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The tradable permits system in water management: an analysis of the main case studies

Simone Borghesi

The Tradable Permits System in Water Management

of Simone Borghesi

Facoltà di Scienze Politiche
Dipartimento di Scienze Giuridiche
Economiche e di Governo
Università di Siena
via Mattioli, 10,
53100 Siena
borghesi@unisi.it

Abstract

Over the last few years the growing problems of water scarcity and water pollution have induced ever increasing attention towards the application of market mechanisms based on tradable permits in the water sector, similar to those adopted for air pollution. In spite of the growing interest surrounding this instrument, a general critical valuation of the application of tradable permits for water management in literature is still missing. This paper aims to fill this gap, by critically analyzing the experiences of various countries who have adopted tradable water permit programs (water usage and pollution), underlining both the advantages and disadvantages to have emerged in each case, with the objective to offer useful indications for possible future applications in other regions. Notwithstanding the decided advantages of tradable water permits and their success in some contexts, the case studies analyzed also highlight significant difficulties during implementation, which distinguish the permits market from the perfectly competitive market described in textbook analysis, and can thus prevent its full functioning in reality.

Introduction

In the last few years, the rapid economic and demographic growth in many regions of the world has caused a rise in problems tied to water scarcity and pollution. In order to deal with these problems the introduction of a system of market incentives in water management has been proposed. In literature in particular, there is increased attention towards market mechanisms based on pollution rights and water usage. These are better known as tradable permits, similar to those applied to air pollution, and more recently, adopted at an international level in the reduction of CO2 emissions levels included in the Kyoto Protocol. In the case of water resources, two forms of rights or tradable permits can be distinguished: those that consent a maximum limit of pollution on the resource, and those resources which limit water use. In a system of tradable water pollution rights, hereafter referred to as TWPR, the water management authority stipulates the maximum amount of emissions according to the load capacity of the ecosystem in question. Therefore, the total amount of emissions is subdivided into a fixed number of permits or rights to pollute, initially this is carried out according to the past levels of pollution (grandfathering) or via auction. The holders can trade the rights purchased in a secondary permit market. A polluting point source, for example, which has low costs for reducing pollution (emissions) can increase its depuration capacity and sell permits to sources who, instead, have high cleanup costs. In this way the total cost of reducing pollution is minimized due to the depuration effort being taken on by the firm who can meet the objectives with lower costs. The tradable water abstraction rights program, TWAR, is structured in a similar way, although where in a TWRP the reduction costs for pollution with more efficient technologies tend to be redistributed, the TWAR aims to redistribute the available water resources towards a more efficient use of the resource. The objective of employing tradable water rights on water resources is to provide signs of demand and supply to the agents within the sector in order to safeguard the water, coordinate usage and provide better incentives to the private agents to invest in the safeguarding capital of the water sector. The supporters of the application of tradable water permits maintain that these permits can stabilize and modify the price of pollution and water usage overtime, according to the simple connection with the supply and demand of permits. In this way creating an artificial market for a common good, such as clean water, which otherwise could not be considered a tradable object. Tradable water permits can also satisfy the objectives of the stakeholders, or namely, all of the interested parties in both the usage and pollution of water resources, allowing them to intervene on the same permit market in order to improve both the quantity and quality of water. An ecological association can, for example, buy permits in order to remove them from the market and in this way, not only are the number of permits effectively in use lowered and in consequence so is the usage or pollution of the existing water resources, but the demand is also increased, increasing the price and this, in turn, increases the cost which the firm has to pay to pollute or use the water source. As illustrated in the following paragraph, a series of noteworthy objections regarding the use of market instruments in water management exist, from the future of the market to an uneven distribution of the resource.

A general critical valuation of tradable permits (both in usage and pollution) in literature does seem to be missing. To fill this gap, this paper aims to critically analyze the experiences of various countries who have adopted tradable water permit programs, highlighting the advantages and disadvantages to have emerged in each case, with the objective to offer useful indications for possible future applications in other regions. This aspect appears to be particularly important given the increasing success enjoyed by tradable permits adopted as an instrument of air pollution control together with the principle role they have played in the implementation of the Kyoto protocol, and confirms the possibility that the permits can be used extensively in the future for the safeguarding of water. This likelihood which necessitates the complete comprehension of the limits of effectiveness of this instrument in the case of water resources, shunning preconceived refusal on behalf of certain environmental groups as well as the acritical acceptance of the market solution by some radical economists. The following paragraph provides a short review on the theoretic literature on tradable permits and the possible problems underlined by economic theory in the application of this instrument in water resources. The two successive paragraphs critically analyze the most significant experiences where tradable permits have been employed for water pollution (paragraph 3) and usage (paragraph 4). The final paragraph, provides suggestions which can be drawn from these programs and their implications, with the aim to improve the practical application process of the permits in other countries and hydrographical basins in the future.

Theoretical foundations
of tradable permits and conceptual problems in their application on water resources.

The concept of tradable permits is attributed to Dales (1968) who was the first to propose the stipulation of property rights on environmental resources and to allow free trade between agents, both of which had not been previously considered. A concept which utilizes the market properties as an instrument of optimal allocation and thus, avoid over exploitation of the common goods, to which they would otherwise be destined (tragedy of commons).

