Assessment of Nonpoint Pollution Instruments: The Case of Spanish Agriculture

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ABSTRACT Nonpoint pollution is characterized by imperfect knowledge of biophysical processes, stochastic components, and asymmetric information among agents. The design and implementation of measures to abate emissions is a difficult task because of this lack of biophysical information and the strategic behaviour of stakeholders. The development of input-intensive agriculture in Spain during the last century has created large discharges of nutrients and other harmful substances into water bodies, causing damage to aquatic ecosystems. In Spain and other European countries, the control of nonpoint pollution is a crucial step in achieving the “good” ecological status of water bodies sought by the European Water Framework Directive. The empirical findings challenge the current approach to pollution policies and call for policy efforts focused on nurturing stakeholders’ collective action and on supporting the necessary institutional setting.

Introduction

Water resources are being subject to growing quantitative and qualitative pressures from urban, industrial, and agricultural uses. The increasing water extractions are especially worrying in arid and semiarid regions, where the huge overdraft of resources is destroying aquatic ecosystems and jeopardizing human activities. Water quality is also being seriously affected by point and nonpoint pollution loads, which make entire river tracts and aquifers useless. The case of pollution is the typical situation of a negative externality, which is defined as a public “bad” that results from “waste discharges” associated with the production of private goods (Cropper & Oates, 1992). The task of water authorities is to assess these water-scarcity and water-quality problems in order to develop policy strategies that improve water allocation and management. However, this requires the cooperation of stakeholders willing to internalize the damages and protect water resources.

Agriculture generates significant pressures on water resources worldwide, and it has significantly changed the natural environment for centuries. Agriculture produces goods and services, and provides a variety of environmental externalities both positive and negative. Traditional agriculture has, during centuries, supported the rural environment and its associated environmental services to society, for example controlling weather
effects and pests, supporting biodiversity and providing shelter and recreational services. However, the intensive agriculture of recent decades has several drawbacks, such as emissions of nutrients and pesticides that degrade natural ecosystems. The runoff and leaching of pollutants, for instance nitrates, phosphorus, pesticides, or salts, degrade water resources and soils, the habitat of flora and fauna, and the services provided by ecosystems. Pollution emissions damage aquatic ecosystems. Rivers, estuaries, lakes, and streams are being affected by negative impacts on many types of aquatic biota, such as fish, vertebrates, invertebrates, flora, wetlands, and grasslands. The emissions from agriculture not only affect ecosystems, but also affect downstream human activities in farms, urban centres, and industries.

Another issue is water scarcity, with a large pressure from the development of irrigation. Especially worrying is the overexploitation of groundwater resources during recent decades. Groundwater resources are important sources of fresh water, storing 89% of the fresh water on Earth (Koundouri, 2004). Groundwater resources are used for household, industrial, and agricultural uses, but the largest use is irrigation. When extractions are greater than recharge, the result is the depletion of aquifers and the desiccation of surrounding areas. Most extractions of groundwater are out of the control of any public authority. This groundwater overdraft reduces the quantity and the quality of the water stored, with significant negative impacts on the ecosystems depending on these water bodies.

The paper is organized as follows. The following section presents the different instruments to control nonpoint pollution and the difficulties in their implementation. The third section analyzes the role of cooperation in nonpoint pollution control. In the fourth section, the Spanish case is explained with a brief description of the most important irrigation areas. Finally, the concluding section summarizes the main ideas and highlights the recommended policy actions.

The Control of Nonpoint Pollution

Pollution loads from agriculture into water bodies are characterized by being nonpoint emissions at the source. This type of pollution is linked to an important problem of information and knowledge, because of the impossibility of identifying the agent generating the emissions, the spatial location, and the amount of emission load at the source. This problem explains the difficulties in the design and implementation of policies to control nonpoint pollution. These issues are discussed in the nonpoint pollution literature and are presented by Shortle and Horan (2001), Tomasi et al. (1994), and Weersink et al. (1998).

Several policy measures have been proposed to internalize the social damages from nonpoint pollution emissions. These pollution measures are classified in three types of instruments: command and control, economic, and institutional (Table 1). The more common measures to abate agricultural pollution are regulations over inputs or practices, ambient pollution taxes, liability rules, and trading of pollution permits.

The complexity of biophysical processes and the heterogeneity of pollution functions among agents imply that first-best policy measures are almost impossible to implement. The reason is that policy makers would need a huge amount of information and knowledge on agents’ characteristics and biophysical processes. Additionally, the transaction costs involved in implementing control measures could be quite large. Therefore, the only option suggested for real-world situations is to achieve a second-best policy. An important
question that has to be considered is the issue of the enforcement and monitoring mechanisms, which are required for any pollution regulation. In the vast majority of studies, these transaction and administrative costs are not considered.

Several issues arise in the design of policies to control nonpoint pollution. These issues relate to the number of agents and their spatial location, the production technologies and practices, the pollution transport and fate processes, and to risk and uncertainty. The strategic behaviour of agents has to be taken into account because of the asymmetric information between the social planner and the agents, and information problems such as moral hazard and adverse selection (Segerson, 1988; Xepapadeas, 1991, 1992; Shortle & Dunn, 1986).

