that there is also the opportunity that the low-intensity farmer conceals information about his pre-contractual farming practices and he declares himself as a high-intensity farmer, in order to receive higher payments.

Moral hazard refers to the impossibility to monitor perfectly the action and the terms of the contract by the agency. The economics literature defines moral hazard as post-contractual opportunism that occurs when after the definition of the contract phase, the agents perform unobservable actions (by the principal) influencing the utilities of both the parties. In this case, farmers have a greater incentive to renege their contractual obligations. If farmers know that they can easily avoid the detection of the compliance by the agency, due to the imperfect compliance monitoring, they have a greater incentive to renege their contractual obligations.

The economics of information addresses what are the main consequences of moral hazard and adverse selection under the market forces and it analyses the contractual or institutional mechanisms adopted by agents with the aim of preventing the developing of the opportunistic behaviours. In this context the role of incentives become critical and the players must be encouraged to undertake certain behaviours efficiently.

Since the thesis focuses on the research of the contractual mechanisms that lead to the definition of an optimal cost-effective system of incentives (payments) in the pre-contractual phase, the analysis deepens the problem of limiting adverse selection and it excludes the problem of hidden actions. However, a more complete analysis of the optimal incentive mechanisms should also include the issue of moral hazard, but since it goes beyond the scope of this research, because it arises in the post-contractual stage, it can be a potential focus for further studies.

Policy mechanisms designed to address adverse selection and reduce hidden information have been broadly cathegorized by Latacz Lhomann and Schillizzi (2006) into two categories: self-selection mechanism (through contract menus) and auction mechanism.

Self-selection mechanisms rely on the principles of incentive-compatible contracts (Laffont and Martimort, 2002) developed by Mirrlees (1971), Dasgupta et al. (1979), Guesnerie and Laffont (1984) and others. The classic approach is to set up a principal-agent (PA) model whereby the principal (the government) arrange optimal contracts for different resource settings or compliance costs of agents (the farmers) ensuring that agents voluntary select the contract designed for them. In order to overcome the presence of hidden information the contracts must be incentive compatible, meaning that the contracts must remove the incentive for farmers to misrepresent their characteristics and compliance costs in order to obtain a favourable combination of management prescriptions and payment rates. Thus, by offering different management practices and payment levels, the principal orients farmers' choices in order to detect information about their respective adverse selection parameter and to ensure that farmers with a particular resource setting, such as highly productive farmers or high compliance cost farmers, prefer the contract intended for them to all other options offered in the menu. The application of incentive compatible contracts through mechanism design in the context of agri-environmental policy (Wu and Babcock, 1996; Moxey et al., 1999; White, 2001) ensures that farmers will find it optimal to choose the appropriate contract for their type, revealing the information about their characteristics to the uninformed principal and thereby reducing information asymmetry. In order to offer incentive compatible contracts, the government must chose the contract variables (e.g. management prescription as production input or production technique, and payment rates) that for a highly productive type it will provides exactly to this type the highest payoff compared to all other contract option on offer. Moreover, the appropriate contract must also contain and satisfy the farmers' participation constraints (i.e. "individual rationality" constraint) implying that farmers must get at least their reservation payoff (Latacz Lhomann and Schillizzi, 2006). The result is that the agri-environmental contract is feasible if it satisfies both the self-selecting constraint and the participation constraint, and if it is feasible, it ensures that the farmer will choose the options intended for him or her maximizing the government objective function.

Contract Theory was previously applied at the end of '90 to the problem of designing second-best agro-environmental programmes. Early papers include Smith (1995) who analysed how mechanism design theory could be applied to reduce the programme outlay of the US Conservation Reserve Programme and Smith and Tomasi (1995) who addressed the problem of limiting pollution runoff from farmland with an input taxes instrument. Their work focused on the analysis of how the transaction costs affect the optimality of the input taxes mechanism when the parameters of the profit function are just known by the farmer. Further studies related to agri-environmental policies were carried on by Wu and Babcock (1995, 1996), Moxey et al. (1999) and Glebe (2008). Wu and Babcock (1996) develop a model of an environmental stewardship that aims to maximise the social surplus of agricultural production. Their model takes into account the difference between revenue from, and costs of, agricultural input use minus the cost of pollution and taxes of raising government funds. They consider different farm types, according to their land quality and they found a uniform optimal payment equal to the minimum payment needed to induce the farmers with the best land type to participate. The optimal solution that they found is a combination of management prescription and payment rates that differ from the ones that would be socially optimal under perfect information, since farmer are allowed, due to the presence of information asymmetry, to use more input than the socially efficient level. The policy conclusion is that the farmers that declare to be more productive must be allowed to use more inputs than farmers that declare to be less productive. However, since the compensation for both farmer types must be the same, the less productive farmer have an incentive to declare himself as high productive and thus the programme finish to be the same of a fixed price scheme.

Moxey et al. (1999) developed an alternative agri-environmental contract to reduce agricultural pollution related to input use and they come up with a second-best solution dealing with information asymmetries. Their model uses the self-selection mechanism to reduce farmers' information rent and overcoming adverse selection without recourse to negotiation. They looked at two farm types considering raising funds for farmers' compensation payments socially costly. By modelling only two discrete farmer types, low-productivity and high-productivity, they assume that the regulator has a subjective prior probability of whether a farmer is a high-productivity or low-productivity type. These probabilities are used as weights in the regulator objective function that is maximized subject to two participation constraints and two incentive-compatible constraints, one for each farmer type. The former assures the existence of a unique separated solution of the problem removing the incentive for one type of farmer to declare himself untruthfully to be another type, while the latter guarantees that the farmers must at least compensate for their opportunity cost of participating to the measure. The second best solution that Moxey et al. (1999) has found requires to the low-productivity producer to abate optimally receiving a higher transfer payment compared to the one he or her receives under the first best solution and it requires less demanding input reduction level for the high-productivity farmer. Latacz Lhomann and Schillizzi (2006) argue that the cost associated with the deviation from the first best solution may be interpreted as the cost of information asymmetry relating to the farmer type. The truth-telling second best solution have been designed by Moxey et al. (1999), to minimise farmers' rent, and represent a significant progress compared to the third best solution of offering a uniform single payment to a group of heterogeneous farmers. The authors claim that improvements are possible with the recourse of revelation principle through mechanism design and the use of incentive compatible contracts avoiding for the public administration the recourse of costly re-negotiation process with each farmers.

Glebe (2008) compares an analysis of an optimal menu of agri-environmental contracts based on the study of Wu and Babcock (1996) with that of a multidimensional bidding model based on the model developed by Latacz-Lohmann and van der Hamsvoort (1997). With regard to the modelling framework of the self-selecting contract model, the author develops a cost-minimisation problem, based on an exogenously given environmental target function, to select an optimal input level and payment schedule. According with Wu and Babcock (1995) the analysis of the optimal self-selecting contracts has been introduced first by referring to a discrete number of land types (i.e. farmers), then has been generalised by considering a continuum of land types. The modelling framework considers a principal-agent relationship in which farmers are paid for participating in a voluntary agri-environmental scheme. Information asymmetry arises due to the fact that the opportunity costs linked with alternative practices and different types of land quality are directly known by the farmers, but not readily known by the public administration (Canton et al., 2008). In other words, the government only understands the range and distribution of different types of land quality and their related production technologies, but is unable to attribute compliance costs to individual farmers. Land quality has been assumed as a continuous variable and the farming activities, which are related to site-specific characteristic, are determined by the combination of land quality and management prescription. The impact of such activities on the environment has been exogenously determined by an environmental cost function that expresses the social value of environmental degradation linked to land use. Thus the public administrations objective becomes to find the optimal contractual agreement that reduce the profit-maximising input level of farms activities to the minimum level of environmental degradation with the minimum budget expenditure. Under a discrimination policy offering a menu of contracts, each of which specifies an input constraint and the respective compensation payment, the author finds that the optimal payment for input reduction should follow the environmental target function (i.e. the marginal payment should be equal to the marginal value of environmental degradation) in order to satisfy the incentive compatibility constraint. Then, by adding participation constraint to the problem, the government expenditure linked to a cost-minimising contract schedule is determined by a payment schedule that ensure the most productive land types to keep the highest input quota and receive the lowest payment corresponding only for the cost involved with programme participation. Then all the lower input quotas choose an input-payment combination that leads to individual high net return and ensures that marginal payment for input reduction are given by the marginal value of environmental degradation, selecting the targeted optimal input quotas. However the author concludes that while this result would be more cost-efficient compared to a uniform policy, the comparison with the bidding approach shows the superiority of the optimally designed auction to reduce government expenditure. Glebe (2008) result confirms the extant literature suggesting that an incentive-compatible scheme can improve welfare but at the cost of informational rent for the low-cost farmers, while the conservation level required from the high-cost farmers is below the first-best level (Smith and Tomasi 1995; We and Babcock 1996; Moxey et al. 1999). Thus, the incentive-compatible contracts can be designed to mitigate excess compensation, but the outcomes of these instruments are always second best so that other instruments, such as conservation auctions, may be preferred.

An emerging number of other contributions, in order to provide a second chance to incentive-compatible contracts to induce conservation at higher cost-efficiency rates, have deepened the nature of the preservation costs (Arguedas and P. van Soest, 2011), the potential integration of contracts with targeting mechanisms (Bartolini et al., 2005; Canton et al., 2008) and the opportunity to design mixed contracts that include both an input-based payment for conservation actions and an outcome-based payment on a measure of environmental benefits (White and Sadler, 2011). Arguedas and P. van Soest (2011) suggests that considering fixed cost in conservation contracts allows the first-best solution to be incentive compatible under symmetric information. Extending the archetypical model of asymmetric information (i.e. Moxey et al. 1999) by allowing only part of the conservation costs to vary in dependency of the conservation services provided, and explicitly taking into account for fixed cost, they develop a payment mechanism that consist in the compensation for the variable and for the fixed costs. To this extent they found that the first-best solution might be implementable under asymmetric information if farmers with lower variable conservation costs face higher fixed costs. While Bartolini et al. (2005) found that targeting can be able to solve present problem in AEMs if is accompanied with contract diversification in terms of both constraint and payment, Canton et al. (2008) suggests that spatial targeting may improve the regulator ability to keep ex-ante information and therefore simplify the trade-off between allocative efficiency and information rents. White and Sadler (2011) demonstrate that a mixed contract represents a viable second-best alternative to a conservation auction, where conservation spending is spatially targeted.

Auction theory (Riley and Samuelson, 1981; Mcafee and McMillan, 1987; Milgrom, 1989; Klemperer, 2002; Klemperer, 2004) applied for agri-environmental issues uses bidding rules through market competition to encourage farmers to reveal their adverse selection parameters (i.e. compliance costs, resource setting) in order to reduce farmers' incentive to increase the contract price, mitigating or avoiding rent seeking (and the resulting inefficiencies) arising from asymmetric information about farmers' parameters. According with Mcafee and McMillan (1987), auctions create decentralised incentives to offer bids close to farmers' opportunity costs, even when the government holds little information about these opportunity costs. Holt (1980) suggests that the award of contracts on the basis of competitive bidding is a method used in procuring goods and services for which there are no well-established markets, as in the case of the provision of environmental benefits that are a public-type non-market good. Thus, an agri-environmental (AE) auction can be viewed as a procurement auction (Laffont and tirole, 1993) where the government (auctioneer) announces a contract for the procurement of environmental improvements and calls for bids from farmers (bidders): the auctioneer establishes a set of rules including the prescription of some AEMs in order to reach an environmental target. The bidders offer sealed bids describing actions they are willing to take and the associated payment they are willing to accept. The government subsequently select and rank bids for funding based on some measure of cost-effectiveness until a fixed budget is exhausted or a pre-set reserve price is reached. This implementation mechanism can be different if the public administration decides to establish a target of contracted land area (Viaggi et al., 2008). In both cases the farmer must decide his or her price in response to the public administration’s contract offer, while in the case of target participation is difficult the public administration to determine the final overall expenditure ex-ante. However, in both cases the condition that the auctioneer accepts bids until the budget or the reserve price is reached generates competition among farmers. According with Latacz Lhomann and Schillizzi (2005) the competition must be the driving force behind the cost revelation mechanism of the auction: bidders facing competition are more likely to reveal their true valuation than strategically inflated the value. Latacz-Lohmann and van der Hamsvoort (1997) has demonstrated through theoretical model that optimal bids increase with both the bidders’ opportunity costs and his/her expectations about the bid cap. This bid cap correspond at least to the highest accepted bid within the available budget, and representing the reserve price per unit of environmental good. According to the literature, the government must keep this value secretly to the potential bidders, since when they formulate their own choice they must ignore its exact value and they must face a trade-off between a higher net gain from a higher bid and a reduced probability of winning. The expectation about the bid cap and the probability of winning the auction induce farmers to reveal their true opportunity cost of producing the environmental good in question and reduce the probability of overbidding by farmers. In these terms, the auction mechanism represents a price discovery mechanism that takes account of private information since it is determined through a decentralised process where each farmers express his or her own valuation. Thus, comparing with a centralised uniform price policy, the auction prices appear to reflect better the farmers’ true opportunity cost.

The main contributions of the literature on auction theory are formed by game-theoretic models (Rothkopf and Harstad, 1994; Klemperer, 2002) based on the Revenue Equivalence

Theorem (RET) introduced by Vickrey (1961, 1962), further developed by Myerson (1981) and Riley and Samuelson (1981), which constitute the guide to construct and assess auction design.

The RET suggests that all major auction designs will lead to the same expected revenues for the auctioneer and it provides the theoretical foundation for the developing of environmental auction models that are underpinned by some of the main RET assumptions, including: (i) bidders are risk neutral; (ii) bidders have independent privates value; (iii) there is symmetry among bidders; (iv) payment is a function of bid alone; (v) there are no costs associated with bid construction and implementation; This model is referred to in the literature as the benchmark model.

However, in the context of agri-environmental auction these approaches are often constrained by analytical tractability due also to several features that distinguish the environmental auctions from the benchmark model. In other word, to deal with environmental auction some of the restrictive assumptions that form the RET in some cases need to be relaxed, making the model more realistic. For example, most of the classic auction theory has dealt with the sale of a single indivisible unit (Klemperer, 2002), while most of the agri-environmental problems have been analysed with multi-unit approach of divisible unit. Schillizzi and Latacz-Lohmann (2006) argues that the Nash-equilibrium of a multi-unit procurement auction can be calculated if bidders offer a single unit each, but agri-environmental auction generally involves information asymmetry and the supply of multiple unit each that make the computation of equilibrium bidding strategies more complicated. Hansen (1988) and Che (1993) have developed multi-dimensional auction models where only a single bid is accepted and where the economic efficiency is achieved only if the government announces his true utility functions through a scoring rule. Moreover, bids tend to have multiple dimensions as monetary compensations are weighted with estimated environmental benefits (Iho et al., 2014).

In the light of the complexities related to game-theoretic approaches and of the practical limits of the RET assumptions, some contributions in the simulation and experimental economics literature have analysed the efficiency of hypothetical auction models subject to controlled manipulation of the classical assumptions (Connor et al., 2008). For example, Latacz-Lohmann and van der Hamsvoort (1997), used a utility theoretical simulation model to compare the optimal bid response of auctions to uniform payment policy. Modelling farmers' expectations of the highest acceptable bid as an exogenous variable they found that the optimal bid level is an increasing function of agency reservation price uncertainty and they conclude that as bidder uncertainty regarding auction reservation prices converges to zero, the optimal responses of the auction and the uniform payment converge. In other words, when the level of uncertainty about the auctioneer reservation price is high, a discriminant price auction can lead to inefficient outcomes. About the convergence of the outcomes of auction and uniform policy Hailu and Schillizzi (2004) has observed that can only occur in the context of repeated auctions, where the government treat the information about the reserve price in a way that creates room for bidders to learn about the reservation price. Meanwhile, Banerjee et al. (2015) use laboratory experiments to investigate the impact of information revelation on the performance of an iterative auction with spatial targeting and they conclude that rent seeking is intensified with more information and increased bidder familiarity with the auction. Other studies since dealing with one-shot auctions do not need to capture potential learning effects of repeated auctions (Hailu and Schillizzi, 2004). Viaggi et al. (2008) simulates the bidding behaviour of individual farmers on the basis of the budget constrained model proposed in Latacz-Lhomann and van der Hamsvoort (1997) comparing the results with those of two alternative mechanisms based on flat rate payments. Considering a one-shot one-dimensional auction approach, their results confirm the superiority of the auction approach compared to traditional flat rate payment based on average compliance cost, while they demonstrate that the payment based on marginal compliance cost can be even better than the other approaches, but it is difficult to implement because it implies a greater degree of information about compliance costs on the part of the regulator. By extending the modelling framework of Latacz-Lhomann and van der Hamsvoort (1997), Glebe (2008) develops a bidding model that allows farmers to propose input levels of their own choosing. The two dimensions (i.e. the input quota and the compensation payment) are integrated into a single ranking system through a defined scoring index. Within this approach farmers are informed about the calculation of the scoring index, but not about its critical value, above which no bids will be accepted. The announcement of the scoring system aims to induce farmers to propose input quotas that are targeted by the regulator and it will be determined at a level ensuring that the environmental target can be reached with the smallest programme outlays. The analysis of the bidding model compared with that of a self-selecting contract demonstrated the potential of the auction approach to reduce farmers' rent and consequently the programme outlays. However the author suggests that this savings depend on the assumptions that the expected bid cap is uniformly distributed, and that the scoring system is additively separable inducing optimal price-quality combination. Thus, when the scoring system assumes that the optimal input quotas depend on financial bid, the cost-effectiveness of the auction model can be enhanced, if the scoring system induces farmers to offer the input quotas that are targeted by the government with the related financial bids. However Glebe (2008) concludes that the budget cost savings may easily be eroded if farmers' expectations about the bid cap are increasingly suboptimal. Moreover, for a systematic analysis of the attributes and properties of scoring auctions, we refer to Che (1993), Branco (1997) and Asker and Cantillon (2008). Asker and Cantillon (2008) provides a complete analysis of the situation in which a buyers cares about attributes other than price when evaluating the offers submitted by suppliers. Thus, they analyse the equilibrium behaviour in scoring auctions when suppliers' private information is multidimensional demonstrating the dominance of scoring auctions on other commonly used procedure for buying differentiated products (i.e. menu auction, the beauty contest and price-only auctions with minimum quality thresholds).