Successively, Montgomery (1972) demonstrated that this instrument can reach a given environmental quality objective with lower incurred costs, in comparison to alternative instruments (prohibition, sanctions, judicial responsibility, environmental taxes) which is consistent with the Coase theorem (1960) where in a competitive permits market it is possible to achieve cost efficiency independently from the initial allocation of property rights on the resources.

As underlined in the studies by Dales (1968) and Montgomery (1972) the economic advantage of tradable permits is created by the fact that their price is the same for every polluted point source, therefore, through price mechanisms it is possible to balance the marginal cost of abatement by firms in every given period.[1] Whilst these contributions had a prevalently static nature, Tientenberg (1985) provided the conceptual dynamic base for tradable permits by analysing the properties of this instrument in intertemporal contexts where the banking and the borrowing

1 For an introduction to the theory of tradable permits see, for example, Musu (2000) e Tietenberg (2003).

of permits is allowed.[2] In a dynamic scenario of this type it is possible to demonstrate that the actual net value of the marginal cost of abatement is equalled over various periods of time.

These early contributions opened the doors to vast amounts literature dealing with, and analyzing the benefits and disadvantages of tradable permits compared with the other environmental political instruments and in particular, taxes. It is common knowledge that under certain conditions taxes and permits represent two equal ways to internalize the externalities. However, if uncertainty exists regarding the nature and extent of ecological damage and on the firms reactions to taxes, then tradable permits are preferable to the pigouvian taxes, as they are able to reach a determined environmental standard with less demanding information requirements than is needed by taxes (Cropper and Oates, 1992). Applying taxes on water usage, for example, means that it is necessary to know the marginal beneficial curve of all the users of the water resource, whereas in the case of permits, it is the economic agents who reach cost effectiveness by voluntary trading. Similarly, a tax on water pollution necessitates that the government knows the precise marginal costs and damages of production, otherwise it is not able to accurately calculate the total amount of tax which could achieve the desired environmental result, risking therefore, to violate the environmental constraints. Thus, in uncertain conditions a system of tradable permits is a more reliable option in respecting the sustainability of an ecosystem compared to the environmental taxes, as it fixes "a priori" the maximum level of usage and/or pollution of the resource. Given the strong uncertainty which characterizes the majority of environmental issues, the very same problems affecting the water resources and their part in the interaction with the ecosystems in which they find themselves, could contribute in explaining why there is growing interest surrounding this instrument in environmental policy. Another argument often used in favour of permits is that, if the initial distribution occurs using the grandfathering principle, the firms receive a free transfer by the regulator. This increases the appreciation of permits on the part of the market, as it increases the political feasibility of this type of program in comparison to an environmental tax, particularly in a country where

2 As with any asset, the permit holder can decide to sell today, the quote of permits which have not been used or in the case where it is permitted, can deposit them in a bank, to use or sell them in the future (banking). In this case the holder will have access to the interest matured on the value of the permit, which will remunerate the agent for the sacrifice of having postponed using the permit. Even though banking is acknowledged in the water permits scenario, up until now it has been mainly used for the atmospheric permits, in particular for sulfur oxide pollutants and particulates produced from the iron and steel industry. In the case however, where the borrowing of permits is allowed, an agent can pollute more than allowed by the emission permits, in his possession today, in exchange for an emissions level below his permits tomorrow.

fiscal pressure is very high. This said, the free distribution of permits reduces the internal revenue gathered by the central authorities, and therefore, the possibility of a double dividend deriving from the environmental tax is reduced. From this point of view it is possible that the attribution of permits by way of an auction system is preferable to grandfathering, where the revenues can be used to reduce distortion taxes.[3] An auction system, moreover, can bring about more incentives for innovation, lower administrative costs and cut implementation delays in comparison to a grandfathering system, which is frequently characterised by long negotiations between the central authority and interested parties who invest time and resources in guaranteeing the largest amount of initial permits as possible (Cramton and Kerr, 2002).[4] Given the increasing claims that permits can be used as instruments of environmental policy, over the last few years many studies have also examined which aspects could have negatively influenced their efficiency, such as the existence of asymmetric information, the uncertainty of the agents regarding the changes in the supply of permits, the unpredictability of prices and the absence of regulatory and control instruments of the market structure. Regarding the first aspect, in spite of the minor data requirements of permits in comparison to other instruments, they are not immune to information problems. For example, the central authority may have less information on the total extent of pollution of the product and/or their water usage than the firms, information which, nevertheless, they would need to have in order to stipulate the number of permits to be introduced onto the market, or the initial price when starting the auction for the initial assignment of permits. The offer of tradable permits is, therefore, subject to periodic revisions on behalf of the regulator according to the new scientific evidence available. This can lead to the withdrawal of a part of the existing permits or vice versa, where the allocation of extra permits is based on the ecosystem's status which could have, in the meantime, improved or worsened.

These revisions allow for a policy of "fine tuning" which, given the uncertain character of the water sector, seems to be particularly important for correcting eventual errors made by the regulators,.[5] However, the changes in the number of available permits must be organized inside a clear normative framework according to procedures and circumstances that have been well

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3 For a review on the double dividend and the relative performance of different instruments of intervention in a second best context, see Bovenberg and Goulder (2001).