The existence of multiple polluters distributed across space complicates the design and implementation of nonpoint pollution policies, since scientific knowledge and statistical information are quite scarce and costly. Another issue is the heterogeneity of agents displaying different production and pollution functions. This heterogeneity between agents implies different emission loads and pollution abatement costs. Heterogeneity also arises from the spatial distribution of biophysical features, where agents using the

### Table 1. Classification of pollution control instruments.

| Type of instrument                     | Description                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------|
| **Command and control instruments**   |                                                                             |
| Standards                             | Input control over quantity Input use restriction Output control: quotas or   |
|                                       | prohibitions Regulation of the maximum quantity of emissions Output        |
|                                       | production quantity restriction                                             |
| **Economic incentives or market-based**|                                                                             |
| instruments                           | Input or output taxes per unit of product Subsidies for practices that reduce |
|                                       | emissions Crop land retirement subsidy                                      |
|                                       | Deposit paid, repayable on achieving compliance                             |
|                                       | Payments in compensation for damage                                          |
| Markets                               | Input trading Exchange of input rights                                       |
|                                       | Emissions trading Exchange of permits of emissions or emissions rights        |
| **Institutional instruments**         |                                                                             |
| Basin authority                       | Coordination of water resources by stakeholders Planning and management by   |
|                                       | stakeholders at basin, watershed and district levels                         |
| Liability rules                       | Negligence laws and rules Codification of rules of liability for environmental |
|                                       | damage                                                                      |
| Voluntary approaches                  | Non-compliance fees Payments made by polluters for non-compliance with a     |
|                                       | limit of emissions                                                           |
| Development of social responsibility  | Education and social programmes Energy conservation and environmental      |
|                                       | labelling; promotion citizenship                                              |
| Facilitation bargaining               | Costs of bargaining are reduced Polluter information placed in public domain |

*Source: adapted from Perman et al. (2003) and Shortle and Horan (2001).*
same technologies generate different emissions, just because of the location attributes. Stochastic elements represent imperfect information on the relationships involved in production and pollution functions, but also uncertainty in the pollution transport and fate processes. These issues explain why nonpoint pollution control is fraught with problems of moral hazard and asymmetric information.

Finally, an additional issue to consider is the transaction costs associated with monitoring and enforcement. The substantial differences in transaction costs among policies have to be considered when selecting the right policies for nonpoint pollution control.

Some authors consider that the best option to reduce pollution is that agents control their level of emissions voluntarily. However, voluntary schemes have been criticized in the literature for not achieving any significant pollution abatement. The alternative to voluntary schemes, but also to economic instruments, is institutional instruments where the public administration promotes cooperation among farmers, leading to collective action in the protection of water resources. Collective action could be used to address problems such as uncertainty and insufficient information (Byström & Bromley, 1998).

The economic analysis of point source pollution has been broadly dealt with in the literature and the typical control instruments are emission standards, emission permits, and Pigouvian taxes on emissions (Baumol & Oates, 1988). The tools used in point source pollution are not suitable for nonpoint pollution. As explained previously, the analysis of nonpoint pollution is more difficult because the regulator lacks information about the source of pollution and the emissions loads. This situation favours the strategic behaviour of agents, since the information is asymmetric and the polluting agent has more information than the agency regulating pollution. From a theoretical perspective, the seminal work dealing with nonpoint pollution includes the contributions of Griffin and Bromley (1982), Shortle and Dunn (1986), Segerson (1988), Xepapadeas (1991), and Byström and Bromley (1998).

The foundations for analyzing agricultural nonpoint pollution was developed using biophysical models that link production decisions with emission loads (Griffin & Bromley, 1982). Pollution is made dependent on inputs and production practices, and then several control instruments can be considered such as taxes, subsidies and standards on polluting inputs and on emissions. A further refinement consists in introducing uncertainty from random natural processes and taking care of the imperfect information about biophysical processes (Shortle & Dunn, 1986).

Since pollution at the source cannot be observed, an alternative is to design measures to control ambient pollution instead of trying to control pollution at the source (Segerson, 1988). This type of control measure can be a tax or subsidy, depending on whether farmers pollute above (tax) or below (subsidy) an ambient pollution threshold. The tax or subsidy is calculated by multiplying a tax rate by the difference between the observed pollution and a threshold fixed by the regulatory agency.

A large body of literature analyzes the best policy measures to reduce pollution emissions, with measures such as taxes and subsidies on inputs, on source pollution or on ambient pollution, and group fines or group lump-sum payments. The procedure followed in these studies is to develop a theoretical model, and then validate the results empirically by doing “experimental economics”. These models maximize social welfare, defined as the private profit of farmers’ production activities minus the environmental pollution damages coming from these activities. The common feature of this literature is that pollution policies are tested using students in laboratory experiments (see Cochard et al., 2005; Spraggon, 2002, 2004; Vossler et al., 2002).
There are two problems with this type of approach: the difficulty of abating nonpoint pollution by using pure economic instruments, and the validity of students’ responses in representing the behaviour and decisions of farmers and other public and private stakeholders.