Finally, few studies provide evidence-based assessment of transaction costs involved in agri-environmental auctions. Fang and Easter (2003) analyses the Minnesota river nutrient trading programme, finding that when the transaction costs of participating in the programme are included the net benefits of the auction may be negative, Connor et al. (2008) provides similar conclusion suggesting that the estimated cost savings under the auction may be reduced slightly when transaction costs associated with auction implementation are considered.

According with the analysed literature, despite auctions demonstrates a potential to increase programmes cost-effectiveness, they are complex incentive mechanism, involving a higher risk of failure: there is the potential problem of insufficient bidding competition with small group of potential bidders that increase the likelihood of collusion and strategic behaviour by the farmers. There is the risk of learning in repeated auction on the part of the bidders and finally auction involves high transaction cost that may deter farmers from participating in the scheme. Glebe (2008) points out that a crucial factor determining the relative cost-effectiveness of a bidding approach relates to transaction costs arising from programme implementation and monitoring.

1.5 AUCTION MODELS

Following the one-shot budget constrained auction model first introduced by Latacz-Lohmann and van Der Hamsvoort (1997), and subsequently by Viaggi et al. (2008) and Glebe (2008), two bidding behaviour models of individual farmers, respectively Auction Model 1 (AM1) and Auction Model 2 (AM2), are presented in this chapter.

While AM1, as in Latacz-Lohmann and van Der Hamsvoort (1997), dealt with one-dimensional bids, the AM2 further extends their analysis allowing farmers to offer a combination of payment and a measure of their uptake in the agri-environmental programme, calculated as a quota of their land committed to the programme. AM2 in this fashion still assumes that only a single, but multi-dimensional bid for each farmer is accepted in order to achieve economic efficiency defined by the classical theoretical auction assumptions.

According with the previous literature, both models assume that farmers differ in the costs of compliance they incur participating in the AEM and both consider bidders' expectations of the highest acceptable bid as an exogenous variable.

In AM1 the hypothesis is that the regulator seeks to purchase multiple units of environmental goods that substitutes traditional cultivation selecting numerous farmers to participate in the agri-environmental auction. Each farmer can choose to produce with a conventional production technology or to comply with some agri-environmental prescriptions. While profit Π_0 expresses the conventional profit without participating to the measure, profit Π_1 expresses the farmer's profit linked to the agri-environmental prescription. Both profits are perfectly known to the farmer and are net return to land expressed per hectare without considering the agri-environmental payments, thus the difference between the two represents the compliance costs:

$$k = \Pi_0 - \Pi_1 \tag{1}$$

If the AEM consists, for example, of land set-aside Π_1 can be zero (or even negative). Generally, for other practice-based technologies can be positive, but smaller than Π_0.

Assuming that farmers are profit-maximizing agent, they choose to participate to the scheme, if it is profitable for them. Thus, they accept to participate to scheme if through the auction they will receive a payment that must be at least equal to the compliance cost defined through equation (1). So, under the auction mechanism, each farmer offer a bid b if the expected utility in case of participation exceeds his or her reservation utility:

$$U[\Pi_1 + b] \cdot P(b \leq \beta) + U(\Pi_0) \cdot [1 - P(b \leq \beta)] > U(\Pi_0) \tag{2}$$

Where β indicates the farmers' expectations about the maximum bid cap above which all bids are rejected; P denotes the probability that the submitted bid is accepted and $U[\Pi_1 + b]$ is the expected utility in case of participation. Following Lactaz-Lohmann and van der Hamsvoort (1997) the probability that the bid is accepted can be expressed as:

$$P(b \leq \beta) = \int_{\underline{\beta}}^{\overline{\beta}} f(b)db = [1 - F(b)] \tag{3}$$

Where $f(b)$ indicates the density function, $F(b)$ the distribution function, $\underline{\beta}$ represents the bidder's minimum expected bid cap and $\overline{\beta}$ the maximum upper limit to his or her expectations. $U(\cdot)$ is a monotonically increasing twice differentiable von Neumann-Morgenstern utility function. In the case that the submitted bid is rejected, the bidder's utility coincides to the reservation utility $U(\Pi_0)$.

Equation (2) shows that the farmer must find out the balance between net payoff and the acceptance probability. If he/her submits a higher bid, he/her increases the net payoff but reduces the probability of winning, and vice-versa. Thus the farmer's problem is to determine the optimal bid, which is the one that maximizes the expected utility on the left-hand side of equation (2), over and above the reservation utility on the right-hand side of equation (2).

Since it is a budget-constrained auction, the public regulator will set ex post, after all bids have been received, the maximum acceptable bid cap. This bid cap correspond at last to the highest accepted bid within the available budget, and representing the reserve price per unit of environmental good/services. According to Lactaz-Lohmann and Schillizzi (2006), we have assumed that the government keeps secretly its value to the potential bidders. Moreover we have assumed that there are no cost in the preparation and implementation of the auction, that the payment is only function of the bid and that farmers are risk neutral. Within this rules the bidder's problem becomes to decide the optimal *b* that maximizes his/her expected utility, so equation (2) can be simplified in:

$$(\Pi_1 + b - \Pi_0) \cdot [1 - F(b)] > 0 \tag{4}$$

For a risk-neutral farmer that simply maximizes expected net payoff, the optimal bid b* is then obtained by maximizing equation (4) with respect to *b* which yields:

$$b^* = \Pi_0 - \Pi_1 + \frac{[1 - F(b)]}{f(b)} \tag{5}$$

Assuming that for a risk neutral farmer, the expectations about the maximum bid that is accepted β are uniformly distributed in the range $\left[\underline{\beta},\ \overline{\beta}\right]$, where $\underline{\beta}$ represents the bidder's minimum expected bid cap and $\overline{\beta}$ the maximum, the optimal bid b^* is derived solving the follow maximization problem:

$$b^* = max\left[\frac{1}{2}\left(\Pi_0 - \Pi_1 + \overline{\beta}\right), \underline{\beta}\right] \tag{6}$$

$$\text{s.t. } b^* > \Pi_0 - \Pi_1 \tag{7}$$

equation (5), states that the optimal bid increases linearly with both bidder's opportunity costs and his expectation about the bid cap $\underline{\beta}$ and $\overline{\beta}$.

According with Viaggi et al. (2008) equation (1) can be represented as a function of the contracted area for the AEM. If *k(X)* represents the cumulative compliance costs and $k_X(X) = \Pi_0(X) - \Pi_1(X)$ the marginal cost with the profit as a function of the area under agri-environmental contract, the optimal bid, equation (6), becomes:

$$b^{*}(X)=max\left[\frac{1}{2}\left(k_X(X)+\overline{\beta}\right),\underline{\beta}\right] \tag{8}$$

equation (8) represents the optimal bid as a function of the area. Then when $\underline{\beta}$=0 the total cost for the public regulator becomes:

$$TC=\left[\frac{1}{2}\left(k(X)+\overline{\beta}X\right)\right] \tag{9}$$

in this case the government objective of maximizing farmers participation to the AES, measured by the degree of the uptake to the measure, is represented by the maximization of the contracted area under a fixed budget constrain B:

$$TC=\left[\frac{1}{2}\left(k(X)+\overline{\beta}X\right)\right]\leq B \tag{10}$$

equation (10) will always hold with equality obtaining the maximum area under contracts X^{*} as a function of the optimal bid:

$$X^{*}=\left[\frac{2B-k(X)}{\overline{\beta}}\right] \tag{11}$$

According with Viaggi et al. (2008), to evaluate the AM1 performance it is possible to compare this result with the one that can be obtained considering a marginal flat rate payment (MFR). If the government can fix the payment equal to the compliance cost of marginal participating farmers, the maximum X* becomes:

$$X^{*}{}_{MFR}=\left[\frac{B}{k_X(X)}\right] \tag{12}$$

To apply the mechanism described by equation (12) the government needs a great degree of information about compliance cost compared to the optimal bidding results equation (11). Thus, if we consider the opportunity to screening contracts and targeting the payment to some specific area where compliance costs are different from the average this solution is still feasible.

Another approach would be, according to the EU regulation, to set a flat rate payment (FR) φ based on the average compliance cost of all farmers in the same area. This mechanism restrict the participation to those farmers whose compliance cost is below the average marginal payment, determined by:

$$X^{*}{}_{FR}=\left[\frac{\mathrm{B}}{\varphi}\right] \tag{13}$$

Equation (12) imply a rent (R) for individual farmers that is determined by the difference φ - $\mathrm{k}_{\mathrm{X}}^{*}(X)$. Moreover when R<0 farmers do not participate to the programme according to their incentive rationality constraint. According to Viaggi et al. (2008), the theoretical comparison between the three instruments is not straightforward. From the one hand, it depends on the farmers' expectation on the maximum acceptable bid cap $\overline{\beta}$ and marginal cost. From the other hand, it depends on the level of budget compared to total cost.

AM2 while maintains all the theoretical foundation developed for the AM1, further extends the first analysis, allowing farmers to offer a multi-dimensional bid, composed by the financial payment and by a measure of their uptake in the agri-environmental programme, calculated as a share of the AEM participating area on their utilised agricultural area. In the first model, farmers whose bid has been accepted, and for which they will receive the agri-environmental payment, they commit themselves to replace traditional cultivation with the agro-environmental prescription across their whole agricultural area. In the second model, the farmers can choose to offer just a share of their agricultural area to be committed under the agri-environmental scheme and a per hectares payment to compensate them for the compliance costs.

While in the first auction model, it is hypothesized that farmers participate with all their productive land to the AES, in the second auction model it is hypothesized that farmers can choose how to allocate their agricultural area between the profitable traditional production and the less profitable or totally unprofitable agri-environmentally friendly one, but for which they can receive, if they win the auction, the agri-environmental payment.

The second model assumes that farmers have private information about their individual profit $\Pi_0 = \Pi_0(X)$, which expresses the total conventional profit without participating to the measure as a function of the total agricultural area X, with $\Pi_0'(.) > 0$ and $\Pi_0''(.) < 0$. Profit $\Pi_1(X - x)$ represents the farmer's profit linked to the agri-environmental prescription that is a decreasing function of the share of the agricultural area x that the farmer commits to the AEM. If farmers do not participate to the measure, so x=0, the $\Pi_1(X)$ correspond to the conventional profit $\Pi_0 = \Pi_0(X) = \Pi_1(X - 0) = \Pi_1(X)$.

In AM2, it is hypothesized that the farmer, taking constant the marginal profit, and on the basis of his/her expectation about the maximum bid cap β, will offer bid that is a combination of a share of land x and a per hectares payment b higher enough to cover the compliance costs in order to maximize the total profit.

While maintaining the same assumption of AM1 that the maximum profit does not include the agri-environment payments, the difference between the two profits represents, in a similar fashion of AM1, the marginal compliance cost as a function of the contracted area x in AM2:

$$k_X(x) = \Pi_1(X) - \Pi_1(X-x) \tag{14}$$

Assuming a risk-neutral farmers' behaviour in the auction, called for simplicity Auction behaviour (Ab), who simply maximizes expected net payoff, the bidder's problem becomes to decide the optimal quota of participating land x and the bid b that maximizes his or her expected utility. According with equation (2) and (3) of AM1, the bidding problem can be rewritten in AM2, as:

$$\mathrm{Ab}(x,b) = [\Pi_1(X-x) + bx\,] \cdot [1 - F(b)] + \Pi_1(X) \cdot \mathrm{F}(b) - \Pi_0 > 0 \tag{15}$$

The optimal bidding behaviour $\mathrm{Ab}(x^*, b^*)$ is then obtained maximizing equation (15) with respect to x and b, thus taking first order conditions, and solving each system of derivatives as:

$$\frac{\partial \mathrm{Ab}(x,b)}{\partial x} = 0 \tag{16}$$

$$\frac{\partial \mathrm{Ab}(x,b)}{\partial b} = 0 \tag{17}$$

for equation (16), solving the derivative with respect to x, we obtain:

$$\frac{\partial \mathrm{Ab}(x,b)}{\partial x} = \left[\Pi_1{'}\left(X - x\right) + b\right] \cdot \left[1 - F\left(b\right)\right] = 0 \tag{18}$$

$$b^* = -\Pi_1{'}(X - x^*) \tag{19}$$

Intuitively, the farmer finds it optimal to maximize his/her expected total surplus submitting a bid that must at least cover the marginal cost of changing cultivation by adopting the AEM.

If we solve now the equation (17) from the first order condition, with respect to b, we obatin:

$$\frac{\partial \mathrm{Ab}(x,b)}{\partial b} = x \cdot \left[1 - F\left(b\right)\right] - \Pi_1\left(X - x\right) \cdot f\left(b\right) - bx \cdot f\left(b\right) + \Pi_1(X) \cdot f\left(b\right) = 0 \tag{20}$$

$$bx \cdot f(b) = \Pi_1(X) \cdot f(b) - \Pi_1(X-x) \cdot f(b) + x \cdot [1 - F(b)] = 0 \tag{21}$$

$$b = \frac{\Pi_1(X) - \Pi_1(X-x)}{x} + \frac{[1 - F(b)]}{f(b)} \tag{22}$$

Supposing that for a risk-neutral farmer, the expectations about the maximum bid that is accepted β are uniformly distributed in the range $\left[\underline{\beta},\ \overline{\beta}\right]$, in accord with Latacz-Lohmann and van der Hamsvoort (1997) the density and distributions functions of a rectangular distribution are defined as:

$$f(b) = \begin{cases} 0 & if\ b < \underline{\beta} \\ \frac{1}{\overline{\beta}-\underline{\beta}} & if\ \underline{\beta} \le b \le \overline{\beta} \\ 0 & if\ b > \underline{\beta} \end{cases} \tag{23}$$

$$F(b) = \begin{cases} 0 & if\ b < \underline{\beta} \\ \frac{b-\underline{\beta}}{\overline{\beta}-\underline{\beta}} & if\ \underline{\beta} \le b \le \overline{\beta} \\ 0 & if\ b > \underline{\beta} \end{cases} \tag{24}$$

Which states that for the farmer does not make economic sense to submit a bid that is lower (greater) than the minimum (maximum) expected bid cap. Taking the properties of equation (23) and equation (24), we expand and analyse the last right-hand terms of equation (22), and we obtain:

$$\frac{[1-F(b)]}{f(b)} = \frac{\left[1-\frac{b-\underline{\beta}}{\overline{\beta}-\underline{\beta}}\right]}{\frac{1}{\overline{\beta}-\underline{\beta}}} = \left[\frac{\overline{\beta}-\underline{\beta}-b-\underline{\beta}}{\overline{\beta}-\underline{\beta}}\right] \cdot \frac{\overline{\beta}-\underline{\beta}}{1} = \overline{\beta} - b \tag{25}$$

Taking this result, and substituting equation (25) into equation (22), the optimal bid b^* of a risk-neutral farmer becomes:

$$b = \frac{\Pi_1(X)-\Pi_1(X-x)}{x} + \overline{\beta} - b \tag{26}$$

$$b^* = \frac{\frac{\Pi_1(X)-\Pi_1(X-x^*)}{x^*}+\overline{\beta}}{2} = \frac{\Pi_1(X)-\Pi_1(X-x^*)+\overline{\beta}x^*}{2x^*} \tag{27}$$

Substituting equation (14) into equation (27), the optimal bid becomes:

$$b^* = \frac{k_{x^*}(x^*)+\overline{\beta}x^*}{2x^*} \tag{28}$$

Which states that optimal-bid is an increasing linear function of farmer expectation about maximum acceptable bid and marginal compliance cost.

In order complete the farmer decision-making problem and derive the bidders' optimal share x^* of agricultural land to commit under the AEM, we further explicit the profit function using a quadratic form, as:

$$\begin{cases} \Pi_0 = \Pi_1(X) = aX - cX^2 \\ \Pi_1(X-x) = a(X-x) - c(X-x)^2 = aX - ax - cX^2 - cx^2 + 2cX \cdot x \end{cases} \tag{29}$$

In order to make more simply the next analytical part of the problem, we derive now the marginal profit function under the AEM, $\Pi_1{}'(X-x^*)$, making the first derivative of $\Pi_1(X-x)$ of equation (29) with respect to x, which becomes:

$$\frac{\partial \Pi_1(X-x)}{\partial x} = \frac{\partial a(X-x)-c(X^2+x^2-2X\cdot x)}{\partial x} = 2c\cdot X - 2c\cdot x - a = \Pi_1{}'(Xt-x) \qquad (30)$$

We are now able to find out the farmers optimal share x^* of agricultural land, taking the results from the optimization problem, equation (19) and equation (27) and using the marginal profit equation (30), we need to operate by substitution and solve with respect to x the following system of results:

$$\begin{cases} b^* = -\Pi_1{}'(X-x^*) \\ b^* = \frac{\Pi_1(X)-\Pi_1(X-x^*)+\overline{\beta}x^*}{2x^*} \\ \Pi_1{}'(Xt-x) = 2c\cdot X - 2c\cdot x - a \end{cases} \qquad (31)$$

By equating the equations in the first two lines of the system with respect to b^*, and substituting the explicit formula of the marginal profit (third line), we calculate the optimal share as follow:

$$-2c\cdot X + 2c\cdot x + a = \frac{\Pi_1(X)-\Pi_1(X-x^*)+\overline{\beta x^*}}{2x^*} \qquad (33)$$

$$-4c\cdot X\cdot x + 4c\cdot x^2 + 2a\cdot x = \Pi_1(X)-\Pi_1(X-x) + \overline{\beta}x \qquad (34)$$

$$-4cXx + 4cx^2 + 2ax = aX - cX^2 - aX + ax + cX^2 + cx^2 - 2cXx + \overline{\beta}x \qquad (35)$$

Operating simplification in equation (35) we obtain:

$$x(a - 2cX + 2cx - \overline{\beta}) = 0 \qquad (37)$$

from which we derive the optimal quota of land x^* as follows:

$$x^* = \frac{2cX-a+\overline{\beta}}{3c} \qquad (38)$$

Equation (38) states that the optimal quota of land x^* increases linearly with the expectation about the maximum bid cap, and that farmers have an incentive to commit more land when the profit from traditional cultivation is lower.