4 Some authors, (Parry *et al.*, 1998) estimate that the costs incurred in reducing atmospheric emissions in the case of grandfathering are three times more than in an auction system. To our knowledge, and at this time, analogue studies comparing the two tools for water sources do not exist.

5 In the case of water resources in particular, uncertainty is linked to both the inadequate prediction of atmospheric events (drought or rainfall) which influence the availability of groundwater and its diffuse nature, and is therefore difficult to monitor with regards to pollution.

defined “a priori”.[6] Otherwise, the uncertainty regarding the manner and the eventual occurrence of an ex- post revision of the supply of permits may discourage purchasers or could cause firms to demand them for solely speculative means. Given the fact that the permit markets are new and initially ‘weak’ can end up extremely volatile, and are strongly susceptible to the accuracy of the available scientific data and the potential changes on the supply side.

Another extremely relevant factor regarding the efficiency of the permits concerns the regulation and monitoring of the market. With this in mind, the managing authority of the basin must stipulate, not only the ecological objectives (a fixed quantity for usage or of pollution which the basin can tolerate in order to preserve sustainability) but must also ensure that it is able to issue sanctions in the cases of default (non-payment) or where the firms use the resource or emit pollution at a higher level than consented by the number of permits in their possession. Apart from verifying that the maximum limit of usage or pollution consented by the permits is respected, the regulating authority should also operate continuous monitoring to ensure the correct functioning of the market and degree of competitiveness generated by the trading of permits. This aspect, frequently underestimated in studies of tradable permits, plays a crucial role in determining the efficiency of this instrument. The very idea at the origin of a permit system is to exploit the benefits of a competitive market (Walrasian theory) which, according to economic theory, is capable of bringing about Pareto efficient allocations. If the permits market is not competitive, it will obviously not be able to determine efficient solutions. This tests out, for example, in the presence of monopolies or oligopolies which generate barriers preventing the entrance of new firms. If indeed the few firms that hold permits refuse to sell them to new entrants, the latter will find themselves unable to operate on the market. The presence of a limited number of firms/or the existence of monopolies or oligopolies on the market can therefore impede the access of new firms, transforming the tradable permit from an instrument of environmental policy into a strategic instrument which excludes competition. Where collusion exists between the firms who hold the largest part of the market, this can also contribute to limiting the price of the permits and thus the incentive to adopt a more environmentally-friendly technology (Hahn 1984, Hagem e Weskog 1998).

Beyond the general problems which have already been discussed here, there are other theoretic issues linked directly to each type of permit. With regards to TWPR, there is wide lite-

6 For a discussion regarding the necessary conditions and an efficient revision of contracts, see Shavell (2004). Even where the regulator has tried to overcome the problem of missing information, typical of the water sector, through detailed auction rules, the ex-post renegotiation between the parties turned out to be frequent and costly for all involved (see Anwandter e Rubino, 2006, with particular reference to the Italian case).

rary consensus on the fact that these must be specific for each individual water basin, according to the type of pollution source and its location, its geographical nature and biological characteristics, the specific polluting agents, the existing regulations and legislation, and the social contest which characterizes the economic system which exploits the basin. There are two types of water pollution sources: point and nonpoint. Whilst the first type is fixed and easily recognizable from the moment the effluents enter the watercourse (e.g., an industrial site), the nonpoint sources are widespread and do not have clearly defined entry points (e.g. agricultural and urban waste). Therefore, in this second case, the regulator has to monitor small, independent and different pollution sources, whose specific contribution to pollution is difficult to identify. (Shortle e Horan, 2001).

Some authors believe that to regulate these sources from an administrative point of view is difficult and economically inefficient for the community, due to the high costs to be paid by the management authority. (McCann e Easter, 2000). However, in many water basins the major sources of pollution are nonpoint sources and which, generally speaking, have lower depuration costs than point sources (Jarvie e Solomon, 1998). The experiences of various countries up to now have mainly involved point sources trading exclusively or between nonpoint sources exclusively. In some countries, however, trading between different combinations of pollution points, point and nonpoint is frequently encouraged. In order to obtain an adequate implementation of permit trading between heterogeneous sources, they must fulfill three fundamental conditions (Zhang e Wang, 2002): (I) the nonpoint sources must be significant and contribute a large share of water pollution (II) the abatement of nonpoint sources should be feasible and effective (III) the abatement cost of the nonpoint should be cheaper than the cost of further point source abatement on a per unit basis. Beyond this typology of pollution points, another particularly relevant aspect concerns the number and position of points on the water basin. Regarding the first aspect, if the water basin covers a small surface area, and the number of pollution points are limited, this will impede the permit market to take off. The opposite would occur where the basin is very large and the number of source points potentially involved in trading are very high, thus reducing the costs of transactions faced by the agents when seeking a commercial partner. (Stavins, 1995). With regards to the location of the source points, when the discharges are situated in different places along the watercourse, the price of the permit should reflect the different source locations, so as to take the negative externalities into consideration which otherwise, could interfere in the production of those higher up in the hills and those who are lower down in the valleys. It is, therefore, necessary to stipulate not only the maximum quantity of rights to pollute in the water basin as a whole, but also the maximum quantity of permits which can be used in the single areas of the basin, where the environmental impact from the same production activity differs and where the ecosystem's resilience varies.