Most of the pollution policies consist in using economic instruments to compensate the private benefits of agents causing pollution damages, or using public funds in financing investments in pollution abatement technologies. But such policies seem ineffective in curtailing the large nonpoint pollution loads in river basins around the world. What might be useful is the cooperation of stakeholders managing the water resources. The economic argument supporting this collective action approach is that water resources are mostly common pool resources, requiring cooperation rather than just economic instruments that are harder to implement in the case of public goods (Albiac, 2009).

Policies to control nonpoint pollution are not easy to design. Some authors such as Vitousek et al. (2009) mention the United States (US) and the European Union (EU) as examples of places that have reduced nutrient imbalances, yet pollution remains very high in their water bodies.

In the US, it seems that there is no improvement in nonpoint pollution loads over the last decade in the Mississippi basin. A large study completed by the National Oceanic and Atmospheric Administration (NOAA) in 2000 on hypoxia in the northern Gulf of Mexico has not spurred any significant reduction of nitrogen loads in the Mississippi basin (Environmental Protection Agency, 2007). The major effort in the US to curb nonpoint pollution has been made in the Chesapeake Bay during the last 25 years, but results there show only a moderate abatement. Reductions in nitrogen and phosphorus loads are still far from the sought thresholds. The implication is that the current voluntary measures in the Chesapeake Bay have to be supplemented with stronger regulatory measures (Linker et al., 2009).

In Europe, the policy efforts to curb pollution have been considerable but results appear disappointing. European regulations include the Urban Wastewater Treatment Directive and the Nitrates Directive, both of 1991 (EEC, 1991a, 1991b), and the Water Framework Directive of 2000 (EC, 2000).

The huge investments of the Wastewater Directive, above €100 billion, should have reduced pollution in the European water bodies. However, the European data for the past 15 years on nitrate concentration indicate only a slight reduction in rivers and a large increase in aquifers (European Environment Agency, 2009). The data from the Organisation for Economic Co-operation and Development (2008) also found that most major European rivers show no abatement of nitrates, and some have even grown worse.

The Nitrates Directive of 1991 also sought to reduce pollution. It was initially based on information and voluntary compliance, and more recently farmers have been required to keep a nitrogen balance book. Noncompliant farmers drawn by chance are being penalized in their Common Agricultural Policy payments. The Nitrates Directive applies to cultivation over aquifers declared officially polluted. But the directive ignores cultivation over whole basins and very polluting crops that are not receiving subsidies, such as greenhouses. The achievements of this directive are quite questionable (Albiac, 2009).

The Water Framework Directive of 2000 relies heavily on economic instruments to achieve sustainable management of water resources. Water pricing and “full recovery costs” are advanced as the key policy measures. But these water-based instruments to abate pollution do not seem to be good enough to curb nitrate pollution since the pollution driver is fertilizer and not water.
Nonpoint Pollution Control Is Beyond Economic Instruments

The economic theory argument explaining the difficulties of previous pollution abatement policies is the following: Nonpoint pollution is a common pool "resource" (or public bad), where economic instruments such as taxes and subsidies are likely to fail. Nonpoint pollution policies cannot be just based on pure economic instruments, following the "polluter pays" principle. Pollution abatement measures such as pollution taxes or markets for emission permits are very good for point pollution, but break down with nonpoint pollution.

The key policy issue is that an institutional setting is required to induce farmers’ cooperation. Pollution abatement is impossible without farmers’ involvement and active support to spur the needed collective action.

Measures leading to sustainable water management require understanding the basic concepts of policy analysis, such as objectives, instruments (institutional, economic, command and control), optimum, target, cost efficiency, private good, common pool resource, public good, cooperation among stakeholders, and collective action. The control of nonpoint pollution is unfeasible without these policy concepts, because of the public good aspects of nonpoint pollution. Pollution abatement becomes quite challenging since there are incentives to free-riding.

The general situation regarding nonpoint pollution in many countries is the absence of any authority or policy. As indicated in the previous section, even the few existing policies in the European Union and the United States are limited, with policy instruments and enforcement mechanisms that seem largely inadequate. The current lack of cooperation in pollution abatement is driven by the structure of incentives, which may lead to the well-known tragedy of the commons and the free-riding of polluters (Hardin, 1968).

The lack of cooperation results in the Nash equilibrium of the game, while full cooperation would maximize social welfare. Figure 1 illustrates these outcomes from cooperation in pollution abatement (A), using marginal benefit and marginal cost functions of abatement. For each polluter $i$, $MB_i$ are the marginal benefits and $MC_i$ the marginal costs from pollution abatement, while $MB = \sum MB_i$ are the total marginal benefits from abatement. Under $A^0$, there is no effort on pollution abatement. The non-cooperative solution $A^{NC}$ is the Nash equilibrium where polluters equalize individual marginal benefits

![Figure 1. Pollution abatement under non-cooperative and cooperative solutions. Source: Perman et al. (2003).](image-url)
with individual marginal costs \( MC_i \). The abatement in the full cooperative solution \( A_C \) maximizes welfare, and applies the condition for efficient provision of public goods 

\[ MB = \sum MB_i = MC_i. \]

The specification of the marginal benefit function requires knowledge on biophysical processes and pollution damages to ecosystems. When this information is not available, the optimum level of abatement \( A_C \) is not known. In such a case the alternative is to establish a “reasonable” abatement threshold \( A_T \), where cooperation implies minimizing total abatement costs across polluters to reach the threshold.