In order to compare the AM2 performance with the MFR and FR payment, as we derived for AM1, according with equation (8) and equation (28), the optimal bid becomes:

$$b^*(X)=max\left[\frac{1}{2}\left(\frac{k_{x^*}(x^*)+\overline{\beta}x^*}{x^*}\right), \underline{\beta}\right] \qquad (39)$$

and when $\underline{\beta}$=0, the total cost for the public regulator (TC2), is equal to:

$$TC2=\left[\frac{1}{2}\left(k_{x^*}(x^*)+\overline{\beta}x^*\right)\right] \tag{40}$$

Assuming that regulator objective is to maximize the uptake to the AEM, thus the problem becomes to maximize the contracted area under a fixed budget constrain B:

$$TC2=\left[\frac{1}{2}\left(k_{x^*}(x^*)+\overline{\beta}x^*\right)\right] \leq \mathrm{B} \tag{41}$$

That will always hold with equality obtaining the maximum area under contracts x^* as:

$$x^* = \left[\frac{2B-k_{x^*}(x^*)}{\overline{\beta}}\right] \tag{41}$$

Is now possible to compare this result with the two alternative policy instrument introduced in AM1, respectively, the equation (12) for the MFR payment, and the equation (13) for FR payment, which in AM2 becomes:

$$x^*_{MFR2} = \left[\frac{B}{k_{x^*}(x^*)}\right] \tag{42}$$

$$x^*_{FR2} = \left[\frac{\mathrm{B}}{\varphi}\right] \tag{43}$$

1.6 AUCTION PERFORMANCE

In this chapter we provide a theoretical note on different ways of measuring auction performances in comparison with uniform policy. From the theoretical models we achieved that the optimal bidding strategy of a risk-neutral bidder increases linearly with both bidder's opportunity costs and his or her expectations about the bid cap (i.e. expressions 6 and 28). Thus with the auction mechanism the farmer's bid carries information about his or her opportunity costs, which are the information unknown to the public administration. The information asymmetry is thus reduced but not completely, since under the discriminatory price format the auction's cost revelation property is shaded by the bidder's beliefs about the critical bid cap (Latacz-Lohman and Schillizzi, 2006), creating room for bidders to bid above their true opportunity costs and thereby to gain an information rent (Figure 1).

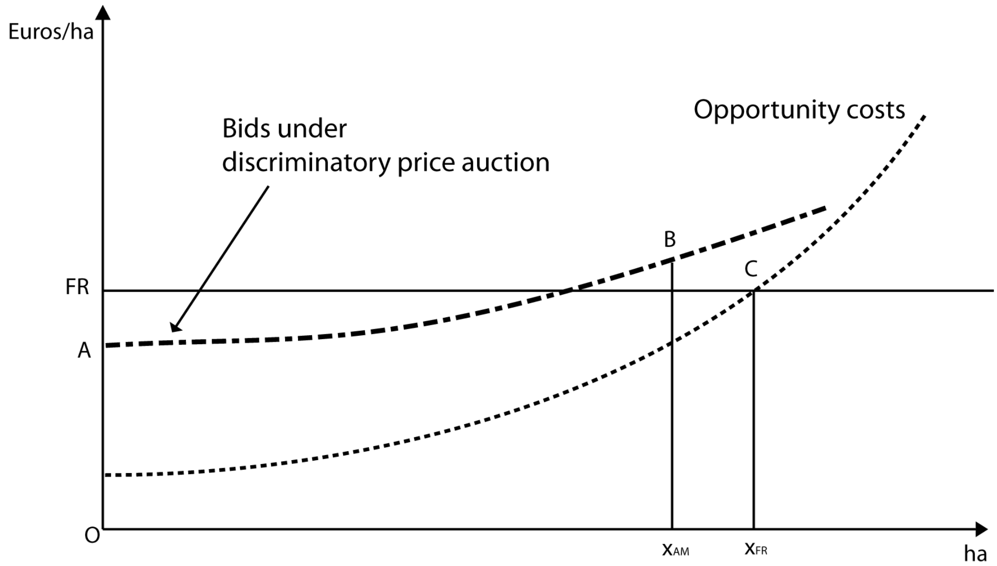

Figure 1. Discriminatory auction and flat rate payment: when auction is less cost-effective

Under the fixed-price scheme, X_{FR} ha of land will be traded at price FR with a total budget represented by the area $OFRCX_{FR}$. Assuming the same budget as under FR (area $OABX_{AM}$= area $OFRCX_{FR}$), we have that X_{AM} ha of agri-environmental service can be bought with the auction approach. Thus the FR mechanism is more cost-effective than the auction for the given budget. Under the auction approach the ordered bids (not the opportunity cost function) represent the supply function. Bidders are thus accepted in the order of their bids until the budget is exhausted, but when farmers shade their bid to a greater extent (i.e. Figure 1) a smaller number of farmers are able to be selected by the auction that becomes less cost-effective. By contrast when bid shading would be low, as normally we expect, the auction is superior to the fixed-price scheme (Figure 2).

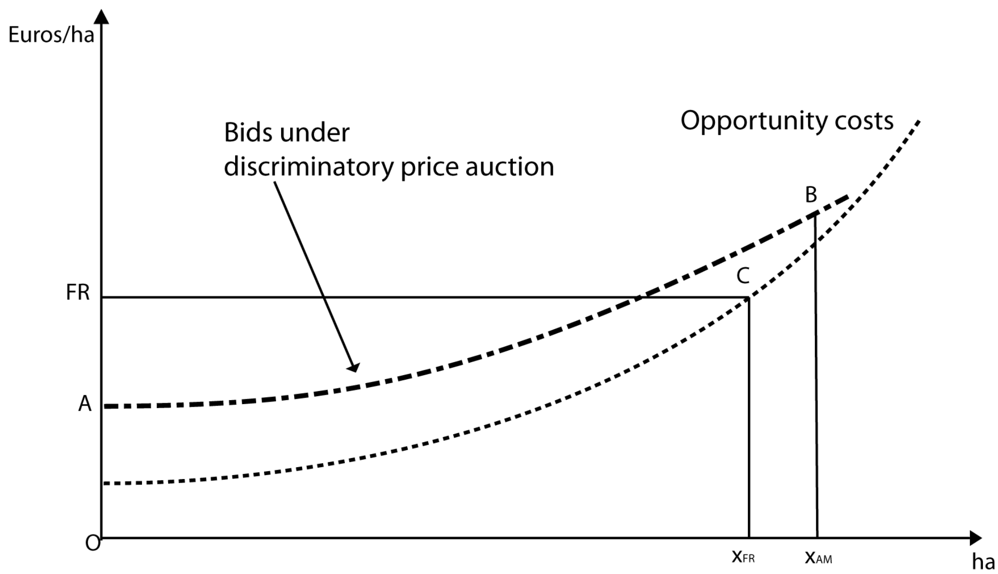

Figure 2. Discriminatory auction and flat rate payment: when auction is more cost-effective

When a fixed payment is offered, it is important to remark that the opportunity cost function is the relevant supply function. Then all farmers with opportunity costs below the fixed payment gain a positive rent (R) that will be determined by the difference between the payment and the compliance cost. On the other hand when R<0, the farmer is not expected to participate according to profit maximizing behaviour. Moreover, in this case the FR is less cost-effective for the given budget (area $OABX_{AM}$= area $OFRCX_{FR}$) and $OX_{AM} > OX_{FR}$.

However a degree of bid shading remains under the discriminatory price, which depends on bidders expectation and knowledge about the maximum bid cap. For example, if bidders have learned the bid caps from previous auction rounds, bid shading can be significant, resulting in a lower auction performance (as shown in Figure 1).

1.7 CONTRACT MODEL

In this chapter the adverse selection problem has been framed in the context of the extant literature of self-selecting contracts providing a contract model (CM) that extend the archetypical model of asymmetric information for two type of farmers (Moxey et al., 1999) according with the procedure developed by Bolton and Dewatripont (2004) to a model of a finite number of farmers, which can be more than two types. The model focuses only on land enrolment, through programme participation, in an asymmetric information context. In CM the principal objective is to maximise the degree of uptake to a hypothetical agri-environmental measure that substitutes traditional cultivation with some agri-environmental prescriptions.

Under a discriminating policy, the public regulator provides a menu of contracts to the farmers, which must be able to induce farmer's self-identification through contract choice (Bartolini et al., 2005). Each contract offers an amount of land to enrol in the measure *x* that is a share of the total available land *X* and an associated payment schedule *b* that must sufficiently generous to cover the compliance costs. To simplify the programme we suppose a linear relationship for each additional unit of participating land and the marginal benefit *v* from this unit, thus the social benefit (SB) from programme participation becomes:

$$SB = \sum_{i=1}^{n} vx_i - \mathrm{b_i} \tag{44}$$

Considering a finite number of heterogeneous farmers, the information asymmetry arise due to the fact that public regulator is not able to know each different type of farmers in terms of site-specific production condition and compliance cost. Following Bolton and Dewatripont (2004) we can extend the basic framework of two types to a situation where farmers can be more than two types. First we consider the general formulation of the problem for three types and then we extend this formulation to $n \geq 3$. Thus, we hypothesize that the principal only knows the existences of three different types of farm:

$\beta_n > \beta_{n-1} > \cdots > \beta_1$

with $n \geq 3$, we can define γ_i the proportion of famers of type β_i in the farmer population and the three farmers types as $\beta_i > \beta_{i-1} > \beta_1$.

As for the auction models, the CM assumes that farmers have private information about their individual profit $\Pi_0 = \Pi_0(X)$, which expresses the total conventional profit without participating to the measure as a function of the total agricultural area X, with $\Pi_0'(.) > 0$ and $\Pi_0''(.) < 0$.

Profit $\Pi_1(X - x)$ represents the farmer's profit linked to the agri-environmental prescription that is a decreasing function of the share of the agricultural area x that the farmer commits to the AEM. If farmers do not participate to the measure (i.e. x=0), the $\Pi_1(X)$ correspond to the conventional profit $\Pi_0 = \Pi_0(X) = \Pi_1(X - 0) = \Pi_1(X)$.

Since the maximum profit does not include the agri-environment payment, the difference between the two profits can be used as a proxy of compliance cost as a function of the contracted area x. We use $k(x)$ that is assumed to be monotonously increasing with respect to the enrolled area x, to represent the cumulative compliance costs and $k_X(x)$= $\Pi_1(X)$ - $\Pi_1(X - x)$ as the marginal cost ($k_X(x) > 0$).

Let $\{(x_i, b_i); i = 1, \dots, n\}$ the menu of contracts offered by the public regulator to the farmers, the principal problem, by the revelation principle (Laffont and Tirole, 1993), is to choose from among all feasible contracts to solve the problem:

$$Max_{\{(x_i,b_i)\}} \quad \sum_{i=1}^{n} vx_i - b_i \tag{45}$$

subject to

$$b_i - \beta_i k(x_i) \geq 0 \tag{46}$$

$$b_{i-1} - \beta_{i-1} k(x_{i-1}) \geq 0 \tag{47}$$

$$b_1 - \beta_1 k(x_1) \geq 0 \tag{48}$$

for all i

$$b_i - \beta_i k(x_i) \geq b_{i-1} - \beta_i k(x_{i-1}) \tag{49}$$

for all i $\quad b_i - \beta_i k(x_i) \geq b_1 - \beta_i k(x_1)$ (50)

for all i $\quad b_{i-1} - \beta_{i-1} k(x_{i-1}) \geq b_1 - \beta_{i-1} k(x_1)$ (51)

for all i $\quad b_{i-1} - \beta_{i-1} k(x_{i-1}) \geq b_i - \beta_{i-1} k(x_i)$ (52)

for all i $\quad b_1 - \beta_1 k(x_1) \geq b_i - \beta_1 k(x_i)$ (53)

for all i $\quad b_1 - \beta_1 k(x_1) \geq b_{i-1} - \beta_1 k(x_{i-1})$ (54)

Where the equations, from (46) to (47), state the classic participation constraint, and the equations, from (49) to (54), are the incentive compatibility constraints. Since the main difficulty in solving this problem is to reduce the number of incentive constraints from $\mathrm{n}(\mathrm{n}-1)$ to a more tractable set of constraints. According with Bolton and Dewatripont (2004) we can reduce this set to a more tractable one, by considering that among all participation constraints only the one concerning type β_1 will bind and the other ones will automatically hold (i.e. see Bolton and Dewatripont, 2004 p. 52-56); Thus, we derive that:

$$b_i - \beta_i k(x_i) \geq b_1 - \beta_i k(x_1) \geq b_1 - \beta_1 k(x_1) \tag{55}$$

Then, we assume that the farmer's utility function, defined as $[b - \beta_i k(x)]$, satisfy the Spence-Mirrlees single-crossing condition that implies monotonicity and the sufficiency of local incentive constraints, the set of relevant incentive constraints is the set of local downward incentive constraints (LDICs). Considering the three types $\beta_1 < \beta_{i-1} < \beta_i$, since only the LDICs constraints are binding when the monotonicity condition $k(x_{i-1}) \leq k(x_i)$ and consequently $x_{i-1} \leq x_i$ holds, the public regulator problem, reduces to:

$Max_{\{(x_i, b_i)\}} \quad \sum_{i=1}^{n} v x_i - \mathrm{b_i}$ (56)

subject to

$$b_1 - \beta_1 k(x_1) \geq 0 \tag{57}$$

for all i $\quad b_i - \beta_i k(x_i) = b_{i-1} - \beta_i k(x_{i-1})$ (58)

and $\quad x_i \geq x_{i-1} \quad$ where $\beta_i \geq \beta_{i-1}$ (59)

To solve this problem we consider the Lagrangian:

$$\mathcal{L} = \sum_{i=1}^{n} \{[v x_i - k(x_i) - R_i]\gamma_i + \lambda_i [b_i - b_{i-1} - \beta_i k(x_i) - \beta_i k(x_{i-1})]\} + \mu[b_1 - \beta_1 k(x_1)] \tag{60}$$

The Lagrange multiplier related to the LDICs for type β_i is λ_i, while μ is the multiplier associated with the participation constraint for type β_1.

For $1 < i < n$, the first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial x_i} = v\gamma_i = \gamma_i \beta_i k'(x_i) + \lambda_i \beta_i k'(x_i) + \lambda_{i+1} \beta_{i+1} k'(x_i) \tag{61}$$

$$\frac{\partial \mathcal{L}}{\partial b_i} = \lambda_i = 0 \tag{62}$$

and, for $i = n$,

$$\frac{\partial \mathcal{L}}{\partial x_n} = v\gamma_n = \gamma_n \beta_n k'(x_n) + \lambda_n \beta_n k'(x_n) \tag{63}$$

$$\frac{\partial \mathcal{L}}{\partial b_i} = \lambda_n = 0 \tag{64}$$

Thus, if we analyse the solutions of the optimisation generalising for n types, for $i = n$ we have $v = \beta_n k'(x_n)$, the marginal social benefit from program participation equal the marginal compliance cost of type n, which imply that no rent is associated with this type.

By contrast for $i < n$, we have $\beta_i k'(x_i) < v$ since $\beta_i k'(x_i) < \beta_i k'(x_n)$, which means that to increase the social benefit the regulator should increase the participation of the types $i < n$. However the result also embed the trade-off between efficiency and information rent highlighting the distortion induced by asymmetric information: to increase participation to one type of farmer, there is an additional rent that must be given to all the types $i < n$ in order to benefit from a truthful direct revelation mechanism reducing the risk of imitative behaviours. The generalization to n types of the classical results established for two types allowed us to further characterize the optimal menu of contracts providing analytical insight to support the relevant conditions emerged from the literature review. According with Moxey et al. (1999) and Canton et al. (2008), the proposed payment for the types $i < n$ should be higher than the one under perfect information, including the additional rent to ensure the indifference of this types between selecting the contract intended for them or that intended for the type n. Finally, the second best contracts should propose a payment that leads to lower effort (participation) of type n than under perfect information.

METHODOLOGY

1.8 RESEARCH HYPOTHESES

Chapter 3.2 and 3.3 showed that in both auction and contract models the government seeks to minimize payments adopting alternative payment mechanisms that take into account the presence of hidden information. Information asymmetries arise because the public administration can only understand the range and distribution of different types of farms in terms of their production technologies and associated compliance costs. The rationale of auction is to induce agents to reveal their adverse selection parameter through competitive bidding (Latacz-Lohmann and Schillizzi, 2006).