Another aspect to consider when planning a TWPR system concerns the complexity of the hydrographic basin. The relationship between agricultural activities and pollution does not solely depend on natural phenomenon, e.g., climate conditions, but on other geographical parameters which characterize the ground and basin waters. Moreover, the underwater flows are difficult to monitor, which generates uncertainty regarding the actual quality of a hydrographic basin given the risk that there could be a systematic deviation between the pollution detected and actual emissions.

As in the case of water pollution permits, some obstacles in the implementation of usage permits also exist. In the first place, more efficient water markets require well defined and tradable property rights, as well as, the realization of benefits deriving from trading for the participants.

Therefore, a considerable obstacle when implementing permits concerns the variability in the water supply over time and over space, which causes problems in the definition and implementation of property rights. Another aspect, which is just as relevant and must be remembered when applying a TWAR system, concerns the possible regressive redistribution effects which a system of this type could generate. The costs incurred for water services significantly weighs upon the low income population rather than the higher. The application of a TWAR system in a context where water is insufficient could bring about an increase in the price of water (which serves as a sign of scarcity), and as a result directly affects the families at the bottom end of the income distribution. The existence of regressive effects on the distribution of income, is even more noticeable where there is a lower level of competitiveness on the permits market. In the case where a small number of firms (or at least one) detain their permits for water usage, the price will, in fact, be higher than on a competitive market forcing the poorer families to spend an even higher quote of their income to acquire permits to use water.

Indeed, where the water markets are not sufficiently developed and the poorest families need the permits in order to carry out their agricultural activities, some developing countries are increasing the sale of high priced water rights by the monopolists, and as a result furthering the poverty levels of the low income population (for more information, see paragraph 4). Applying a permit system for water usage therefore, can help to protect the environment in reducing water usage, giving confidence to the participants regarding water rights and encouraging them to employ water more efficiently. It is necessary however, to ensure that there is a sufficient level of competition on the market, which must establish itself in order to avoid perverse effects from a distributive point of view.

TWPR application cases in various countries

The application of tradable water pollution rights (TWPR) has gradually increased over the last few years. This has been seen primarily in the United States, where up to 40% of rivers, 45% of lakes and 50% of estuaries are subject to fishing and swimming prohibition (EPA, 2003). Since the 1980's, 42 programs based on tradable rights, were started in the US, 27 with the objective to reduce pollution from nutrients (phosphorus and nitrogen) in various water basins. Another country to have successfully applied TWPR systems is Australia where, since the beginning of the 90's they have effectively introduced these programs to monitor the salinity of water. In the other countries, and in particular, developing countries, this type of instrument has not yet been used, with the exception of China where they are currently establishing the foundations for future developments in a TWPR system.

In most of the pollution permit cases studied up to now the number of transactions has been rather limited. Although the reasons behind the success or failure of each application are numerous and frequently linked to the specific environmental context it is, however, possible to discover the conceptual problems of many cases, dealt with in the previous paragraphs, and identify some common criticality in the various experiences of application. In the Fox River in Wisconsin, and Lake Dillon in Colorado cases for example, the causes are principally linked to the lack of information available to the control authority and the consequential difficulties of regulation and monitoring of the market structure. The Fox River is characterized by low levels of biological oxygen demand, one of the main water pollution indicators which measures the deterioration of the oxygen regime in water. In order to reduce this form of pollution, a program of tradable pollution rights between the point sources was initiated in 1981 (Kraemer and Banholzer, 1999). The program gave an allowance of emission permits to the 14 paper mills, located on the river, and 4 urban wastewater treatment plants in exchange for a reduction of their emissions which were above the existing legal limits (Bresso, 1994). The theoretical simulation which was carried out forecast a potentially significant reduction in the annual costs for the firms, estimated between 29% and 66% in respect to the best practice technology[1] (O'Neill et al., 1983). In reality, however, the program failed considerably: the only transfer to occur was in 1995 when a new firm, the McDonald Marina, acquired the permits of one of the paper mills, Procter and Gamble, in order to operate in the basin (Jarvie e Salomon, 1998). A similar scenario occurred on Lake Dillon where, in 1982, the State of Colorado fixed a maximum limit on the phosphorus emissions from point sources which were discharged into the lake (Kraemer and Banholzer, 1999; Woodward, 2003). The amount of permits according to historical levels of pollution were assigned to 4 of the municipal firms who managed wastewater discharge. This however, was revised in 1984 when it was decided to admit nonpoint sources into the trading market. In fact, these latter sources presented marginal costs in the reduction of pollution, substantially lower than the point sources (Kraemer and Banholzer, 1999), which should have favored the trading of permits between the two sources. However, despite the significant difference in the marginal costs of abatement between the various sources, the permit market did not take off. [2]

In both applications described here, the stipulated trading rules proved excessively restrictive and significantly increased the firms transaction costs. In the Fox River case scenario the sources could buy extra permits, but only where they were expanding production or opening a new source. Each transfer was also subject to a long review process from the regulatory authority prior to authorization which took as long as 6 months (Hahn e Hester, 1989). In the Lake Dillon case, however, the program vetoed trading between point sources, as well as requests for a banking system for future sales on behalf of the nonpoint sources. These restrictions discouraged the point sources to lower their effluents as they could not trade their surplus permits with each other. On the other hand, the nonpoint sources were also discouraged

1 This term indicates the less polluting technology among those available for all firms when the permits program is introduced. As previously underlined, from the heuristic point of view the introduction of a permits system could reduce the overall costs incurred by the firms to meet the ecological boundaries, since it induces the most technologically advanced firms to further improve their technology, so as to avoid buying permits and being able to sell them to less efficient firms.