What is the policy message from these game theory outcomes? The European Water Framework Directive relies on economic instruments in application of the “polluter pays” principle. Using economic instruments, such as an emission tax on every individual polluter, the result achieved is the non-cooperative solution. Under this solution \( A_{NC} \), the marginal benefit of abatement is just the tax applied to every farmer \( MB_i(A_{NC}) \) and the farmer responds by incurring a marginal cost of abatement equal to the tax \( MC_i(A_{NC}) \).

However, the suitable policy measure should be applied over the set of polluters to achieve cooperation \( A_C \), instead of applying economic instruments to individual polluters that result in non-cooperation \( A_{NC} \). This type of sustainable management calls for control mechanisms designed to induce collective action among stakeholders. The approach to follow is governing the commons by the stakeholders’ involvement in the management of nonpoint pollution (Ostrom, 2010). Therefore, pollution abatement efforts would be more effective if focused on nurturing collective action and providing the right institutional setting to support it.

**Nonpoint Pollution Policies in Spain**

The analysis of water quality and water scarcity problems is an important topic in Spain because of the pervasive degradation of river basins in recent decades. This topic is politically relevant for the different economic sectors, groups of stakeholders, and public decision makers at state and federal levels. Another reason is the large negative effects that climate change is likely to have on water resources in Spain, aggravating further the current water scarcity and quality degradation problems.

Water policies should be integrated into climate change strategies and plans, especially in adaptation measures. Reasonable policies should induce stakeholders’ cooperation through institutions, in order to achieve the required collective action in protecting resources and adapting to climate change. Cooperation is a key element in order to improve the allocation of water resources to human uses and the environment. But it is also a key tool in order to improve water quality by abating nonpoint and point pollution emissions.

The responses and adaptation to water scarcity and water quality degradation in Spain during the last 20 years have been shaped by the national water policies and also by the European Water Framework Directive. The main water policies have been the National Hydrological Plan proposal of 1993, the National Hydrological Plan of 2001 modified by the AGUA project (Proyecto de Actuaciones para la Gestión y Utilización del Agua) of 2004, the National Irrigation Plan of 2002, the Upper Guadiana Plan of 2008, and the First and Second Sanitation Plans of 1995 and 2008. The European Water Framework Directive was enacted in Spanish legislation in 2003. The directive does not address water scarcity
which is the main issue in Spain, but rather deals with the water quality of water bodies and the attainment of their good ecological status.

Large-scale aquifer depletion in southern and eastern Spain led to the proposal of considerable interbasin water transfers in both the National Hydrological Plans of 1993 and 2001. These large interbasin transfers were met by the opposition of political parties, groups of interest, and donating territories. Finally, the large interbasin water transfers were abandoned and replaced by the AGUA project. This project involves large investments in desalination plants to supply the Spanish south-eastern coastal fringe with an additional volume of $600 \text{ Mm}^3$ per year.

The investments of water policy planning in Spain are considerable, with the main policies summing up to almost €50 billion: €19 billion for the National Hydrological Plan, €6 billion for the National Irrigation Plan, €3 billion for the Upper Guadiana Plan, and €20 billion for the Second Sanitation Plan. The National Irrigation Plan and the Second Sanitation Plan seem well designed to improve water quality by reducing pollution loads.

![Figure 2. Nitrate concentration (mg/l NO$_3$-N) in Europe, by basin, 2008. Source: EEA (2011).](image)
But other policies embodied in the Upper Guadiana Plan and the AGUA project of the National Hydrological Plan seem poorly designed or even misguided.

Regarding water quality, it is important to evaluate the quality parameters of Spanish rivers in the European context (Figures 2 and 3). The quality parameters of the main Spanish and European rivers show modest or no improvement despite the large investments in urban waste water plants in recent decades. During the last 20 years, these investments have been above €100 billion in the European Union, and close to €10 billion in Spain. There are high nutrient loads in the Guadalquivir, Thames, Seine and Scheldt rivers, and high concentrations of heavy metals in the Seine, Scheldt, Tagus, Guadalquivir and Porsuk rivers (OECD, 2008). Another difficulty for policy design is that the knowledge about the impacts of water quality on aquatic ecosystems is very scarce.

It seems that water quality is improving very slowly in Europe, with some rivers even undergoing quality deterioration. An important pollution reduction should have been achieved in the loads of organic matter, nitrogen and phosphorus because of the urban
waste water treatment plants, and a reduction of heavy metals and chemical substances from industries.