From the previous literature review on methodologies and from the theoretical analysis, the following hypotheses have been identified:

H1: The heterogeneity of compliance costs seems to justify the advantage for the application of complex allocation rules such as auction, while the uniform payment policy implies $R>0$ for those farmers with lower compliance costs.

H2: With regard to the low-compliance cost farmers, a uniform payment based on MFR hypothesis can lead to higher uptake than auction, but the feasibility of that payment strongly depends on the availability, quality and cost of information for the public decision maker.

H3: The performance of the auction, in terms of optimal participation rate within a given budget level, is always located between the marginal payment and the average payment results.

H4: Increasing the available budget will reflect a decrease in the difference between the auction mechanism and marginal payment performance, while it has an opposite trend in the average payment case.

H5: The efficiency benefits associated with auction are strongly affected by farmers' expectations about budget levels, transaction costs and the critical bid cap above which bids are rejected.

H6: Under a discriminatory auction scheme, an increase (decrease) in the expectations about the critical bid cap value reflect an increase (decrease) in the bidders' shade behaviour resulting in a decrease (increase) of the auction performance.

1.9 DATA AND CASE STUDY DESCRIPTION

The two auction models introduced in chapter 3 have been applied through a simulation exercise for agro-environmental goods in E-R. This chapter mainly provides the description of the data used and of the case study.

The empirical models are developed with the FADN data of E-R (2010-2011). Two dataset, respectively about the 2010 and for the 2011, containing general economic data of E-R about livestock and cultivation, compose the regional FADN database. The analysis has been carried out at farm level focusing only on the cultivation dataset.

The case study region has a heterogeneous territory that includes hills and mountains and is located in the highly productive, densely populated and industrialized Po valley (northern Italy). E-R covers an area of more than 2.2 million hectares, of which, in 2007, the Utilized Agricultural Area (UAA) was nearly 1.1 Million hectares with an average of 12.8 ha per farm and with a total of approximately 82,000 farms. The UAA is about the 47.6 percent of the entire area of the region that is the highest percentage of utilized agricultural area of all of the Italian regions, even higher than the national average (42.3 per cent), whilst among the top for European regions.

Given the relevant impact of agriculture on the regional economy, the Rural Development Policy through the provision of the agri-environmental measures has always played a major role to mitigate the significant environmental pressures from agriculture and to provide environmental goods and eco-system services to the region.

According with the Regulation (EC) 1698/2005 and 1305/2013, the E-R agri-environmental policy is defined on the basis of the RDP 2014-2020 mostly by the measures 10, 11 and 12 concerning Agri-environmental and climate payments. In E-R the agri-environmental and climate payments are organized into several sub-measures (operations) that target different environmental objectives and areas. Operation 10.1.01 concerns the integrated production measure, operation 10.1.02 regards the manure managements, operation 10.1.03 is directed to increase the organic matter of soils, operation 10.1.04 aims to conservation agriculture practices contributing to increase the organic matter of soils, operations 10.1.05/06 are directed to protect agro-biodiversity, operation 10.1.07

provides no-tillage and extensive grassland measure, operation 10.1.08 is related to the management of buffer strips along water courses to contain the transfer of pollutants from soil to water sources, operation 10.1.09 regards the management of Natura 2000 areas and the conservation of natural and semi-natural habitats and of the agricultural landscapes, while operation 10.1.10 is set-aside. Moreover operations 01 and 02 of measure 11 are related to organic farming measures.

These actions cover a substantial part of the RDP budget: in 2010 the share of public resources was about 30% of the entire RDP, with total budgetary resources of approximately 296 million of euros (Regione Emilia-Romagna, 2010). In the current programming period (2014-2020), this support is increased to about 42.8% of the total RDP budget, with total budgetary resource of 509 million of euros for the macro-theme of environment and climate, of which the 74%, approximately 376 million of euros, are dedicated to agri-environmental support through payments.

The overall strategy of the Region through the RDP agri-environmental and climate measures is to promote sustainability and combat climate change promoting agricultural practices capable of producing and protecting public goods such as biodiversity, agricultural landscapes, air, soil and water.

Under this regional framework we assumed for the first simulation model (AM1), the replacement of conventional wheat cultivation by a generic environmental good (AEM1) that provides most of the economic properties of various landscape improvement measures that have been applied within the programming period 2000-2006, 2007-2013, defined in the current RDP under measure 10. More in detail, we assume that AEM1 mirrors several landscapes improvement and biodiversity protection measures described by the operation 10.1.09 and 10.1.10 of the abovementioned measure 10 of the current E-R RDP. These measures aim to preserve the quality of cultivated landscapes and can be viewed as horizontal measures (Uthes et al., 2010) that indirectly aim to protect birds and other wildlife, to improve the network of habitats and to reduce the entry of harmful substances in the bordering habitats protecting flora and fauna. The E-R region attaches great importance to these actions in relation to the biodiversity targets of the RDP and supports unprofitable investment, such as hedges of tree, with purpose of buffer strips to reduce the transport phenomenon of polluting elements and also groves, ponds, lakes, and reservoirs for the phytoremediation of water. Despite this type of measure concerns a wide number of crops, the focus of the simulation for AM1 is on wheat, which is one of the most common crops in E-R.

For AM2, we assumed a hypothetical agri-environmental service (AEM2) that substitutes a mix of conventional cultivation with a non-profitable environmentally friendly land use. AEM2 mirrors again the prescription and the economic properties of the landscape improvement measures applied in the E-R and described above. However, for AM2 we further extend the number of crop involved in this measure to a mix of crops, while for AM1 we only focused on wheat. Implicitly assuming that AEM2 can be applied on a wide number of cultivation. Thus, adopting "the number of cultivation" (n≥4) as selection criteria, we selected from the FADN 2011 dataset a sample of 100 farms that grow the largest number of crop in E-R. The selected farms thus represent the ones that produce the largest number of cultivations at regional level in 2011.

1.10 EMPIRICAL AUCTION MODEL 1 (AM1)

In this chapter we analyse the assumptions and the simulation strategy adopted for AM1.

For AM1, we have assumed that the main difference between AEM1 and the real measure implemented in the two programming periods of the RDP E-R is that for AEM1 no investment or maintenance cost are linked with participation to this measure, thus the compliance costs are represented by the opportunity cost due to substitution of the conventional cultivated wheat.

The compliance cost function is derived from FADN data. We have included all the 306 farms that cultivate wheat in E-R during both 2010 and 2011 and following the procedure developed by Viaggi et al. (2008), the compliance cost is calculated through the estimation of profit Π_0, related with conventional cultivation, and profit Π_1 linked with the hypothetical AEM1.

Profit Π_0 is estimated using directly the FADN dataset by calculating the gross margin for each farm (i.e. subtracting to the gross saleable agricultural product of each farm the cultivation costs). Then, for the computation of Π_1 on the basis of FADN data, we have first reduced the farms' gross revenue, then we have adjusted the cultivation costs and then we have added costs for the increased risk, administrative and transaction costs. The percentage of adjustment used for calculating the gross revenue, the cultivation costs and the percentage used to estimate the transaction costs are those used for the justification of payments in the RDP of E-R (Regione Emilia-Romagna, 2007).

After the estimation of profit Π_0 and profit Π_1 we have calculated each individual FADN farm's compliance costs for AEM1. Then, the farms have been ordered according with increasing compliance cost, and then have been plotted against the cumulative UAA, assuming that each farm in the FADN sample can be considered as 1/306st of total wheat UAA in E-R. Finally, the cost function was estimated for AEM1 by interpolation of each individual compliance costs as a function of the cumulative UAA, using a 3^{rd} degree equation (Figure 3).

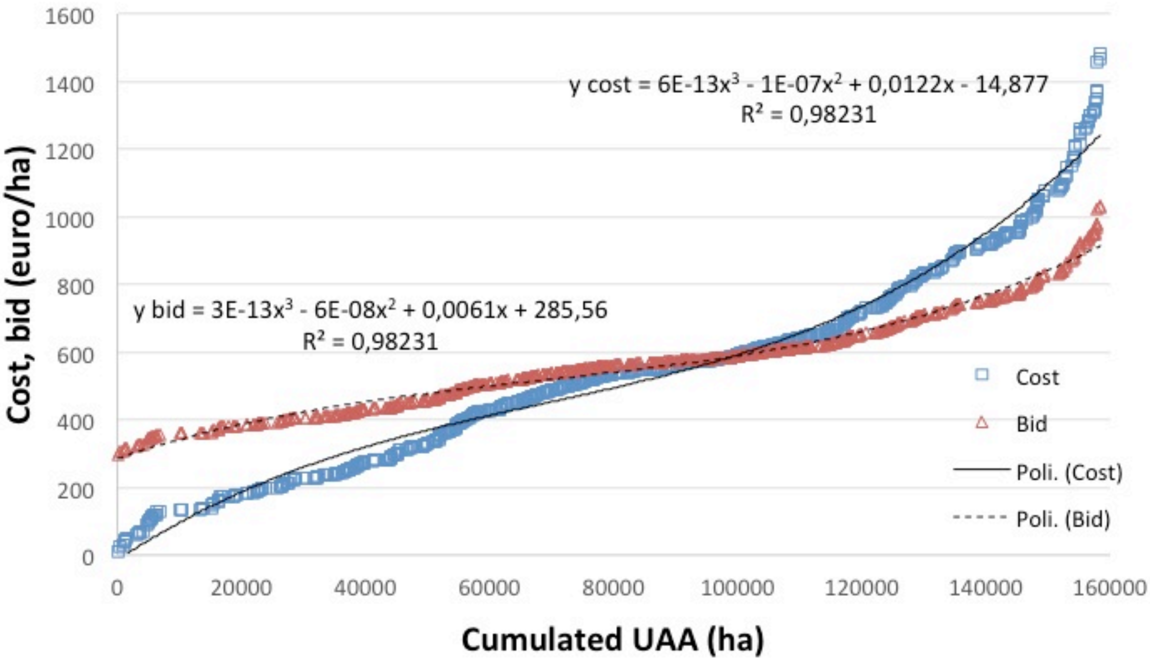

Figure 3. Cost and bid as a function of participating UAA – Substitution of wheat cultivation (AEM1)

The continuous line expresses compliance costs to AEM1 that range from the minimum value of 10 euros/ha to the maximum value of 1480 euros/ha, showing a high degree of heterogeneity captured by the interpolation (i.e. the compliance cost function is more steeper than the bid function). The mean value of the compliance costs of the population of 306 farmers is about 565 euros/ha, with the median around 549 euros/ha and the standard deviation about 277 euros/ha. The same cost function has been used directly for the computation of the expected outcome of the MFR and FR payments following equation (12) and (13).

The dotted line represents the bid function for AM1, which we have obtained by applying equation (8) to each individual cost level and plotting the results to the cumulative wheat UAA and we have interpolated also with a 3^{rd} degree equation. More in detail, in AM1, we have assumed a reserve bid $\underline{\beta}$=0 and the bid cap $\overline{\beta}$ has ben assumed equal to the average of the payments for a similar measure in the RDP E-R 2000-2006 (i.e. 567 euros/ha). The minimum bid is about 298 euros/ha and the maximum is about 1033 euros/ha. With regard to the mean bid, the value is about 575 euros/ha, the median 567 euros/ha and the standard deviation expresses less variability compared to the compliance costs 138 euros/ha (i.e. the bid function is more flattened). And this is explained by the bidding strategies that are determined through Nash equilibria, in which the bid formulation depends not only on a bidder's own compliance cost but also on his or her expectations about the highest acceptable bid cap. Thus the resulted bid values are more concentrated around the bid cap value, which is close to the mean value of the bid distribution and resulting in a lower variability of the distribution. Moreover the left-tails of the bid function seems to capture better the trend of bid shading strategy by farmers, which characterise the discriminatory price auction format as we described in the previous chapter (Latazc-Lohmann and Schillizzi, 2006). Under this format farmers' bid determines both the chance of winning and the price received for participating to AEM1. This creates room for bidders to shade their true opportunity costs in order to gain themselves an information rent. According with Latazc-Lohmann and Schillizzi (2006) the strategy of overbidding is more pronounced by the lower compliance cost farmers (i.e. left tail of cost function) while the high-cost bidder (i.e. right tail of bid function) offered lower bid under their compliance costs and thus they do not participate.

1.11 EMPIRICAL AUCTION MODEL 2 (AM2)

Following the computation method used for AEM1, we assumed that for our hypothetical scheme, no investment or maintenance cost are linked to the farmers' compliance, thus also for AEM2 the compliance costs are represented by the opportunity cost of substituting the intial mix of cultivation. Then, following equation (14) we approximated compliance cost of each farmer to the difference between profit Π_0, taken as the income derived directly from FADN considering the conventional mix of cultivation of each individual farm, and profit $\Pi_1(X-x)$, which expresses the profit as function of the share of the agricultural area x that each individual FADN farm is willing to commits to the AEM2 and to bid through the auction mechanism. Thus, assuming a partial replacement with a non-profitable land use, we calculated $\Pi_1(X-x)$ on the basis of FADN data, by the following steps:

i) In a first step, we computed the gross revenue and the marginal revenue for each farm's crop. Then, we ordered the gross revenues in descending order of marginal revenue and we calculated the cumulative gross revenue and the cumulative cultivated area.

ii) According with the functional form expressed in equation (29), in a second step, we estimated the function of conventional profit $\Pi_0(X)$, as a function of the total agricultural area X, by plotting the cumulated gross revenue against the cumulated cultivated area. We estimate profit using a 2^{nd} degree equation (Figure 4).

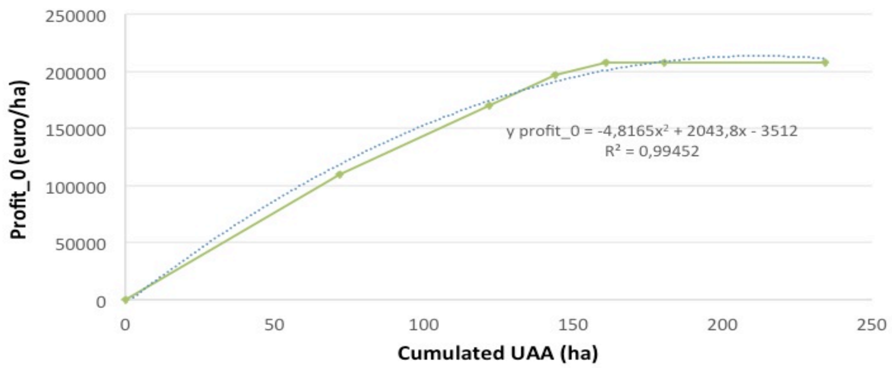

Figure 4. Example of an Estimated Profit Function with traditional cultivation mix (farm code n. 103314)

iii) In a third step, we derived the optimal share of land x^* for each individual farm, following equation (38) and using the coefficients from each estimated profit functions $\Pi_0(X)$. Moreover, according with equation (38), since the optimal share of land x* depends also on farm expectation about the maximum acceptable bid, we assumed a reserve bid $\underline{\beta}$=0, and we formulated four hypotheses of bid cap $\overline{\beta}$ to analyse the different auction performance. The first assumed a maximum bid cap equal to the average of the payments for a similar measure in the RDP E-R 2000-2006 such as for AM1 (i.e. 567 euros/ha). In the second we hypothesize $\overline{\beta}$=567/2 euros/ha, in the third $\overline{\beta}$=567x1,5 euros/ha , and in the fourth $\overline{\beta}$=567x2 euros/ha.

iv) In a four step, we calculated the profit $\Pi_1(X - x^*)$ and according with equation (27) we derived the relative optimal payment for each individual farm. We repeated this step for each of the different bid cap hypotheses.

v) In the last step, adding administrative and transaction cost, following equation (14) and with the four hypothesis of bid cap, we estimated the compliance cost of each farm participating to AEM2 through the difference between the profit derived from the FADN dataset and the estimated profit $\Pi_1(X - x^*)$.

Then, the farms have been ordered according with increasing compliance cost and have been plotted against the cumulative offered optimal share of UAA. Finally, the compliance cost function has been estimated for AEM2 by interpolation of each individual compliance cost as a function of the cumulative offered share of UAA, using a 3^{rd} degree equation (Figure 5).