2 The only transfer to have occurred was when a hotel operator bought a ski-station with the intention to create new residential complexes and a shopping centre which would have surely violated the pollution limits for the phosphorus-based compounds.

in reducing effluents due to the low probability of finding point sources to sell their permits to. (Woodward, 2003). The shortage of sufficient scientific information, which makes it difficult for the regulatory authorities to stipulate the correct number of permits to allocate on the market was the main cause behind the malfunction of these two programs. In the Fox River case, the foreseen pollution limits for each polluting point source were probably too severe, and for this reason only a few firms were able to reduce their own emission levels other than those stipulated by law and thus, were unable to obtain further permits. The opposite occurred in the Lake Dillon case, where the maximum cap of emissions foreseen for each single source proved too high, thus provoking in consequence, a lack of demand of permits on behalf of the sources who had managed to reduce their emissions well below the stipulated emissions cap. Similar problems emerged in other U.S programs (Gulf of Cherry Creek and the Valley of San Joaquin) where the lack of information on the firm's actual clean up capacity resulted in the regulatory authority stipulating excessively weak pollution limits which, in turn, generated a low demand of permits and consequently limited the number of transactions.

In order to prevent the eutrophication of the Cherry Creek reserve in Colorado, the maximum daily amount of phosphorus emissions has been stipulated since 1984, which consents the firms who operate in the area to buy credits for the reduction of phosphorus-based compounds.[3] From the beginning of the program, however, there have been just 3 permit transactions. The low number of transactions could be attributed to the low concentration of pollutants introduced into the gulf over the years, due to the adoption of better technologies, which could have reduced the firm's need to use more permits. Currently, the authority for the quality of water is revising the trading program with the aim to encourage more trading by adjusting the maximum permitted daily pollution load according to new available scientific data.

Likewise, the permits market in San Joaquin Valley in California did not enjoy success. In 1998, the local body responsible for monitoring water pollution adopted a commercial trading system between irrigation districts to reduce selenium pollution in order to improve fishing levels in the San Joaquin/Sacramento Delta (Podar 1999, Woodward et al. 2002). Over the first two years the number of transactions was limited (9 up to February 2000) even though the transaction costs were quite low (Woodward et al., 2002).[4] In spite of this, the water quality improved and a

3 An estimated 80% of pollution from phosphorus in this basin is caused by the nonpoint source activities, which are legally obliged adopt the best known technology.

4 This highlights that low transaction costs are a necessary, but not sufficient, condition to avoid an excessively thin market which can depend on many other factors (reduced dimension of the basin, low numbers of firms operating on the basin, entrance barriers, unequal distribution of the benefits....etc)

substantial reduction in emissions was seen, probably due to the adoption of better technologies by firms after the introduction of the permits program, resembling the Gulf of Cherry Creek and the Lake Dillon cases. The low demand for permits registered in these cases suggests that, in many cases, the firms had already gained access to improved technologies which were able to reduce emission levels, information which is not readily available to the regulator and which poses a further obstacle in the design of the permits.

Another factor behind the failure of some permit applications is represented by the inadequate market competition. On the Fox River for example, the oligopolistic structure of the cardboard and paper industry has caused a strategic, competitive accumulation of permits. The larger the paper mills and their quote on the market, meant that they were able to obtain a higher number of permits in comparison to the smaller firms. When the smaller firms tried to expand their production levels, they looked to the bigger firms in order to buy extra pollution permits who, in turn, refused to sell their permits and as a result prevented market expansion and the competitiveness of the smaller firms. In this way the pollution permits were used strategically by the bigger firms, and not as an environmental policy instrument (their original function), but as an instrument of industrial politics, manipulated to maintain and exploit the dominant position of these firms in the market output.

The absence of permit sales to the smaller firms, preventing them from reaching a sufficient size to benefit from the potential economies of scale, may force them to leave the market and thus, worsen the output market structure without reaching the relevant ecological objectives. In this case, therefore, the concentration in the output market and in the trading rights market tend to reinforce each other, thus, negatively conditioning the permit system's performance.[5] In comparison to the case studies cited here, the application of the TWPR on the Hunter River in Australia represents an indubitable success story in the employment of this environmental, political tool. The reasons behind this positive outcome seem to be exactly what was missing from the previous cases, or rather, the capacity to regulate the market and reduce the uncertainty for the agents who are potentially interested in trading. The river, which runs through the New South Wales region, presents salinity problems due to the saline water offloads by coal mines, electrical centers, irrigation firms and other industries. Since the beginning of the 1970's the Australian Agency for Environmental Protection set up a license system which gave 11 coal mines and 2 electrical centers permission to introduce a fixed limit of saline water into the river (James, 1997). Using this existing license system, a 7 year pilot project was launched in 1995 with the aim to develop a trad-

5 For an analysis of the impact that market concentration (in the output or in the permit market) can have on the functioning of permits, see respectively, Malueg (1990) and Misolek and Elder (1989).

able permits system. According to the project every source could emit a quota of the total quantity of admissible waste calculated in relation to the environmental impact, to production, employment and gross earnings (James, 1997).