The only available historical data series on water quality in rivers is published by the OECD (2008). These data show the acute quality deficiencies in European rivers during the last 30 years, which have prevented their ecological recovery. Biochemical oxygen demand has improved in Spain in the beginning of the 2000s, and also in the majority of European countries. Pollution by nutrients does not improve in Spain or in the majority of European countries, and even worsens in some countries. Information on heavy metals is very scarce, and the few available data indicate some reduction in Spain and other countries by the end of the 1990s.

A possible explanation for the poor performance of nutrient loads is that the agricultural nonpoint pollution of nitrogen and phosphorus is not controlled, and these emissions compensate the presumed reductions achieved with waste water treatment plants (Figure 4).

Figure 4. Nitrogen emission loads (kg N/ha) from agriculture in Europe, 2009. Source: EEA (2011).
Another factor could be the increase in nonpoint pollution as a consequence of urban sprawl. In Spain, many public decision makers and environmentalists are in favour of supporting the more profitable and input-intensive irrigation agriculture and the dismantling of the less profitable and less input-intensive irrigated agriculture of inland Spain. However, profitable irrigated agriculture is the main activity responsible for the acute pressure on and severe degradation of aquatic ecosystems.

The highly profitable crops are very intensive in capital and inputs, and generate pollution loads much larger than the extensive low-profit crops of inland Spain. In intensive greenhouse agriculture, fertilization is around 900 kg/ha of N, 400 of \( \text{P}_2\text{O}_5 \), and 1,200 of \( \text{K}_2\text{O} \), whereas cereals under irrigation in inland Spain are fertilized with around 100 kg/ha of N (300 for maize), 70 of \( \text{P}_2\text{O}_5 \), and 40 of \( \text{K}_2\text{O} \). In relation to pesticides, intensive greenhouse agriculture uses around 40 kg/ha of products or 5,000 liters/ha (not including soil disinfection). In extensive irrigated agriculture producing cereals, the pesticide use is around 3 kg/ha of products or 370 liters/ha (herbicides and insecticides).

This water management approach of supporting highly profitable crops follows the motto “more money per drop of water”. It is the foundation for promoting water pricing as the silver bullet to solve water scarcity and quality degradation in irrigation. Most decision makers in the European Union institutions, their counsellors, and many think tanks across Europe embrace this approach.

In the case of Spain, the most severe scarcity and quality problems occur in the Júcar, Segura, Sur and Guadalquivir basins, all of them located in the eastern and southern Iberian Peninsula. There is a dual situation in Spanish irrigated agriculture. The eastern and southern areas have quite profitable intensive agriculture, with severe pollution problems. On the other hand, inland Spain has extensive agriculture, not as profitable but with much lower contamination problems.

Agriculture in inland Spain is based on collective surface irrigation systems and low-profit crops, causing a moderate degradation of water resources. Basin authorities are able to enforce the minimum ecological flows in surface water bodies, with the participation of users in the watershed boards. In the intensive agriculture of the eastern and southern regions, control of water extractions is much more tenuous because of the importance of individual groundwater pumping. Groundwater users are not involved in watershed boards, and therefore extractions are beyond the enforcement capabilities of basin authorities. The increasing pressures in the eastern and southern regions are the consequence of the lack of control over groundwater extractions. The ensuing massive overdraft creates serious problems of water quality and quantity in entire river basins, with large negative impacts on aquatic ecosystems (Esteban & Albiac, 2011).

Nutrient pollution results from the use of fertilizers in Spanish agriculture, which consumes 1.05 million tons of nitrogen (\( \text{N}_2 \)), 0.56 million tons of phosphorus (\( \text{P}_2\text{O}_5 \)), and 0.43 million tons of potassium (\( \text{K}_2\text{O} \)). By state, Castilla-León, Andalucia and Castilla-La Mancha have substantial acreage under cultivation with a large consumption of fertilizers. However, the basins in Spain displaying the worst concentrations of nutrients in rivers and streams are the Júcar, Guadalquivir and Cataluña basins for nitrates, and the Júcar, Cataluña, Sur and Tajo for phosphorus. The aquifers with the highest concentration of nitrogen are located in the Guadalquivir and Júcar basins, and the aquifers with the highest concentration of salinity are located in the Sur and Segura basins (Hernández et al., 2010).
There are two general policy approaches in Spain to deal with quantity and quality problems faced by irrigated agriculture in the eastern and southern regions. One is the traditional water policy approach based on expanding water supply. The other is the approach based on new water management initiatives. These initiatives are based on instruments such as abstraction limits on surface and subsurface waters, revision of water rights, water reuse and regeneration, and water pricing and water markets. Following the Water Framework Directive, most of the policies are based on increasing water prices up to full recovery costs, or some other economic instrument such as water markets. But the problem with these water policies is that economic instruments seem to be inefficient in controlling nonpoint pollution or dealing with water scarcity in irrigation (Albiac et al., 2009).