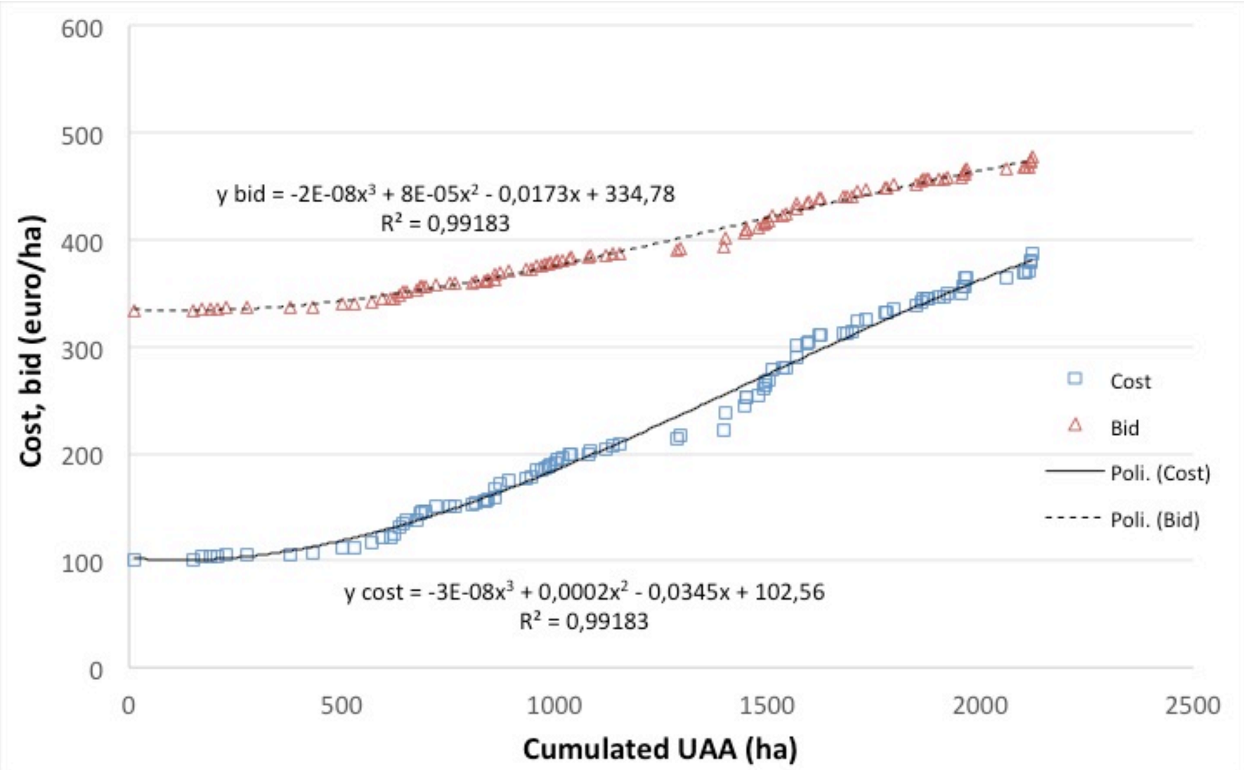

Figure 5. Cost and bid as a function of the cumulative offered share of UAA ($\overline{\boldsymbol{\beta}} = \mathbf{567}$ euros/ha) – Substitution of a mix of conventional cultivation (AEM2)

The total UAA of the sample is about 7545 hectare of which the maximum cumulated share of UAA offered by farmers with AM2 under the first hypothesis of bid cap (i.e. $\overline{\beta} = 567$ euros/ha) is 2121 hectares (we deepen this result in the next chapter). The continuous line represents compliance costs to AEM2 that range from the minimum value of 99 euros/ha to the maximum value of 387 euros/ha. More in detail, the mean value is about 231 euros/ha, with the median around 207 euros/ha and the standard deviation about 90 euros/ha. Despite we have focused on a sample of 100 farmers that correspond to 1/3 of the population used for AM1, the variability measure of compliance costs confirms that there is still a certain degree of heterogeneity between farmers that is around 1/3 of the variability we found with the previous model.

The bid function for AM2 is obtained by applying equation (28) to each individual cost level, plotting the results to the cumulative optimal share of UAA and interpolated with a 3^{rd} degree equation (i.e. triangular point in the Figure 3). The minimum bid is about 333 euros/ha and the maximum is about 477 euros/ha. With regard to the mean bid, the value is about 399 euros/ha, the median 387 euros/ha and the standard deviation 45 euros/ha, which results in a more flattened function if we compare with the bidding function of AM1.

When we hypothesize that the expected bid cap is halved (i.e. assuming $\overline{\beta}$=567/2 euros/ha), according with equation (28) and (38) since the optimal bid and the optimal share of UAA that farmers offer in AM2 depend on their expectation about the maximum acceptable bid cap, farmers find convenient to reformulate their previous bids in order to be accepted. Thus when the maximum bid cap decreases the farmers reduce their previous bid. As a consequence the relevant supply curve (the bid function) decreases and also their offered share of UAA is lower (Figure 6).

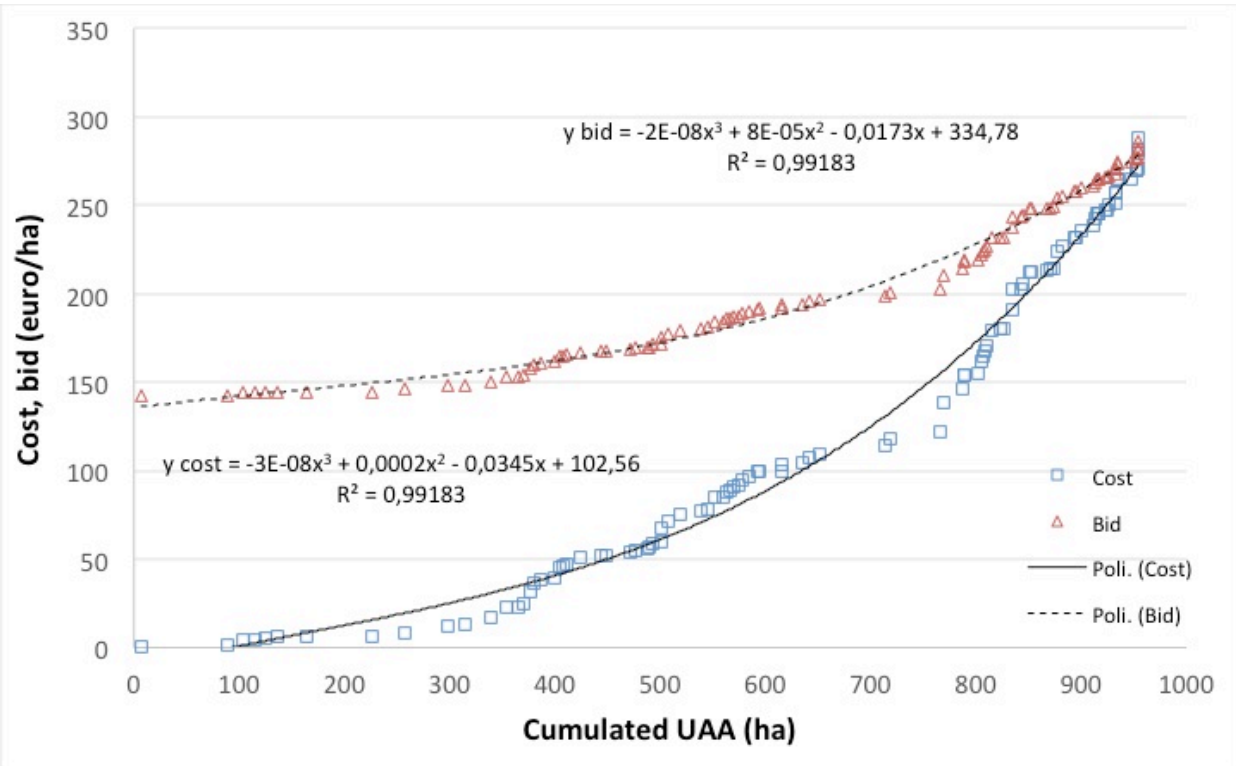

Figure 6. Cost and bid as a function of the cumulative offered share of UAA ($\overline{\boldsymbol{\beta}} = 283{,}5$ euros/ha) – Substitution of a mix of conventional cultivation (AEM2)

Since farmers decrease their bids, the total offered share of UAA under the second hypothesis of bid cap (i.e. $\overline{\beta} = 567/2$ euros/ha) becomes 954 hectares. According with equation (14) when the offered share of UAA decreases also the compliance cost function decreases, which ranges in this case from the minimum value of 4 euros/ha to the maximum value of 288 euros/ha. The mean value of compliance cost is about 132 euros/ha, with the median around 108 euros/ha and the standard deviation about 90 euros/ha. Moreover, the minimum bid is about 142 euros/ha and the maximum is about 285 euros/ha. With regard to the mean bid, the value is about 208 euros/ha, the median 195 euros/ha and the standard deviation 45 euros/ha.

By contrast when we hypothesize that the expected bid cap is doubled (i.e. assuming $\overline{\beta}$=567x2 euros/ha), farmers find convenient increasing their previous bids. The result is that we have an increase of the relevant bid function and also of the offered share of UAA (Figure 7).

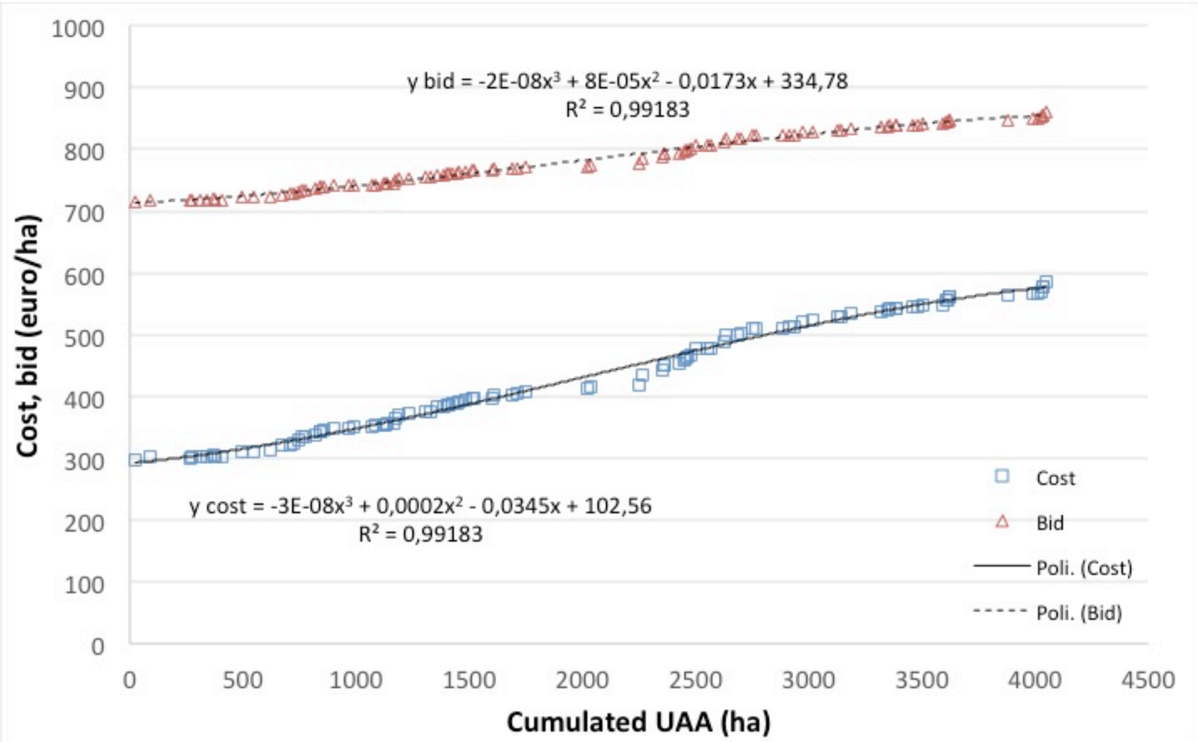

Figure 7. Cost and bid as a function of the cumulative offered share of UAA ($\overline{\boldsymbol{\beta}} = 1134$ euros/ha) – Substitution of a mix of traditional cultivation (AEM2)

The total offered share of UAA under the fourth hypothesis of bid cap (i.e. $\overline{\beta} = 567*2$ euros/ha) becomes 4455 hectares. Moreover, according with equation (14) the increase in the offered share of UAA determines an increase of the compliance costs, which range from the minimum value of 298 euros/ha to the maximum value of 586 euros/ha. The mean value of compliance cost is about 430 euros/ha, with the median around 406 euros/ha and the standard deviation about 90 euros/ha. Moreover, the minimum bid is about 716 euros/ha and the maximum is about 860 euros/ha. With regard to the mean bid, the value is about 782 euros/ha, the median 770 euros/ha and the standard deviation 45 euros/ha.

For each of the bid cap hypothesis, we have used these cost functions to derive the expected outcome with MFR2 and FR2 payments, following equation (42) and (43).

1.12 Model Results

In this chapter the results of the two auction simulation models are reported. First we illustrate the results for AM1 and then we proceed for AM2.

Considering two budget levels, respectively a low-budget, amounting at 0,25 million euros per year, and high-budget level, amounting at 2 million euros per year, the results of the first simulation model (AM1) are represented by the maximum UAA participating in the three payment mechanisms (Table 7), the Auction scheme (i.e. equation 11) and the two benchmark payment mechanisms (i.e. equation 12 and 13 representing the MFR, and the FR payment mechanism), in the case of a generic agri-environmental measure that substitutes the traditional wheat cultivation (AEM1).

Table 7. Comparison of different payment mechanism in case of substitution of wheat cultivation with AEM1 (Percentage of participating UAA in AEM1 on total E-R UAA of wheat)

	Percentage of participating UAA	
Policy Instruments	0,25 million of euros (low-budget)	2 million of euros (high-budget)
MFR	2,62%	10,61%
AM1	0,62%	3,78%
FR	0,16%	2,26%
MFR/AM1	4,22	2,80
FR/AM1	0,25	0,59

Source: own elaboration.

Under the two budget levels the performance of the auction is always located between marginal flat rate and flat payment results. When the budget increases, the difference between the performances of AM1 and of MFR decreases, and has an opposite trend in the FR case. With the lowest budget level, the maximum UAA up-taken with the MFR is around four times the up-taken area with the auction. This difference decreases under the highest budget level to more than two. Moreover, the percentage of up-take with flat rate is about a quarter of the auction approach, while it increases to around three-fifths under the high budget.

In order to deepen the analysis of the performance of the auction approach, we proceed to compare the farmers' rent among the developed mechanisms. According with Schillizzi and Latacz-Lohmann (2006), which reviews different measures of auction outcomes, we measure the rate of information rent that is computed by the ratio of total payments to total compliance costs (Table 8).

The total payments with AM1 have been computed making the sum of each bid multiplied for the relative participating UAA until the budget exhausted, for the two budget hypotheses. While total FR payments have been computed by multiplying the fixed payment for the total participating UAA until the budget is exhausted. Total costs have been computed by multiplying the estimated per hectares compliance costs for the participating UAA in AEM1 under the two budget hypothesis.

Remembering that the farmer's rent has been defined by the difference between the agri-environmental payment and the compliance cost, since this difference is zero with MFR mechanism because we assumed that with this approach the public administration is able to set the payment on the basis of the marginal compliance cost, we focus only on the comparison between AM1 and FR.

Table 8. Comparison of the rate of information rent between AM1 and FR (AEM1)

	Budget level (0,25 million of euros per year)			**Budget level (2 million of euros per year)**		
Policy Instruments	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC)	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC)
AM1	79914	3867	20,66	1978167	411089	4,81
FR	133073	3867	34,40	1809780	181368	9,97
	FR/AM1		1,66	FR/AM1		2,07

Source: own elaboration.

The rate of information rent under the two budget levels is higher with flat rate payment. Under the first budget level, the rent ratio with FR is one and a half larger than the rent ratio associated with AM1. This difference increases under the higher budget level: the rent ratio with FR becomes the double of the rent ratio with AM1. However Table 8 shows also that when we move from the lower budget level to the higher one, both rent ratios associated with the mechanism decrease. When the budget increases, the more available resources allow the participation of farmers that have higher compliance costs or that have submitted a higher bid for which the rent is lower. Gradually as these farmers participate, the overall rent reduced, but more for the auction.

However, since both total payment and the total compliance cost tend to be overestimated in the first simulation model, because it is assumed that each farmer will participate to AEM1 with all his or her UAA, the total rent with both mechanism reflects this overestimation.

In order to further deepen the analysis of farmers' rent, we provide an alternative comparison between the two mechanisms with a measure of the average per hectare rent calculated on the basis of the higher budget level and on the same participating UAA (Table 9).

Table 9. Comparison of different measures of farmers' rent under the higher budget level (AEM1)

	Budget level (2 million of euros per year)	
Policy Instruments	Average per hectare rent (euros/ha)	Total Rent (% on budget)
AM1	270,48	48,49
FR	454,96	81,42
FR/AM1	1,68	1,68

Source: own elaboration.

Under the higher budget level on the basis of a total participating UAA of about 3619 hectares, the average per hectare rent of the FR mechanism (i.e. 454,96 euros/ha) is more than one and a half of the average per hectare rent with the auction approach (i.e. 256,02 euros/ha). This result is confirmed also by the ratio between the total rent with FR and the total rent with AM1 (i.e. 1,68).

Moreover, the auction mechanism allows an average saving of about 198,94 euros/ha, which means that on a participating UAA of 3619 hectares and with a high budget level, it can lead to about 36% of saving on the total budget. Another result that is worth pointing out is the high total rent associated with the flat rate payment. The 81,42% of rent associated with FR, on the available budget, needs to be explained in the light of the model's assumptions. The key point is that both the absence of any criteria in the selection of applicants and the estimation and level of compliance costs contribute to the resulted rent. In the light of that, first we should remember that we assumed that the government is not able to discriminate between different farmers' typologies and compliance costs. Then, once we have estimated the farmer's compliance cost function and bid function, we have also assumed that the administration does not make any selection procedure or screening activities from the received auction bids: the administration hypothesizes that farmers with lower compliance costs have more incentives to participate, thus simply begins to pay each farmer, ordering the accepted bids from the lowest bid to the higher one, and one by one, until the budget is exhausted. The same procedure has been assumed for the uniform payment, while in the reality the selection can be also random. Thus, we have started to pay farmers from the lowest compliance cost to the highest, determining an overestimation of the rent with the FR. This is a reasonable result, which may happens in the practice of those agro-environmental programs in which there are a lack of priority mechanisms in the selection of applicants, or where differentiated payment or targeting mechanisms have not been implemented. On the other side, the higher value of farmers' rent is strongly connected also to the process of estimation of the compliance cost. For example, if compliance costs are underestimated, the resulting rents are again overestimated. However, with regard to our hypothetical exercise, this result allows us only to emphasize the weight and importance of farmers' rent within a uniform policy and to compare it with an auction mechanism. Thus, the number itself has to be seen in the light of our hypothetical analysis, but is not indicative of any rents received from farmers under the real agri-environmental payment programs of E-R.