The pilot project enjoyed considerable success. During the 7 years it functioned, the number of violations on the maximum limits of discharge were reduced and the number of transactions were increased, (31in the year 2000 alone). The positive results achieved during the pilot phase induced the Australian Agency of Environmental Protection to make the trading program permanent as from 2002. With this in mind the Agency has fixed a telematic register and a system of on-line trading, which is monitored daily by a stakeholder committee (Kraemer et al., 2004). The new regulations foresee a bi-annual deadline for 20% of the permits granted, which will be, in turn, re-allocated on the market through a public auction. This allows the progressive substitution of the initial allocation by the grandfathering system with the auction system, which should, over time guarantee the opportunity for new firms to access the market and thus, increase its competitiveness. Furthermore, the permanent character attributed to the trade program favors the growth of the permits market as it allows the agents to plan their permit trade strategies over a longer time span and to avoid the uncertainty on the reiteration of the program, an uncertainty which frequently discourages agents to invest in the understanding of the functions and opportunities of this innovative tool. Another trading program, similar to the Hunter River scheme, was created in 1992 at an interstate level on the Murray Darling basin, situated in the South West of Australia, with the same objective to reduce the growing problem of salinity in the basin. If a State discharges a quantity of salt (deriving from, for example, the coal industry) into the basin, which is a smaller amount than that consented by the permits assigned, they can acquire credits to sell to the other States who emit higher levels than the permits assigned. According to various observers (cf. The Economist, 2003), the interstate tradable permits program has been successful in achieving its objective. Over the last few years, for example, in some parts of the Murray River the electricity conductivity (which measures the level of salinity) continued to lower, after having progressively increased throughout the 90's (Kraemer et al., 2004). This said, it will be possible to draw more detailed conclusions on the results achieved only at the end of the new program, initiated in 2001 (Basin Salinity Management Strategy), and which should conclude in 2015.

The registered success of the Hunter River pilot scheme has induced other regions to follow the same strategy. In 1992, for example, on the Nanpan River which is situated in southern China, a non-tradable water pollution permit system was established with the aim to monitor emissions from point sources.[6] The current

6 The highest pollution indicators are those relative to the COD - Chemical

permit system represents an ideal departure point for the utilization of a future system of tradable permits so long as it contributes to the creation of institutional expertise in the management and monitoring of the trading programs, and ensures data collection regarding emission sources and their aggregated environmental impact. In order to evaluate the potential benefits of this type of program, Tao et al. (2000) conducted a pilot scheme of trading between the point sources in a commercial area situated within this zone. From the simulations conducted, a tradable permits system could achieve the same cleanup objective for a total cost which is lower by 18.4% in respect to the current NON tradable permits system. Other pollution permit applications which are currently still in full evolution also exist, although it is premature to pass judgment on the registered performance of this tool, even if the results to have emerged so far are particularly encouraging. In the Tar-pamlico basin in North Carolina, for example, the third phase of a TWPR program is currently in place with the aim to reduce nutrients deriving from both point sources (where firms discharge waste) and nonpoint sources (agricultural firms).[7] During the first phase (1990-1994) even though the transfer of permits occurred exclusively between point sources, nutrients were reduced by 28%, surpassing the fixed objective, which can be accounted for by the municipal waste disposal agency's ability to significantly improve their technologies at a relatively low cost (Jarvie and Solomon, 1998).

In the first part of the second phase (1995-2004), however, the results registered in the cleanup were rather disappointing and for this reason in 1998 the Environmental Commission of North Carolina decided to stipulate some obligatory measures for the point sources which seem to have contributed in lowering the concentration of nutrients in the basin. (see table 1). The success illustrated in this application can be mainly attributed to the direct participation of the agents involved in the program, which has been jointly developed by the regulating authority and the regulated firms. The increased support from public opinion towards a TWPR application in the basin, constitutes an important condition of success in a program of this type (Jarvie and Solomon, 1998).

Oxygen Demand, which constitutes one of the degradation measures of oxygen in the water regime. Along the river there are large industrial waste sites (approximately 30 state industries) and municipal wastewater (deriving from the cities of Qujing and Xiping), which make the current levels of pollution in the river so high that it prevents any other usage.

7 The latter contributes to 66% of the total phosphorus emissions and 83% of nitrogen emissions. See Keudel (2006) for a detailed analysis of this case study.

Implementation experiences of water usage permits

Traditionally, most countries have applied a central command and control policy in order to provide water to rural and urban centers, and to guarantee distribution equality. Recently however, in some countries, a new approach has been used and can be defined as water markets based on tradable water abstraction rights (TWAR).