There are several studies—by Orús et al. (2000), Uku (2003), Martínez and Albiac (2004, 2006), Mema (2006), and Esteban (2010)—which analyze measures to control nitrogen and salinity pollution from irrigation in the Ebro basin located in north-eastern Spain. The empirical results from these studies challenge the current European Nitrates Directive, which is based on penalizing the Common Agricultural Policy (CAP) payments of noncompliant farmers drawn by chance. This mechanism seems inadequate, and the empirical results point in a different direction. An example is the large pollution reduction achieved by the Spanish National Irrigation Plan, which is documented in the studies by Uku (2003) and Mema (2006).3 The empirical results from these studies are very relevant for the design of the programme of measures of the Water Framework Directive. These results highlight that the water pricing instrument promoted by the Water Framework Directive is inadequate to reduce nitrogen and salinity emissions. The demand for irrigation water does not respond to prices, and therefore water pricing is far from being an efficient measure to abate pollution. The modernization of irrigation systems is a very interesting measure, because it achieves substantial pollution abatement at quite reasonable costs for farmers in terms of net income losses.

Mema (2006) indicates that irrigation modernization reduces the use of irrigation water and fertilizers, achieving a 40% fall in nitrate emissions (7,000 t) and a 50% fall in salinity emissions (500,000 t). These results are confirmed in the studies by Martínez and Albiac (2004, 2006), where the dynamics of nitrogen in the soil are taken into account in analyzing nitrate pollution, presenting results for different crops and types of soil. These findings demonstrate that water pricing is the worst possible measure to abate nitrate pollution from agriculture. As indicated above, the type of instrument for nonpoint pollution abatement cannot be an individual incentive for each farmer separately, because then the non-cooperative solution is achieved (or Nash equilibrium, see Figure 1 above). What is needed is a cooperative solution, where farmers choose the pollution abatement with the higher collective welfare. The empirical results by Esteban (2010) on salinity pollution show that the best abatement instruments are those that induce farmers’ cooperation based on measurable pollution load limits within the appropriate institutional setting.

Cooperation between water users is a necessary condition to achieve a sustainable management of water resources. Current policies consist of compensating interventions using market instruments for private benefits of individual farmers who cause the damages. These policies are not efficient and quite expensive to implement because of the information problems. Collective action approaches achieve higher efficiency levels (as shown in the third section) and require less information. This argument is supported by Byström and Bromley (1998), who propose an economic incentive promoting cooperation between farmers to solve nonpoint pollution problems. They suggest a tax instrument over all farmers if they exceed a threshold previously established by the regulatory agency.
The implementation of cooperation is not an easy task, and the difficulties increase with the number of agents and their heterogeneity. But cooperation is feasible under the appropriate institutions and using the correct instruments, as demonstrated by the case of the Eastern La Mancha aquifer in Spain. The large extractions during the last 30 years caused an important depletion of the aquifer. The pressures from downstream users and the possibility of a ban on extractions from the basin authority made farmers cooperate in groundwater extractions. The creation of the institutional setting (water user association) made cooperation feasible and it is an example of successful cooperation among stakeholders.

The task of abating nonpoint pollution is quite difficult for water authorities, not only in Spain or Europe but all over the world. In Spain, water quality and water scarcity problems are important and intertwined issues, aggravated by the pervasive degradation of river basins in recent decades. The pending tasks for water basin authorities are a true challenge, because both irrigation water and agricultural nonpoint pollution are common pool resources which also have significant environmental externalities for ecosystems. Furthermore, the effects of climate change are going to reduce the available resources in the coming decades, especially in the more arid regions of the Iberian Peninsula. The sustainable management of water resources by basin authorities would entail setting up the right incentives. These incentives have to be capable of bringing about cooperation among the agents managing the resource, in order to achieve the needed collective action in the protection of water resources and dependent ecosystems.

**Conclusions**

The control of nonpoint pollution is a complex task because of the difficulty in identifying the polluting agent, and the exact location and amount of emissions at the source. There is a large body of literature addressing water resource scarcity and quality problems from theoretical and empirical perspectives, with recommendations to engage the widespread degradation of water bodies. Within the context of the pervasive and escalating mismanagement of water resources worldwide, this article explores the reasons that could explain the failure of water policies to reduce or damp down the degradation of water resources.

Current pollution policies consist in using economic instruments to compensate the private benefits of agents causing pollution, or using public funds in financing investments in pollution abatement technologies. But such policies alone do not seem effective in curtailing the large nonpoint pollution loads in river basins around the world. What might be useful is the cooperation of stakeholders managing the water resources. The economic argument supporting this collective action approach is that water resources are mostly common pool resources, requiring cooperation rather than just economic instruments that are harder to implement in the case of public goods.

The Water Framework Directive relies heavily on economic instruments, by advancing water pricing and “full cost recovery” as the key policy measures. But water pricing does not seem to be good enough to curb nitrate pollution, since the pollution driver is fertilizer and not water. This reliance of the Water Framework Directive on economic instruments is based on the “polluter pays” principle, where economic instruments such as emission taxes on individual polluters result in non-cooperative solutions with insufficient abatement. However, nonpoint pollution requires suitable measures applied over the set of polluters to induce cooperation.
In Spain, water quality and water scarcity problems are important topics because of the unrelenting degradation of river basins. Another reason is the large negative impacts that climate change would have in Spain, further aggravating the current water degradation problems.