With regard to the AM2, we focus on the maximum UAA of the sample (i.e. 7545,22 hectares) assuming two different budget levels, whose amount is established respectively at 0,2 million of euros per year for the first, and at 0,8 million of euros per year for the second. The second budget level has been reduced comparing with the 2 millions of euros of AM1, by sizing it on the basis of the smaller UAA area and of the population of farmers to support. As abovementioned in AM2 we do not consider the whole regional UAA, but the simulation has been carried out for a smaller sample of 100 FADN farms each of which produce the largest mix of cultivations at regional level in 2011.

In AM2 farmers bid a share of their conventional UAA to replace with AEM2 and an agri-environmental payment. Following the defined hypotheses about the maximum acceptable financial bid cap, we first report the total quota of land offered by farmers in AM2 as a percentage on the total UAA of the sample (Figure 8).

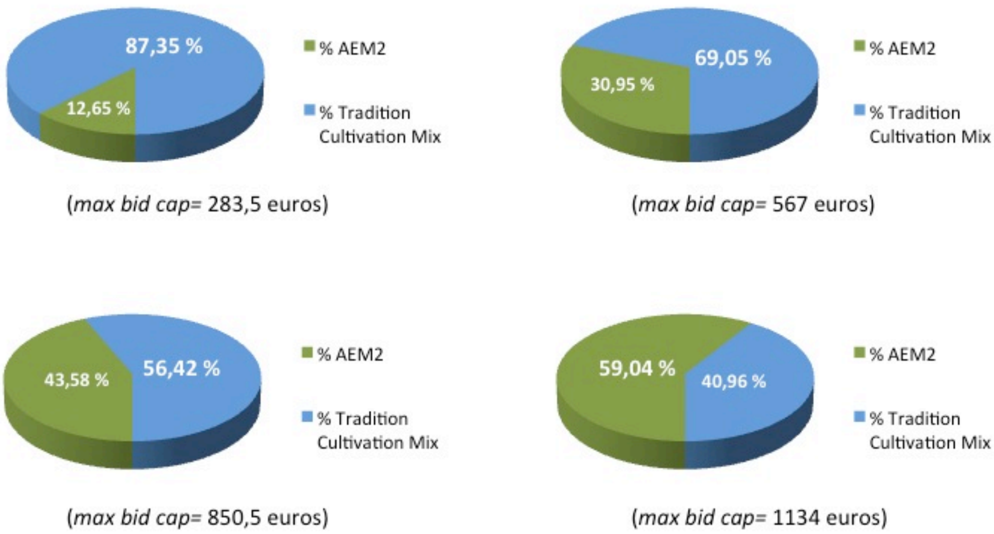

Figure 8. Total offered UAA on the total UAA of the sample in dependency of farmers' expectations on the maximum financial bid cap – Substitution of a mix of cultivation (AEM2)

Since individual optimal quota of land linearly depends on farmers' expectation on the maximum bid cap, the four pie charts show that the aggregated quota of UAA offered to AEM2 increases with increasing farmers' expectation levels about the bid cap. If the maximum bid cap corresponds to 567 euros, the maximum bid-quota of land is around the 30,95% of total UAA of the sample. If this bid-cap halves the aggregated quota of land becomes the 12,65%, corresponding to a decrease of 18,3% of the quota to commit to AEM2 on the total UAA of the sample. If expectation increases of about the 150% from the first bid cap, the total share of land increases of about the 12,63%, corresponding to the 43,58% of the total UAA of the sample. If the maximum bid cap doubles, the total offered quota exceeds the half of the total UAA of the sample (i.e. 59,04%), corresponding to an increase of the 28,09% of the total bid-quota.

In order to deepen the relationship between farmers' expectation about the maximum bid cap and the bid-quota, we plot the total offered quotas of UAA on total UAA of the sample against the different maximum bid cap levels (Figure 9).

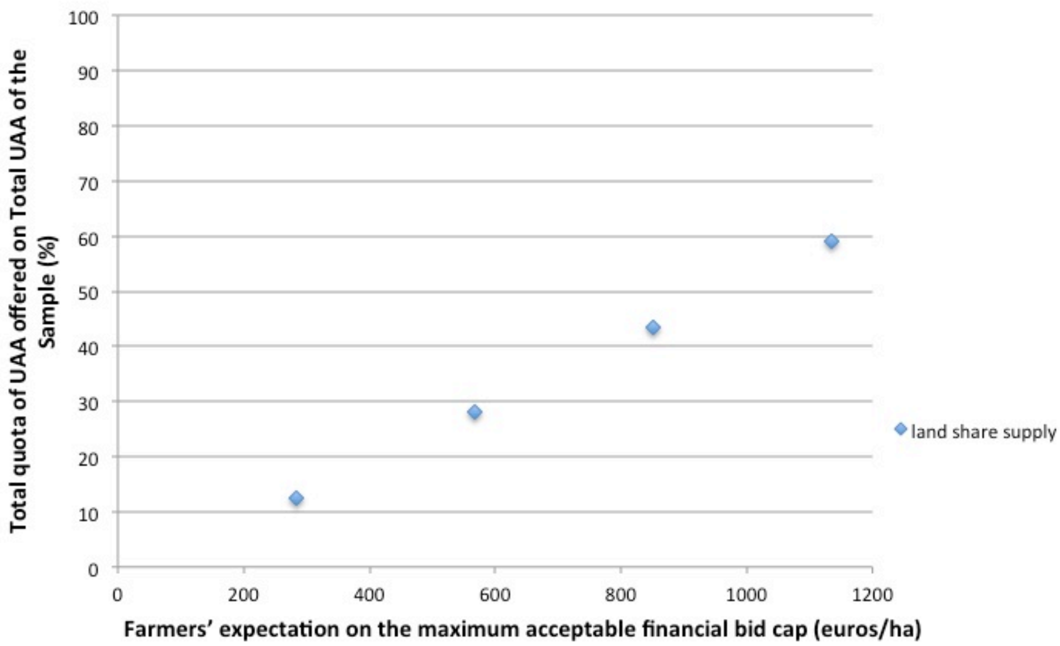

Figure 9. Total offered UAA on the total UAA of the sample in dependency of farmers' expectations on the maximum financial bid cap – Substitution of a mix of cultivation (AEM2)

The land share supply points seem to be distributed as an increasing function of farmers' expectations about the maximum accepted bid cap in the interval [283,5; 1134] euros/ha. Since an aggregate land supply function would be given by the horizontal sum of each individual land share supply that depends on individual estimated compliance cost function according with equation (38), the relation expressed by the union of the land share supply points and the change in farmers' expectations could reflect the trend and the shape of the compliance cost function.

Once all bids have been received and the offered shares of UAA have been analysed, the public administration selects the participants with a given budget level, starting to pay each farmer, from the lowest bid to the highest one, according also with the share of land that he or she has offered, until the budget is exhausted. We must therefore remember that not all the offered share of land will be accepted under the AEM2, but it will participate only that one the administration is able to pay according with the given budget level.

Within the two budget levels (i.e. 0,2 and 0,8 millions of euros per year) the results of AM2 represent the total quota of participating UAA under the Auction approach (i.e. equation 41), the MFR2 payment (i.e. equation 42) and the FR2 payment (i.e. equation 43), in the case of a generic agri-environmental measure that substitutes a mix of traditional cultivation (AEM2), assuming a maximum acceptable financial bid cap of 567 euros/ha (Table 10).

Table 10. Comparison of different payment mechanism in case of substitution of a mix of conventional cultivation with AEM2 (Percentage of total participating share of UAA in AEM2 on total UAA of the sample; $\overline{\beta}$ = 567 euros/ha)

	Percentage of participating UAA	
Policy Instruments	0,2 (low-budget)	0,8 (high-budget)
MFR2	17,16%	100%
AM2	7,55%	27,29%
FR2	5,01%	21,18%
MFR2/AM2	2,27	3,66
FR2/AM2	0,66	0,77

Source: own elaboration.

According with the results of AM1, also in AM2, under the two budget levels the performance of the auction is always located between marginal flat rate and flat payment results. However, when the budget increases, the difference between the performance of AM2 and of the MFR2 slightly increases, while maintains the same trend of AM1 in the FR case.

Within a high-level budget, whereas there are only 100 participating farms that have been paid according to their bid for the share of land that they offered, with MFR2 payment the administration achieves the maximum percentage of up-take with a saved budget of the 44% on the total budget.

With the lowest budget level, the maximum UAA up-taken with the MFR2 is around 2 times the up-taken area with the auction. The difference slightly increases under the highest budget level, to more than 3 times. Moreover, the percentage of up-take with FR, which is two-third (i.e. 0,66) of the auction approach with a lower budget, slightly increases to three-fourths with a higher budget level (i.e. 0,77). According to Figure 3, this is because the cost of the auction mechanism for the public administration rising more than proportionally compared to the cost of the uniform policy, which increases constantly at the same rate per hectare.

With regard to the lower budget level, if we keep constant the participating quota of UAA, the total expenditure with a uniform mechanism will be higher than the expenditure with the auction approach, which is determined by the lower bids value (i.e. left tail of Figure 3). This means that with the auction we still have a share of saved budget, which the public administration can use in order to increase the quota of participating UAA. Thus the participating land quota with the auction, within a low budget level, results higher than the one with the FR2 payment.

However when the budget level increases the public administration is then able to increase with both instruments the level of participating UAA, but for the auction at an increasing cost rate, according to the bidding function and the bid shading behaviour. As a consequence the difference in terms of cost between the two mechanisms decreases and the uptake with the FR2 becomes closer to the uptake with the auction.

Now let us look on what happens on the total quota of participating UAA under the three mechanisms when the maximum acceptable bid cap vary, according to the hypothetical levels defined above (i.e. when the bid cap becomes a half of first, when is one and a half times more and when is twice), according with the two assumed budget levels per year (Table 11).

Table 11. Comparison of different payment mechanism in case of substitution of a mix of conventional cultivation with AEM2 (Percentage of total participating quota of UAA in AEM2 on total UAA of the sample; $\overline{\beta}$ = 283,5 euros/ha; $\overline{\beta}$ = 870,5 euros/ha; $\overline{\beta}$ = 1134 euros/ha)

Panel A: Maximum acceptable bid cap $\overline{\beta}$ = 283,5 euros/ha

	Percentage of total participating quota of UAA	
Policy Instruments	0,2 (low-budget)	0,8 (high-budget)
MFR2	100%	100%
AM2	100%	100%
FR2	5,29%	100%
MFR2/AM2	1	1
FR2/AM2	0,05	1

Panel B: Maximum acceptable bid cap $\overline{\beta}$ = 850,5 euros/ha

	Percentage of total participating quota of UAA	
Policy Instruments	0,2 (low-budget)	0,8 (high-budget)
MFR2	12,61%	35,74%
AM2	4,21%	19,59%
FR2	5,11%	21,32%
MFR2/AM2	2,99	1,82
FR2/AM2	1,21	1,08

Panel C: Maximum acceptable bid cap $\overline{\beta}$ = 1134 euros/ha

	Percentage of total participating quota of UAA	
Policy Instruments	0,2 (low-budget)	0,8 (low-budget)
MFR2	6,58%	28,63%
AM2	3,55%	14,31%

FR2	4,97%	21,19%
MFR2/AM2	1,85	2
FR2/AM2	1,4	1,5

Source: own elaboration.

With regard to Panel A, when the maximum acceptable bid cap is halved from the first level (i.e. $\overline{\beta} = 567$ euros/ha), according with Figure 8, the farmers total offered land share decreases from 2121 hectares to 954 hectares. Then, with a lower budget level, the administration just needs an average payment of about 209 euros/ha in order to support the whole offered land quota. Since the average payment with the auction and with the MFR2, are lower than this amount, through the application of these two instruments the public administration can accept the 100% of the UAA offered by farmers. Instead, for the uniform payment, being 500 euros/ha, the administration is only able to cover the 5.29% of the UAA offered by farmers. However, in order to compare the performance of the auction with that of the MFR2 and FR, in this case, we should refer to the percentage of budget saved before rent as an indicator of the instruments' ability to reach the target (i.e. maximum uptake within the budget level). Moreover, the difference in the saved budget between the three approaches can be used as a proxy indicator of the cost of the various instruments before rents, which are analysed below (Table 12).

With regard to Panel B and Panel C, when the maximum acceptable bid cap is one and a half times more the first one (i.e. $\overline{\beta} = 567$ euros/ha) or even doubled, within both the budget levels, the auction's performance worsens, becoming the latest mechanism, which follows the FR and MFR2 payment. Despite this result can be possible according with literature review (Latacz-Lohman and Schillizzi, 2006), it should be taken carefully in the light of the hypotheses we made, for which the most coherent result remains the one reported in Table 10: the auction mechanism is always located between marginal flat rate and flat payment results. More in detail, the cases in which the FR approach performs better than the AM2, are those where we have assumed the public administration can vary the relevant bid cap. But we know that this variation has been just theoretical (i.e. functional to our analysis in order to test the model), because in the reality of agri-environmental programs, the decision about the relevant bid cap should be linked to a measure of the average compliance cost in relation to the availability or a variation of budget resources. And if there is a variation of the available resources we also expect a change of fixed payment, which, however, we did not. Moreover, the relevant bid cap is generally calculated on the basis of a measure of past payment rates from previous programs, as indeed, we also did for the first hypothesis (i.e. $\overline{\beta} = 567$ euros/ha) that has been taken from the average of the payments for a similar measure in the RDP E-R 2000-2006 and in the light of this, it gives us the most consistent result.

However, in our specific case and according with Figure 7, when the farmers' expectations about bid cap grow, farmers find convenient to reformulate and increase their previous bids. Since the value of the bids exceed the value of the uniform payment, the performance of the auction decreases. Thus, with regard to Panel C, the difference between the MFR2 and the auction increase from 1,85 with a lower budget to 2 with a higher budget level. The same result happens to the difference between the FR and the auction, which slightly increase from 1,4 to 1,5.

Table 12. Comparison of different payment mechanism in case of substitution of a mix of traditional cultivation with AEM2 (Percentage of budget saved before rent in AEM2; $\overline{\beta} = 283{,}5$ euros/ha)

	Percentage of saved Budget	
Policy Instruments	**0,2 (low-budget)**	**0,8 (low-budget)**
MFR2	61%	90,5%
AM2	13%	78%
FR2	0	40%
MFR2/AM2	4,69	1,16
FR2/AM2	0	0,51

Source: own elaboration.

As expected the ability of the auction to reach the participation of the whole offered UAA, within the two given budget, is always located between marginal flat rate and flat payment results, followed by the performance of the flat rate payment. When the budget increases, the difference between the performance of the Auction and of the MFR decreases, and has an opposite trend in the FR case, confirming the previous results. With the lowest budget level, the maximum budget saved with the MFR is more than 4 times the budget saved with the auction, confirming that with the auction there is a positive rent compared to the MFR2 where R=0. The ratio between the two approaches decreases under the highest budget level around 1,16. According to Figure 4 that also confirms this result, with a lower expectation of maximum acceptable bid cap, the bid and the compliance cost functions tend to rise on the right side and being closer. As a consequence the auction performance improves gradually as we move towards higher budget and more participating

UAA. For the same reason explained in Figure 9, the FR payment improves its performance compared to the auction when we move to higher budget levels.

In order to deepen the analysis of the performance of AM2, we proceed to compare the rate of information rent among the analysed mechanisms when changing the expectations about the bid cap (Table 13). As we explained previously the total payments with AM2 and FR2 and the total compliance cost depend on the total participating UAA in AEM2, which in this case changes in dependency of the farmers' expectation about the bid cap and of the budget level. Thus, these measures, particularly with regard to the total payments with FR2, change in dependency of the hypothesis made about the budget level and of the maximum bid cap. Moreover, we do not have calculated the total payment with FR with the total available UAA, but we have used the participating UAA on the basis of the total share of UAA offered with AM2.

Tabella 13. Comparison of the rate of information rent between AM2 and FR2 within two-budget level (AEM2)

Panel A1: Maximum acceptable bid cap $\overline{\beta}$ = 283,5 euros/ha						
	0,2 (low-budget)			0,8 (low-budget)		
Policy Instruments	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros
AM2	173318,21	76031,64	2,27	173318,21	76031,64	2,27
FR2	199736,84	4068,74	49,09	477257,11	76031,64	6,27
FR2/AM2			21,62	FR2/AM2		2,76

Panel B1: Maximum acceptable bid cap $\overline{\beta}$ = 567 euros/ha						
	0,2 (low-budget)			0,8 (low-budget)		
Policy Instruments	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros
AM2	191907,78	60423,20	3,17	794730,05	421605,29	1,88
FR2	189055,85	38969,15	4,85	799049,97	265278,05	3,01
FR2/AM2			1,52	FR2/AM2		1,60

Panel C1: Maximum acceptable bid cap $\overline{\beta}$ = 850,5euros/ha						
	0,2 (low-budget)			0,8 (low-budget)		
Policy Instruments	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros
AM2	167159,73	63875,39	2,61	798509,076	339364,40	2,35
FR2	193032,47	77791,07	2,48	775410,84	360872,83	2,14
FR2/AM2			0,95	FR2/AM2		0,91

Panel D1: Maximum acceptable bid cap $\overline{\beta}$ = 1134 euros/ha						
	0,2 (low-budget)			0,8 (low-budget)		
Policy Instruments	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros	Total payment (TP) euros	Total compliance cost (TC) euros	Rent ratio (TP/TC) euros
AM2	191996,86	80069,56	2,39	777410,48	329636,47	2,35
FR2	187616,12	112489,60	1,66	799664,19	508971,49	1,57
FR2/AM2			0,69	FR2/AM2		0,66

Source: own elaboration.