The main areas where TWAR programs have been implemented are concentrated in the western part of the USA, where a growth in population has aggravated the problem of water provision for the population over time. The increasing scarcity of available water has contributed to the diffusion of tradable water abstraction rights in this area which had generally been allocated using the grandfathering principle. In order to support agriculture and mining activities in this area, the water is transported from their original sources, sometimes over considerable distances, increasing the number of users and thus, the number of potential firms involved in the trading of permits. In the period between 1990 and 1997, as many as 9 western States (California, Idaho, Montana, Oregon, Washington, Arizona, Nevada, New Mexico, Colorado) have introduced a trading water rights permit system (Landry, 1998). Unlike the TWPR systems previously analyzed, where private firms are involved exclusively, in the TWAR system, amongst the principle purchasers there are Federal agents, State agents and environmental organizations, who through trading, have been able to increase the water flow in the main rivers in order to protect fawn and flora, and the value of the recreational activities linked to these areas.

In the State of Idaho, for example, since 1991, a Federal Agency has purchased water rights to increase the water flow in the Snake River, as part of a preservation program to save salmon, whose survival was at risk due to the low levels of water in the river (Landry, 1998).

California represents a particularly interesting case study in the application of TWAR. Following a long period of drought[8] at the beginning of the 90's the State of California introduced a kind of water trading system based on "water banks". With this term we indicate reservoirs which can have multiple functions such as: (I) guarantee a water reserve for irrigation uses for agriculture and private use; (II) provide water for industrial use; (III) refilling the underground water tables via canals which is where the main source of drinking water is drawn; (IV) produce hydroelectric energy.

In the State of California there is a notable difference regarding amounts of rainfall between the north and south. This has induced the State to develop extensive reservoirs, canals and aqueducts which allow the abstraction of water from the north during the winter and its transfer to the south during the summer months (Kraemer and Banholzer, 1999). According to other authors (see Landry, 1998), the Californian transfer program has witnessed encouraging results, not only on an environmental front but also from an economic point of view in the terms of market functioning. The success of the program can be largely attributed to the fact that the monitoring and control of the entire trading process, together with the legal backing for the vendors was under a State agency control (Garrido, 1998). This seems particularly important as it can reduce the legal risks associated to the elevated costs of transaction which can emerge on the trading place, and where necessary, can ensure that the counterparty respects the previously stipulated transaction rules.

Another region where a TWAR application can be considered a success, is Australia, which represents the driest continent with the largest rainfall variability. Over the last 10 years, the Australian government has radically changed its course in order to deal with water problems in cities, passing from a water policy approach based on the construction of dams and providing aid to farmers, to a policy based on the attribution of a price on water through the transfer of resources on the market. The first trading experiments between the agents of tradable water abstraction permits were realized in 1987 but it was with the introduction of the water act in 1989 when the TWAR was officially introduced, even though the first transaction occurred in 1992 (Tisdell, 2001).[9]

8 Between 1987 and 1992 the average annual rainfall was less than half in respect to the normally registered amounts, making it impossible to satisfy the water demand from the substantial urban and farming areas, as well as from the inhabitants of the southern part of the state.

9 Even though each state follows a slightly different approach, the general scenario of these programs is similar and is characterized by the annual attribution of the water usage permits to the agents from the part of the

The water act stipulated the conditions which regulate the transfer between different sectors and agents from different areas, and offers the possibility to transfer both temporary and permanent transactions.[10] In June 1995, a maximum cap of water usage was fixed within the Murry-Darling basin, which represents the principle area of agricultural production in the Australian continent (equal to more than half of the total agricultural production), and also the biggest Australian water reserve which supplies 4 States and the country's major urban centers, of which Brisbane, Sydney, Melbourne, Canberra and Adelaide. The system is enjoying notable success and two computerized centers have been created for trading water permits, on a similar scale to the financial stock exchange present in the major cities for financial trading (The Economist, 2003). Trading has progressively extended to both intrastate and interstate and in the future is also likely to occur between local authorities in large cities and single farmers. The city of Adelaide, for example, has already reached the maximum limit of water usage, according to the water permits allocated and should buy further permits from the farmers who are present in other areas around the basin in order to increase the amount of water for their future usage. Despite the program's success, some authors underline its limitations. Primarily, although the markets are very active, the major part of the water transfers have been limited to the agricultural sector, thus allowing the larger farmers (holders) to expand their cultivation areas using water originating from other holders who have lesser agricultural needs (Garrido, 1998). In addition, only a relatively small fraction of the transfers have a permanent nature. The permanent tradable permit market has been criticized for its possible long term effects on the community. For this reason, temporary permits have been generally preferred to permanent ones since the former allow farmers to respond immediately to seasonal and climatic changes, as well as to changes in personal and market circumstance (see, for example; Young and McColl, 2002). However, as highlighted by Bjornlund and McKay (2002), the permanent characteristics of a transaction is a necessary condition in order to carry out long term investments in the water section and to promote a more efficient use of the resource.

The application of the TWAR is more controversial in some developing countries. Given the central role of agriculture in the southern parts of the world, developing countries have also been encouraged to implement tradable permit systems for water use by the World Bank, having created market mechanisms which are the fundamental elements of water sector policy since the 1990's. Amongst the developing countries, Chile has followed the indications given by the World Bank more closely than others, stipulat-

basin authority, and according to the availability of supply.