The basins in Spain with the highest concentration of nutrients in rivers and streams are the Júcar, Guadalquivir and Cataluña basins for nitrates, and the Júcar, Cataluña, Sur and Tajo for phosphorus. The aquifers with the highest concentration of nitrogen are located in the Guadalquivir and Júcar basins, and the aquifers with the highest concentration of salinity are those of the Sur and Segura basins.

Results from studies in north-eastern Spain raise questions about the European Nitrates Directive, which is based on penalizing noncompliant farmers drawn by chance. This mechanism seems inadequate because it only applies to crops over aquifers declared officially polluted, not to cultivation over whole basins. The enforcement mechanism is too weak and unable to induce cooperation, and leaves out very polluting crops not receiving subsidies. These studies show that the Spanish National Irrigation Plan has achieved large reductions of pollution loads at reasonable costs to farmers. These findings are quite relevant for the programme of measures of the Water Framework Directive, because they show that water pricing is far from being an efficient measure to abate pollution. The best abatement instruments for nutrients and salinity pollution are those that induce farmers’ cooperation based on measurable limits of pollution loads. Pollution abatement would be more effective if it were focused on nurturing collective action and providing the right institutional setting to support it.

The control of nonpoint pollution from agriculture is not an easy task, and the conventional economic instruments being implemented are not achieving good results. Successful policies to reduce emission loads involve cooperation among farmers, because of the lack of information on pollution at the source and on the transport and fate processes. Under cooperation farmers would reveal the information required to achieve optimum abatement.

Institutions play an essential role to promote cooperation and create rules of enforcement among farmers. Without the involvement of stakeholders in institutions, the public authorities lack legitimacy and knowledge of local conditions. The achievement of collective action resolves the information problem, while decreasing the transaction and administrative costs of policies.

The case of the Eastern La Mancha aquifer in Spain is a good example of cooperation working among farmers to care for an aquifer. This is an important accomplishment, and eventually some lessons learned from this experience could be relevant for the design of nonpoint pollution abatement policies.

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Notes

1. A second-best policy could be also infeasible because of the information available or the particular policy sought. In this case, the regulator has to select third-best or even fourth-best policies.
2. The EEA (2005) states that between 50% and 90% of nitrogen loads in surface waters are from agricultural sources.
3. The study by Mema covers 380,000 ha of irrigated acreage in the middle Ebro, where 2,500 Mm$^3$ of water are used with 900 Mm$^3$ of returns, which draw large loads of nitrates and salinity. Annual nitrogen pollution loads
are close to 19,000 tons (N-NO$_3$), coming from nitrogen fertilizers. Salinity pollution loads are around one million tons, mostly from the Flumen, Cinca and Arba watersheds. The control measures analyzed include taxes and quantitative limits on irrigation water and nitrogen fertilizer, taxes on nitrates and salinity emissions, and investments in upgrading the irrigation systems.