Starting from Panel A1, with the first level of bid cap (i.e. $\overline{\beta}$ = 283,5 euros/ha) under the two budget level the rate of information rent with auction is lower than the one with the flat rate payment. With a lower budget the rent associated with FR2 is twenty times larger than the one associated with AM2. This value decreases when we increase the budget level, thus the rent with FR2 becomes around three times larger than the one with AM2.

When the expectation about the bid cap is doubled (i.e. Panel B1), under the lowest budget level, the rate of information rent of AM2 increases of about the 40%, while it decreases for the FR approach of about the 90%. Thus, the rate of information rent associated with FR2 becomes just one and a half the rate of AM2. Then, when we move to the highest budget, each rent decreases, but with a greater degree for AM2. However the rate of FR2 almost remain just slightly more than one and a half the rate of AM2.

With regard to Panel C1, when the bid cap level becomes one and a half the one in Panel B1 (i.e. 850,5 euros/ha), the rate of information rent of AM2 slightly exceeds the one related with FR2 (i.e. the ratio FR2/AM2 is less than one, which means that the farmers' rent with auction becomes greater than the one with uniform policy). The same results can be observed under the two budget levels. Moreover, with regard to Panel D1, when the expected bid cap is twice the one in Panel B1 (i.e. 1134 euros/ha), the two rates of information rent decrease, but mostly for FR2, while the one for AM2 continues to be larger than the one with FR2. The rate of information rent with AM2 becomes almost the double of the one with FR2 within both the budget levels.

In order to deepen the analysis we provide an alternative comparison between the AM2 and FR2, with a measure of the average per hectare rent and the percentage of rent with a higher budget level considering the same quota of participating UAA (Table 14).

Table 14. Comparison of different measures of farmers' rent within a higher budget level (AEM2)

Panel A2: Maximum acceptable bid cap $\overline{\beta}$ = 567 euros/ha; reference UAA=954 ha		
	Budget level (0,8 million of euros per year)	
Policy Instruments	Average per hectare Rent (euros/ha)	Rent (% on the budget)
AM2	215,13	26,42%
FR2	363,26	44,85%
FR2/AM2	1,68	1,69
Panel B2: Maximum acceptable bid cap $\overline{\beta}$ = 283,5 euros/ha; reference UAA=954 ha		
	Budget level (0,8 million of euros per year)	
Policy Instruments	Average per hectare Rent (euros/ha)	Rent (% on the budget)
AM2	54,13	3,99
FR2	324,77	20,47
FR2/AM2	5,99	5,13
Panel C2: Maximum acceptable bid cap $\overline{\beta}$ = 850,5 euros/ha; reference UAA=954 ha		
	Budget level (0,8 million of euros per year)	
Policy Instruments	Average per hectare Rent (euros/ha)	Rent (% on the budget)
AM2	317,39	38,72
FR2	284,28	35,10
FR2/AM2	0,89	0,90
Panel D2: Maximum acceptable bid cap $\overline{\beta}$ = 1134 euros/ha; reference UAA=1080,40		
	Budget level (0,8 million of euros per year)	
Policy Instruments	Average per hectare Rent (euros/ha)	Rent (% on the budget)

AM2	415,09	49,56
FR2	196,18	23,44
FR2/AM2	0,47	0,47

Source: own elaboration.

Since in this case we consider a different quota of the accepted UAA compared to the one used for the previous analysis (Table 13), some small differences arises between the two computations. However the auction approach confirms to perform better with the first bid cap hypothesis.

With regard to Panel A2 ($\overline{\beta} = 567$ euros/ha) the percentage of farmers' rent with FR2 payment is more than one and a half the percentage associated with AM2. The same result is reported with regard to the average per hectare rent. When the expectation about the bid cap is halved (i.e. Panel B2), the percentage of rent associated with both policy instruments decreases, but with a greater degree in AM2. Thus, both the percentage of farmers' rent and the average rent per hectare with FR2 become more than five times the ones associated with AM2. The effect of the decrease in farmers' expectations about the bid cap reflects a more efficiency of the auction mechanism to reduce rents than the uniform payment.

However, the opposite result is obtained with regard to Panel C2. With a bid cap level of one and a half of the first bid cap (i.e. 850,5 euros/ha), the percentage of farmers' rent with AM2 slightly exceeds the one related with the FR2 payment (i.e. the ratio FR2/AM2 is less than one, confirming the previous result, in which the performance of the auction becomes worse). The same effects can be observed with regard to the average per hectare rent. Moreover, with regard to Panel D2, when the expected bid cap is twice the first one (i.e. 1134 euros/ha), the difference between the AM2 and FR in terms of both the percentage of farmers' rent and of the average per hectare rent, roughly doubles and both the ratios FR2/AM2 diminish to around 0,47.

DISCUSSION

1.13 SUMMARY AND CONSISTENCY WITH PREVIOUS LITERATURE

The present study had three aims. First, it intended to provide a comprehensive review of economic instruments that have been applied within the major agri-environmental programs of Europe, United States and Australia in order to analyse the conditions that allow implementation, the relative strengths and weaknesses, providing a framework of the principal design options and the relative implication for cost-effective agri-environmental management in real life. While the second aim was to develop two one-shot auction models (AM1 and AM2) for two-hypothetical agri-environmental measures (AEM1 and AEM2) and to test them through simulation exercises with data from Farm Accountancy Data Network 2010 and 2011 (FADN) of Regione Emilia-Romagna. The third goal was to evaluate the performance of the developed auction models by comparison with two flat rate options (MFR and FR payments).

The review of the applied policy instruments within the major EU, US and AUS agri-environmental programmes has highlighted the European gap with regards to market-based instruments such as auctions (Vojtech, 2010). While in the last decades there was a growing interest in United States and Australia for these economic policy tools (Latacz-Lohman and Schillizzi, 2006), the European Programs were anchored to instruments that aim to induce environmentally friendly changes in farmers' practices through the provision of uniform payments. Latacz-Lohman and Schillizzi (2006) have reported few examples of implemented experimental auction in Germany (Grassland Pilot Auction and Outcome-based auction) and United Kingdom (Challenge funds) that remain isolated experiences in the context of the EU RDP.

The increasing popularity of auctions between the US and AUS programs comes from the different nature of the programs' objectives and implementation principles if compared to the EU counterparts. For example, the payments resulting from the US CRP Auction are directed to reduce the agriculture's negative externalities after a centralized evaluation process with a national EBI index (Hajkowicz, 2009). The attention for negative externalities reflects a great degree of targeting of the US and AUS programs compared to the more horizontal EU measures. Moreover, the use of aggregate environmental benefit index within the US and AUS auctions highlighted a greater focus on outcomes of the US and AUS measures compared to the European counterparts (Claassen et al.

2008). The US CRP and AUS Bush Tender auctions focus on payments to reach environmental objective measured by the quantity of environmental services produced (Hodge, 2000).

One relevant common aspect that emerges from the various analysed payment approaches regards the problem of measuring AEMs outcomes and of the resulting link to public expenditure. Several are those factors that have been recognized as potentially responsible for inefficiencies related to the agri-environmental payments, such as limited information about measures, high administrative burden, the absence or lack of monitoring on farmers' commitments, the lack of information about actual compliance costs and farmers' rent and poor spatial targeting (Engel et al., 2008). According with Connor et al. (2008) setting a uniform payment can be a key challenge to achieve cost effective environmental results when the public administration faces asymmetric information conditions. When the payment is set too high, inefficiency results because farmers with opportunity costs less than the payment rates will recieve a surplus. By contrast, when the payment is too low, low rate of participation can occur.

Since, the implementation of a relatively cost effective agri-environmental programme requires a great deal of information on potential environmental benefits and the adequate system of incentives, and despite the institutional complexity (Ferraro, 2008) the Governments in US and AUS increasingly recognise the potential of auctions as a policy tool for allocating public resources and increasing the cost-effectiveness of payments (Latacz-Lohman and Schillizzi, 2006).

According with Ferraro (2008) also screening contracts can be a theoretical solution to help policy regulator to design more efficient payments. However the reviewed literature highlights that despite the theoretical appeal of this approach to improve the efficiency of agri-environmental policies, it is technically challenging and it has been rarely used in practice.

Through the analysis of the theoretical contract model, according with Moxey et al. (1999) and Bolton and Dewatripont (2004), we analyse the key design features of a second-best contract for a number of finite farmers (more than two type), highlighting the existing trade-off between efficiency and information rent due to the fact that the public regulator cannot provide an incentive payment equal to the marginal compliance cost of each participating farmers. In order to maximise the benefit from farmers' participation reducing the risks of imitative behaviours and adverse selection the public administration should offer incentive-compatible contracts, which specify an higher payment than the one obtained in a perfect information context to the lower compliance cost farmers and a reduced effort (participation) for the higher compliance cost farmers (Moxey et al., 1999; Canton et al., 2008). Moreover, one theoretical way could be to rely on costly-to-fake signals to gathering more information on farmers' attributes (i.e. soil type, the distance to roads and markets, the geographical location) correlated to compliance costs and use this information to improve the design of contracts. In addition, cost targeting approaches and eligibility criteria can be based on this information and used to offer alternative contract schemes and prices between farmers' types (Wätzold and Dreschler, 2005; Vergamini et al., 2013). However, given the level of complexity that this instrument requires, probably the attention has shifted towards alternative instruments, such as the agri-environmental auction (Ferraro, 2008).

Auction can be regarded as a trading mechanism that can be designed in order to achieve allocative efficiency (i.e. selection of participants with the highest benefit-ratio) and budgetary cost-effectiveness (i.e. buying the most conservation benefit with a given public budget). The analysed literature seems to converge on cost reductions through conservation auctions that can be substantial, though the scale of saving depends crucially on the specific auction design (Glebe, 2008; Schillizzi and Latacz-Lhomann, 2007; Stoneham et al., 2003).

Moreover, through competitive bidding the policy makers can learn what farmers are willing to offer for programme enrolment, which practices they are willing to adopt and what level of payment they are willing to accept in order to reduce information rent (Claassen et al., 2008). The competition is one of the main necessary conditions to assure the efficiency of the auction mechanism. Competition is firstly determined by the level of information about what it values in the auction (i.e. the fundamental bid cap). Latacz-Lohman and Schillizzi (2006) suggests that if bidder know their own quality estimates (i.e. compliance cost) and the government's preferences (i.e. the relevant bid cap), they will strategically avoid price competition offering the mix of services attributes that best matches the agency's preferences. They thus face competition with only those farmers that offer the same quality mix, reducing the overall level of competition. By contrast, the lack of information about the fundamental bid cap increases the guesswork that farmers face in formulating their bids. When farmers are unable to supply favourable but costly service attributes and price, the competition becomes the driving forces of the auction, preventing bidders to capture large rents by shading their bids. Moreover, also the auctioneer's reserve price strategy (i.e. un upper limit on the amount that the government is willing to pay) can be considered as a key element for the design of efficient auction (Latacz-Lohman and Schillizzi, 2006). The setting of a reserve price by the public administration would be relevant because it adds the risk that framers might lose the auction by bidding too high. By contrast when the auction is strict budget or target constrained, the reserve price becomes less important. For example, in the US the competition is assured by the limit imposed to the main USDA programmes on budget and acreage enrolment.

However there other factors that influence the farmers' ability to learn the auction cut-off point decreasing the auction efficiency. The number of participating farmers is one of these. Low rates of participation increases the probability that farmers can know each other, and consequently increases their ability to predict the fundamental bid cap. Other relevant factors include the auction format and implementation rules. Under repeated auction the probability of learning by farmers increases among the sequence of repetitions. With a discriminatory price auction the bid formation depends not only on a bidder's own compliance cost but also on his or her best guess of what the highest acceptable bid cap might be. This thus creates room for bidders to shade their bids above their true opportunity costs, securing themselves an information rent (Latacz-Lohman and Schillizzi, 2006). By contrast with uniform pricing the farmers' bid only determines the chance of winning but not the payment they will receive. Uniform price auction prevent bid shading, thus can reveal bidders' true opportunity costs. However the analysed literature suggest that the discriminatory format appears to be the more appropriate payment rule for agri-environmental auction, except for the case when there are reason to believe that bidders will considerably shade their bids. However Latacz-Lohmann and van der Hoomsvoort (1997) demonstrated the advantages in terms of cost-effectiveness of the discriminating auctions compared to a simple flat rate policy.

Finally, also the choice of an appropriate bid evaluation system represents a key design issue. The US CRP and AUS Bush use a multi-criteria environmental benefit index (i.e. EBI) to aggregate the various site-specific effects of conservation activities into one figure representing an estimate of the overall benefit of each bid (FSA, 1999; Babcock et al., 1996). With the bid evaluation system the public administration provides a rank of the collected bids, maximizing environmental benefit per dollar of programme expenditure (Claassen et al. 2008). However, these aggregate measures of agri-environmental benefit draw on environmental assessment conducted by ecologists and are limited by whatever data the public administration is able to collect, and at what cost.

The results of the empirical analyses carried out in this thesis are in line with findings reported in Latacz-Lohmann and van der Hamsvoort (1997) and Viaggi et al. (2008) who simulated farmers' auction behaviour within hypothetical agri-environmental measures. The estimated compliance cost function in AM1 for substitution of wheat cultivation captured almost the same high degree of heterogeneity (i.e. costs range form 0 to 1400 euros/ha) as in Viaggi et al. (2008) confirming the needs for a differentiated payment mechanism for AEM1 in order to reduce the farmers' rent associated with the lower compliance cost farmers (i.e. left tail of Figure 1) and increase the participation to AEM1 of the high cost farmers (right tail). Indeed, the bid function seems to fit well to this heterogeneity even if, given the discriminatory price auction format choose for AM1, it always remains a certain degree of bid shading, especially with regard to lower-compliance cost pool.

Approximately the same results have been obtained for AM2 (i.e. Figure from 3 to 5). Although the second analysis considers a lower number of farms, a different hypothetical agri-environmental measure and different quotas of UAA, the cost functions represented for the three level of bid cap assumed still capture a certain degree of heterogeneity according with expectations. When the expectation about the maximum bid cap is halved the heterogeneity in both cost and bid functions increases, while at opposite, when it doubles the functions become more flat and the heterogeneity reduces. According with the previous results also the discriminatory format for AM2 reveals the potential for bid shading by the lower-compliance cost farmers while the high-cost farmers bids are more closest to the compliance costs functions, especially when the expectation about the bid cap is halved (i.e. Figure 4).

To evaluate the outcomes of auction models according with the criteria reviewed by Schillizzi and Latacz-Lhomann (2007) we first compare the outcomes of the analysed mechanisms in terms of the rate of participation within a determined budget level and secondly we refer to the rate of information rent (the ratio of total payments to total compliance costs) and to a measure of the average per hectares rent.

The simulation results for AM1 under two budget levels (i.e. 0,2 and 2 million of euros) confirm the superiority of the auction approach than the flat rate option (Latacz-Lohmann and Schillizzi, 2006). With a lower budget, the maximum participation to AEM1 with AM1 is four times larger than the one with FR, confirming that the uniform policy can achieve low participation ratio (Groth, 2005). This difference decreases, with a higher budget, to around one and a half. At the opposite, the maximum participating UAA in AEM1 with MFR is around four times larger than the one with AM1 with a lower budget. As we have explained above, this difference is mainly imputable to farmers' rent caused by bid shading behaviours (Latacz-Lohmann and Schillizzi, 2006). Moreover, since bidders are accepted in an increasing order, starting from the lowest bid to the highest one until the budget is exhausted, when we increase the amount of financial resources we allow the regulator to support more bidders from the highest pool, in which the bid are more closest to the compliance costs, thus the difference between MFR and AM1 decreases to around two.

According with Schillizzi and Latacz-Lohmann (2007) the analysis of the rate of information rent (i.e. ratio between total payments and total compliance costs) confirms the superiority of AM1 compared to FR. The flat rate option provides an amount of rents that is one and a half the auction's rents with a lower budget and around two times greater with the higher budget level. Thus we find considerable cost savings from AM1 relative to FR. Almost the same result is obtained with regard to the measure of the average per hectare rent, confirming the empirical evidence analysed in the reviewed literature (Stoneham et al., 2003; White and Burton, 2005) for which the price-discriminating auctions are more cost-efficient than fixed-price mechanisms. The slightly difference between the two different criteria can be attributed to the lack of choice and the overestimation of farmers' participation in AM1. Within the high budget level and considering the total UAA participating with FR payment (i.e. 3619 hectares), the average per hectare rent of the FR mechanism is about 454,96 euros/ha, while the one with the auction approach is 256,02 euros/ha.

With regard to simulation results of the AM2, the total share of land offered by farmers in AM2 increases with increasing farmers' expectation about the maximum bid cap. To a bid cap of 567 euros/ha corresponds a bid-quota of land around the 30,95% of total UAA of the sample. When this bid-cap halves the aggregated quota of land decrease of about the 18,3%. By contrast, when the expectation increases of about the 150% from the first bid cap, the total share of land increases of about the 12,63%, corresponding to 43,58% of the total UAA of the sample. If the maximum bid cap doubles, the total offered quota exceeds half of the total UAA of the sample (i.e. 59,04%), corresponding to an increase of the 28,09% of the total bid-quota.