References

Albiac, J. (2009) Nutrient imbalances: pollution remains, *Science*, 326(5953), p. 665.
Albiac, J., Mema, M. & Calvo, E. (2009) Sustainable water management and nonpoint source pollution control in Spain and the European Union, in: J. Albiac & A. Dinar (Eds) *The Management of Water Quality and Irrigation Technologies* (London: Earthscan).
Baumol, W. & Oates, W. (1988) *The Theory of Environmental Policy* (New York: Cambridge University Press).
Byström, O. & Bromley, D. N. (1998) Contracting for nonpoint-source pollution abatement, *Journal of Agricultural and Resource Economics*, 23(1), pp. 39–54.
Cochard, F., Willinger, M. & Xepapadeas, A. (2005) Efficiency of nonpoint source pollution instruments: an experimental study, *Environmental and Resource Economics*, 30, pp. 393–422.
Cropper, M. L. & Oates, W. E. (1992) Environmental economics: a survey, *Journal of Economic Literature*, 30(2), pp. 675–740.
EC (European Community) (2000) Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Official Journal of the European Communities L 327 of 22.12.2000).
EEC (European Economic Community) (1991a) Directive 91/271/EEC: Council Directive 91/271/EEC concerning urban wastewater treatment (Official Journal of the European Communities L 135 of 30.05.1991).
EEC (European Economic Community) (1991b) Directive 91/676/EEC: Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) (Official Journal of the European Communities L375, 31/12/1991 P).
Environmental Protection Agency (EPA) (2007) *Hypoxia in the Northern Gulf of Mexico: An Update by the EPA Science Advisory Board* (Washington, DC: EPA).
Esteban, E. (2010) *Water as a Common Pool Resource: Collective Action in Groundwater Management and Nonpoint Pollution Abatement*, Ph.D. thesis, University of Zaragoza, Spain.
Esteban, E. & Albiac, J. (2011) Groundwater and ecosystem damages: questioning the Gisser-Sánchez effect, *Ecological Economics*, 70(11), pp. 2062–2069. DOI: 10.1016/j.ecolecon.2011.06.004.
European Environment Agency (EEA) (2005) *European Environmental Outlook*, EEA Report No. 4 (Copenhagen: EEA).
European Environment Agency (2009) Progress towards the European 2010 biodiversity target. EEA Report 4/2009, EEA, Copenhagen.
European Environment Agency (EEA) (2011) *Water Data Center* (Copenhagen: EEA).
Griffin, R. & Bromley, D. (1982) Agricultural runoff as a nonpoint externality: a theoretical development, *American Journal of Agricultural Economics*, 64, pp. 547–552.
Hardin, G. (1968) The tragedy of the commons, *Science*, 162, pp. 1243–1248.
Hernández, N., Martínez, L., Llamas, M. & Custodio, E. (2010) *Groundwater in the Southern Member States of the European Union: An Assessment of Current Knowledge and Future Prospects Country Report for Spain* (Halle, Germany: European Academies Science Advisory Council).
Koundouri, P. (2004) Current issues in the economics of groundwater resource management, *Journal of Economic Surveys*, 18(5), pp. 703–739.
Linker, L., Shenk, G., Wang, P. & Batiuk, R. (2009) Integration of modelling, research and monitoring in the Chesapeake Bay Program, in: J. Albiac & A. Dinar (Eds) *The Management of Water Quality and Irrigation Technologies* (London: Earthscan).
Martínez, Y. & Albiac, J. (2004) Agricultural pollution control under Spanish and European environmental policies, *Water Resources Research*, 40(10). DOI: 10.1029/2004WR003102.
Martínez, Y. & Albiac, J. (2006) Nitrate pollution control under soil heterogeneity, *Land Use Policy*, 4(23), pp. 521–532.
Mema, M. (2006) *Las políticas de control de la contaminación difusa en el Valle medio del Ebro*, Ph.D. thesis, University of Zaragoza, Spain.
Organisation for Economic Co-operation and Development (OECD) (2008) *OECD Environmental Data Compendium 2006–2008* (Paris: OECD).
Orús, F., Quílez, D. & Beltrán, J. (2000) El código de buenas prácticas agrarias (I): Fertilización nitrogenada y contaminación por nitratos. Informaciones Técnicas N° 93. Servicio de Formación y Extensión Agraria. Dirección General de Tecnología Agraria (Zaragoza: DGA).

Ostrom, E. (2010) Beyond markets and states: polycentric governance of complex economic systems, American Economic Review, 100(3), pp. 641–672.

Perman, R., Ma, Y., McGilvray, J. & Common, M. (2003) Natural Resource and Environmental Economics (Edinburgh: Pearson Addison Wesley).

Segerson, K. (1988) Uncertainty and incentives for nonpoint pollution control, Journal of Environmental Economics and Management, 15, pp. 87–98.

Shortle, J. & Dunn, J. (1986) The relative efficiency of agricultural source water pollution control policies, American Journal of Agricultural Economics, 68, pp. 668–677.

Shortle, J. & Horan, R. (2001) The economics of nonpoint pollution control, Journal of Economic Surveys, 15(3), pp. 255–289.

Spraggon, J. (2002) Exogenous targeting instruments as a solution to group moral hazards, Journal of Public Economics, 84, pp. 427–456.

Spraggon, J. (2004) Testing ambient pollution instruments with heterogeneous agents, Journal of Environmental Economics and Management, 48, pp. 837–856.

Tomasi, T., Segerson, K. & Branden, J. (1994) Issues in the design of incentives schemes for nonpoint pollution control, in: C. Dosi & T. Tomasi (Eds) Nonpoint Source Pollution Regulation: Issues and Analysis (Dordrecht: Kluwer Academic).

Uku, S. (2003) Análisis económico y medioambiental de los sistemas de riego: una aplicación al regadío de Bardenas, Ph.D. thesis, University of Zaragoza, Spain.

Vitousek, P., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., Johnes, P. J., Katzenberger, J., Martinelli, L. A., Matson, P.A., Nziguheba, G., Ojima, D., Palm, C. A., Robertson, G. P., Sanchez, P. A., Townsend, A. R. & Zhang, F. S. (2009) Nutrient imbalances in agricultural development, Science, 324(5934), pp. 1519–1520.

Vossler, C., Poe, G., Schulze, W. & Segerson, K. (2002) An experimental test of ambient-based mechanisms for nonpoint source pollution control. Working Paper Series in Environmental and Resource Economics, Department of Applied Economics and Management, Cornell University, Ithaca, NY.

Weersink, A., Livernois, J., Shogren, J. & Shortle, J. (1998) Economic instruments and environmental policy in agriculture, Canadian Public Policy, 24(3), pp. 309–327.

Xepapadeas, A. (1991) Environmental policy under imperfect information: incentives and moral hazard, Journal of Environmental Economics and Management, 20, pp. 113–126.

Xepapadeas, A. (1992) Environmental policy design and dynamic nonpoint source pollution, Journal of Environmental Economics and Management, 23(1), pp. 22–39.