Considering two budget levels for AM2 (i.e. 0,2 and 0,8 millions of euros), and assuming a maximum acceptable financial bid cap of 567 euros/ha, the performance of the auction is always located between marginal flat rate and flat payment results. This result confirms the previous ones in AM1 and is in line with the result of the extent literature. However, when the budget increases, the difference between the performance of AM2 and of the MFR2 slightly increases comparing to the one in AM1, while it maintains the same trend of AM1 in the FR case. With the lowest budget level, the maximum UAA up-taken with the MFR2 is doubled than the up-taken area with AM2. This difference slightly increases with a higher budget level, to more than three times. The percentage of up-take with FR, which is two-third of the auction approach with a lower budget, slightly increases to three-fourths with a higher budget level.

In the light of the hypothesis we made about the opportunity for the public administration to change the maximum acceptable bid cap, we observe that when this relevant parameter is halved from the first and most coherent hypothesis of bid cap (i.e. $\overline{\beta} = 567$ euros/ha), with a lower budget level, the application of AM2 and MFR2 lead the public administration to accept the 100% of the UAA offered by farmers, while with FR2 the administration is only able to accept the 5.29% of the UAA offered by farmers. Moreover, when we hypothesize that the maximum acceptable bid cap is one and a half or even the double of the first level, with both the two budget levels, the auction's performance worsens, following the FR and MFR2 payment. However, we should take carefully this result because in the formulation of such bid cap hypotheses, we did not took into account the opportunity for the administrations to choose the relevant bid cap on the basis of the average compliance cost in relation to the availability of budget resources or on the basis of a measure of past payment rates. Moreover, we did not considered also the opportunity to change the FR as a result of a variation of the available budget. Thus we should point out that the most consistent result remains the one with the $\overline{\beta} = 567$ euros/ha, which is the hypothesis of bid cap that has been taken from the average of the payments for a similar measure in the RDP E-R 2000-2006.

With the lower bid cap expectation and the lower budget level, the maximum saved budget is achieved with the MFR2 approach (i.e. 61%) that result four times larger than the savings with AM2 (i.e. 13%). With the higher budget level the percentage of saved budget with AM2 increase to 78%. White and Sadler (2011) obtain a similar result, although not directly comparable to our case, but in the light of which we can be better frame our findings in the extant literature, since empirical evidence on auction performance is often spurious and capable of distortions. Analysing the optimal conservation investment for a biodiversity-rich agricultural landscape White and Sadler (2011) find that the maximum cost saving that could be achieved by a price discriminating conservation auction is about the 17%.

The analysis of the rate of information rent and the average per hectares rent in AM2 confirms the results of AM1, we can achieve a greater reduction of farmers' information rent with AM2 when compared with FR (White and Sadler, 2011; Iho et al., 2014). With a maximum acceptable bid cap of about 567 euros/ha the rate of information rent with FR2 is one and a half larger than the one with AM2. When the expectation increase, due to our theoretical hypotheses, this ratio decrease slightly less than one, meaning that the cost-effectiveness of the auction worsens. By contrast when the bid cap expectations is a half of 567 euros/ha the rate of information rent wit FR2 range from twenty times larger than the one with AM2 under the lowest budget level, while is around the twice with a highest budget. Despite these results is corroborated by the findings of Latacz-Lohmann and van der Hamsvoort (1997) and are consistent with the findings in experimental economics (i.e. Cummings et al., 2004) we should take it again carefully in the light of the hypotheses we made about the relevant bid cap.

Moreover, with an expectation about the maximum bid cap of 283,5 euros/ha we found similar result, though not directly comparable, of the simulated auctions for phosphorus load reduction from a Finnish pilot by Iho et al. (2014). We obtain from AM2 an average bid of 208 euros/ha with an average per hectares rent of about 54 euros/ha that is close to the one computed by Iho et al. (2014) of about 250 euros/ha, of which 16,9% is composed by farmers rent (42,2 euros/ha). While Latacz-Lohmann and Schillizzi (2005) finds a higher percentage of rent on payment of about the 36,4 % in their first round of the Kiel experiment. Another consistent result to AM2 findings is an average rental rate of 45,95 dollars per acre that has been found for the CRP auction in the US (Latacz-Lohmann and Schillizzi, 2006).

1.14 LIMITATIONS AND WEAKNESSES

The results of this work provide some theoretical and empirical insights with regard to the use of economic instruments in the context of agri-environmental policy design, in order to evaluate the potential to reduce farmers' information rent, focusing on adverse selection, trough alternative approaches, such as agri-environmental auctions. The review of the applied economic instruments within the major agri-environmental programmes of Europe, United States and Australia highlighted the relevance of considering such differentiation in optimisation tools searching for more cost-effective mechanisms.

Auctions are characterized by a certain degree of complexities, but since they require less priori information compared to screening contracts they have found more diffusion in the analysed programmes as a tool to limit farmers' information rents and improve the cost-effectiveness of the agri-environmental programmes. While the discussion has corroborated the main strengths of these approaches compared to the traditional instruments, as fixed payments, several are also the weaknesses that emerge from the empirical analysis.

The simulation exercises carried out for auction models aimed to test basic forms and characteristics of agri-environmental auctions, by providing empirical evidence of auction performance compared to two flat rate options for two hypothetical agri-environmental measures that mirrors the actual measure developed for the RDP E-R. However, the analysis of the weaknesses of the simulation exercises reveals several aspects and some simplifying assumption that must be pointed out in the discussion.

Despite the estimated compliance cost function demonstrates "well behaving" in terms of the sought of the economic properties required for this type of cost function and that the procedure of estimation have been selected from a consolidated procedure of estimation for this type of cost in E-

R by Viaggi et al. (2008), the assumption on the basis of such estimation remains rather simplified, which means that it is difficult to imagine to apply the same mechanism with other type of agri-environmental measures. This in turn can reflect that the knowledge about the compliance cost becomes a key factor that can limit the auction implementation and the ability of models to represent this instrument for both AM1 and AM2.

With regard to AM1, it considers a simplified one-dimensional model according with Latacz-Lohmann and van der Hamsvoort (1997). While AM2, which is more elaborated allowing two-dimensional bid, it still considers just one agri-environmental input (share of participating UAA).

Another weakness of the modelling strategies adopted for AM2 is that despite this model allows for dealing with two types of bid (i.e. one bid is a share of farmers' conventional UAA to replace with AEM2 and the other is an agri-environmental payment), we considered just the budget cost-effectiveness criteria to rank bid. While the literature suggests the use of multi-criteria indexes, in both auction models bids have been ranked from the lowest financial bid to the highest until the budget is depleted, considering the bid quota of UAA linked to the financial bid. Thus the model focusing only on budget cost effectiveness is not capable, in this formulation, to take into account agri-environmental benefits. Since conservation benefit are often site-specific and depend on the resource setting, the use of benefit indicators can help quantifying the effects of agri-environmental activities.

One more point worth mentioning is that both models do not take into account some well-established issues raised from the analysis of the auction literature. From the one hand both models confirm that the simulated payments depend crucially on farmers' expectation about maximum acceptable bid cap and budget level, but the simulation strategy just assume that they are exogenously given and there are no mechanism able to understand how farmers form this crucial expectation about bid cap. Both models only try to understand what happen on farmers bid when changes in these parameters occur. In addition, models do not consider also the transaction cost that can occur during the design and implementation of the auction. On this aspect, Latacz-Lohmann and Schillizzi (2006) argues that transaction cost can be relevant for the public administration when implementing the auction. The costs of operating environmental programmes include both the incentive payments made and the costs to the agency of administering the programme (information cost, contracting costs and policing costs including costs of compliance monitoring and enforcement, and scheme evaluation) (Falconer and Whitby, 1999). These cost tend to be disregarded in policy discussion, but the extent literature confirms their relevance and impact on the performance of the various approaches. However a percentage of transaction costs have been added to farmers into the computation of compliance costs.

Another limitation of our approach is due to the fact that both the models are not able to test crucial factors such as the change in the number of participating farmers and the potential to learn by bidders. As pointed out from the literature analysis the numbers of bidders can determine the potential for learning information and collusive behaviour (typically in small group). Then the assumption of one-shot, implicitly limiting the possibility to repeat the auction, from which it can increase the opportunity for farmers to learn information from the past game and increase their knowledge about the compliance cost of the competitor bidders and their knowledge about other relevant information for the government such as the critical bid cap and the level of budget. However, in the actual US and AUS programmes, the agri-environmental auctions are usually set up as repeated auctions in that tenders for the same contract are invited in a sequence of bidding rounds, this may allow bidders to learn from the outcomes of previous bidding rounds and use this information to update their bids. The risk of this happening in networked industries as farming is quite high, where information is quickly spread through the efficient communication networks of producers organisation, one important design challenge is to contain the scope for bidder learning, as well as that of collusion which can be correlated

A simplified assumption for both models regards the independent private values, which requires that farmers are able to calculate their compliance costs. This is not completely realistic because in the practice of the real agri-environmental programmes there is often an element of uncertainty among farmers resulting in affiliated values instead of independent private values. This element of uncertainty is often related to the long term of agri-environmental contracts (5-10 years) by the difficulties for farmers to predict what will happen to the management practices they have changed after the contracts have expired (Latacz-Lohmann and Schillizzi, 2006).

With regard to the analysis of auction performances all the cases in which we have assumed that the public administration is able to change the critical bid cap, represent only theoretical hypotheses. A more coherent and reliable approach would be to link the decision of the relevant bid cap to a measure of the average compliance cost in relation to the availability of budget resources. Moreover we could expect also to change the value of the flat rate policy according with the variation of the budget resources.

However, according with Connor et al. (2008) auction mechanism can provide the greatest reductions in costs relative to payment policies that involve little use of *a priori* information regarding bidder opportunity costs to differentiate payment levels.

The results of this research while attempting to provide a useful empirical exploration of auction theory, cannot provide a comprehensive solution in most real world settings. However, it can contribute to feed the debate at EU policy level about the role in considering auction design and bidding behaviour so as to limiting the inefficiency related to the actual agri-environmental measures.

CONCLUSIONS

This thesis develops two simulation models of a budget-constrained auction in E-R, in order to assess its capacity to reduce farmers' information rent compared to two flat rate payment options.

The models were developed on the basis of a theoretical framework drawn from an analysis of the major agri-environmental programmes in Europe, United States and Australia and from an overview of the major contributions on agri-environmental auctions (Stoneham et al., 2003; Latacz-Lohmann and Schilizzi, 2005; Glebe, 2008; Viaggi et al. 2008) and screening contracts (Wu and Babcock, 1996; Moxey et al., 1999; White, 2001) theories. From the reviewed design options we have selected the basic, but most relevant conditions that lead to a cost-effective implementation of auctions compared to a uniform policy. Then an assessment of the simulated auction in terms of budgetary cost-effectiveness has been provided for each model and the results have been discussed in comparison with those of the two flat rate payment options.

The first part of this study has presented an analysis of the applied economic incentives to address the issue of farmers' rent, in order to provide a framework of the principal design options and the relative implication for cost-effective agri-environmental management in real life. The overall analysis highlights that reduction of farmers' rent is still an important task for governments that aim to maximize the environmental services obtained with limited budgets (Latacz-Lohmann and Schillizzi, 2006). A better management and allocation of the resources is desirable because it goes in the direction of enlarging the benefit of agri-environmental policies for society and spread consciousness and benefits among farmers, leading to increase the overall sustainability of agriculture. The AUS community-based approaches demonstrate the potential to exploit market based instruments, as auctions, also to share knowledge and information with farmers and relevant stakeholders in order to obtain in return a better land management.

Economic instruments such as auctions have been broadly implemented by the US and AUS government agencies experimenting different elements of novelty compared to the classic features of the auction theory (Riley and Samuelson, 1981, Klemperer, 2004). The reviewed experiences have dealt mostly with multi-unit of heterogeneous agri-environmental goods or services, using discriminatory payment rules that allowed multidimensional bid as in the case of the US CRP auctions (Babcock et al., 1996) and the AUS BushTender (Stoneham et al., 2003). In these auctions bids were ranked and consequently accepted according with multi-criteria indexes (EBI) in order to remunerate the agricultural producers on the basis of the conservation benefit that they offered. On the one hand, despite most of these assumptions deviate from the classics assumption, introducing elements of uncertainty about the overall result in terms of efficiency and effectiveness, still there are no contributions in the literature that explain without unambiguity the consequences of using different rules than those generally recognized in the fundamental theorem on auctions. On the other hand, these experiences have provided little evidence about efficiency gains compared with fixed payments. Stoneham et al. (2003) reported significant efficiency gains in the first round of BushTender auction. White and Burton (2005) find efficiency gains between 200 and 315% for the ALR auction pilot in Western Australia. However, according to Latacz-Lohmann and Schillizzi (2006) the variations of results from each experience suggest that probably it is too early to make a definitive and robust assessment of the cost effectiveness of agri-environmental auctions.

The reviewed literature and the theoretical model on contracts highlighted the existence of a trade-off between efficiency and information rent due to the fact that the public administration cannot provide an incentive payment equal to the marginal compliance cost of each participating farmers. While offering a menu of incentive-compatible contracts through the use of mechanism design (Moxey et al., 1999; Bolton and Dewatripont, 2004) reduces the risks of adverse selection, the solution provides small benefits if compared to the institutional, informational and technical complexity that policy makers face in the application of this instrument (Arguedas and van Soest, 2011). This outcome partially justifies the lack of real-world application of such theoretically powerful approach and why the attention has shifted towards alternative instruments, such as the agri-environmental auction (Ferraro, 2008). Anyway, the theoretical analysis of this instrument allowed us to deepen the issue of adverse selection and contributing to the better understanding and representation of the problem of farmers' rent. Thanks to this background we have chosen to address the problem of information rent through an empirical application that focused on auctions. This approach requires the management of lower complexity and according with the extant literature, it can lead to better results (Glebe, 2008; Schillizzi and Latacz-Lhomann, 2007; Stoneham et al., 2003).

The second part of this thesis focuses on the two-simulation auction models for two hypothetical agri-environmental measures in E-R. The results confirm the findings in Latacz-Lohmann and van der Hamsvoort (1997) and Viaggi et al. (2008). We found that the variability of compliance costs seems to justify the application of complex contract allocation mechanism such as auctions, while traditional flat rate payment policy tend to overcompensate farmers. At the same time the results confirm that the performance of the marginal flat payment is superior compared with the other approaches, both in terms of participation and in reducing farmers' rent. However the feasibility of such payment strongly depends on the information available to the public decision makers and it appears to be theoretically powerful but challenging to implement. One opportunity would be to gather information on observable landowner attributes that are correlated with opportunity costs and use these attributes to design differentiate payment mechanism (e.g. payment related to different geographical locations or different environmental sensitive areas) rather than focus the justification of payment on the average compliance cost of farmers in the same area. The soil type, the distance to roads and markets, the forest type and the assessed value are some examples of these attributes that are often correlated with opportunity costs and costly for farmers to fake. With this information the public administration can create eligibility requirements for receiving a given contract type and price. Furthermore, minimum eligibility criteria can be also used to exclude the participation farmers that produce few environmental goods. This approach is common in EU and US agri-environmental schemes where contract prices differ geographically to reflect regional differences in opportunity costs (Ferraro, 2008).

Moreover the analysis of the performance of the auctions compared with the two flat rate options highlights that cost saving may easily be eroded under the discriminatory auction format since the optimal bids and the relative bid shading quota increase with both the bidder's opportunity costs and his/her expectations about the critical bid cap. Thus the auction models shown better performance with a low level of expectations about the critical value, while with higher values the flat rate policy performs better. Thus, according with Latacz-Lohmann and van der Hamsvoort (1997) within the discriminatory price format the share of information asymmetry is not completely reduced since the auction's cost revelation property is blurred by the fact that the bids also reflect the bid shading behaviour, which is related to the bid cap chosen by the agency.

While the discussion showed several weaknesses of the developed approaches in the current form, the overall message goes in the direction that further improvements are possible in efficiency of AEMs. Such improvements would require a consistent development of implementation data collection, data analysis and ex-ante policy design and evaluation.

The main further activities of this work can be the development of a simulation model for a self-selecting contract in order to compare it with the second auction model, evaluating the performance of these approaches with regard to farmers' rent. At the same time the development of screening contracts may address the problems of dynamic inefficiency (lack of incentives for entrepreneurship). The typical agri-environmental contract does not provide producers with adequate incentives to seek out new methods of reducing costs, to introduce new ideas, or to be willing to take risks for the provision of environmental services.

Further research could involve the comparison of these models from a numerical standpoint, using experimental auctions with students. Moreover, outcome-based agri-environmental payments could be analysed in order to provide further clarity in the context of the debate surrounding the relationship between payments and results in future EU RDP programmes. Outcome-based payment considers the interests of the local people and the relevant stakeholders and their demand for environmental services and goods (Groth, 2005).

Moreover, according with Banerjee et al. (2015), further studies should consider to implement scoring rules that reward pairs of sets of bids for adjacent land use projects in order to test the effects on auction performance of improving targeting objectives. The agglomeration of land uses can often produce much greater conservation benefit than if they are fragmented or disconnected (Dallimer et al., 2010). Thus, this study should try again laboratory experiments to investigate the impact of information revelation on the auction performance with spatial targeting and provide also an analysis of individual bidding behaviour, in order to learn about the nature of agents focusing on the factors that affect bid submission and the potential relation with co-ordination and conservation synergies. According with Latacz-Lohmann and Schillizzi (2006) the lab provides a low-cost means to study auction performance prior to costly field implementation with actual farmers.

Finally further research should focus on the problem of uncertainty over property rights trying to understand the impact on the strategic farmers bidding behaviour when uncertainty vary according to different contracts terms. From the policy-makers point of view the analysis of this problem could help to understand how the uncertainty about the ending of contract agreements can affect farmers' participation and their choices in the pre-contractual stage.

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