10 In the first case the vendor of the permit temporarily concedes ownership of the water usage rights, whilst in the second case, this same ownership passes definitively to the purchaser.

ing a formal regime of trading water rights at a national level. Following the neoliberal approach which has prevailed in the country from the second half of the seventies, the National Water Code regulating tradable water rights was approved in 1981. (Bauer, 1997).[11] Some authors maintain that the Chilean Water Markets function efficiently; the water resources move from lower value to uses with a higher value and prices are indicative of the water scarcity both in the long and in the short term. Hearne and Easter (1997) for example, calculated the benefits produced from the water markets during the period 1986-93 in the case of 4 rivers which run through the northern central part of the country. They highlight notable economic profit deriving from trading in two of the four cases considered, where the markets are more active.[12] Other authors provide a much more critical valuation on the Chilean experience, although it is generally recognized that the water markets have encouraged private investors in the agricultural usage of water and the autonomy of the local associations in the management of the watercourses. The number of transactions were much less than expected and according to Garrido (1998), this is due principally to the initial distribution of water rights being somewhat similar to the market equilibrium.[13] It is possible however, to list the numerous explanations behind the lack of market activity. Firstly, contrary to the Californian and Australian applications where the rights and rules of trading were clearly defined, in Chile there is strong uncertainty at a legal level, as only a part of the TWAR is officially registered with a competent authority. This has contributed to legal disputes emerging between agents with regards to who has the right to use water. (Bjornlund and McKay, 2002). In consequence, the transaction costs are high and the water does not have a sufficiently high price to justify investment. (Bauer, 1997). Secondly, the information regarding the trading of water rights is very unreliable, this also generates uncertainty regarding prices in the future. Generally, the introduction of a permit system induces the participants to expect a future increase in the water price, as it highlights the problem of water scarcity and the willingness of the administration to deal with this using price mechanisms. If the expected price increase is high, many water rights permit holders may refuse to sell

11 The Code foresees different types of rights for water use, amongst which: (I) for the power generating companies the rights to use but not to consume water, and which after use, they must return the water to the river, in such a way so that it does not damage the rights of other agents (II) the contingent right which consents the use of the water in periods of excessive water flow and (III) the alternating rights option where the where the is used alternately by different agents. (Bjornlund and McKay, 2002).

12 The trade benefits are calculated by the authors subtracting from the water value for the purchaser after the transaction, the value of the resource for the seller, before the transfer and transaction costs.

13 It is evident that if the economy is placed, from the beginning, around equilibrium, this tends to limit the possibility of further transactions, since agents have no incentive to depart from the initial situation in order to improve their own position.

because they fear that once sold they will have to face much higher prices to buy them back in the future. Furthermore, the belief that the value of water will rise in the short term could cause the holders to keep the permits today, and decide to sell them in the future when they may benefit from a price increase. There is also a cultural reason behind the low number of transactions registered up to now; it is difficult for the agents to imagine that water abstraction rights for irrigating their crops could be separate from land ownership. This influences the individual reaction to the price signals and market incentives, and contributes in explaining why the only ones willing to sell their water rights are generally those who abandon agriculture to look for a job in the city centers, as they can no longer cover costs with the low income from farming. Finally, and in most cases, permits have been allocated to the "preferred" candidate based on unclear "general interests" of the community, as foreseen in the National Code; Art.148. Bauer (1997) doubts and criticizes the lack of clear environmental criteria in the allocation of permits and believes that the authorities have employed the water rights to undertake decisions which are distinctly political and which have had very little to do with environmental safeguard. An informal system of trading on a limited scale, between farmers has also been present for some years in many southern Asian countries (Bjornlund and McKay, 2002). In Pakistan, water markets are illegal, however, an estimated 70% of farmers rely on water transaction to increase their water usage. A similar situation also exists in Jordan, where the water resources are State-owned and the law prohibits the sale of water without prior written approval; nevertheless, water is sold directly from the source to the farmers and urban markets. In the Yemen there exist numerous water right transactions from farmers to private water companies (Ahmad, 2000). The various markets in the different countries function in a similar way: water is abstracted from the sources with electric or diesel pumps and the pump owners (normally the bigger farmers who can afford the installation costs for the machinery) extract more water than they need, with the aim to sell the excess amount on the market.[14] In these countries the water markets are heading towards the depletion of this resource, particularly where the water rights are not well defined.[15]

14 The payments can be made in cash or by offering an input (land or labor) to employ during the production process. In these cases we refer to a two-way share farming model when one of the parties offers water and the other land, a three-way share farming model when a third agent exists, who in exchange for water, offers his own labor. In both of these forms of farming however, each agent bears the cost of the resource (water, land or labor) offered during the production process, whilst the remaining costs and the profits obtained in the sale of the good produced are divided between the agents involved. (Bjornlund and McKay, 2002).

15 In Jordan, for example, the availability of pro capita water is equal to approx 20% of the absolute water scarcity threshold identified by the World

Where the water source is shared, the pump owners generally try and extract as much water as possible before the others so as to seize the profits from the sale of the water abstraction rights which they have been able to obtain, and in this way, recover the costs of the investment in the pump. This, together with the state financial aid for farmers to cover the electricity costs incurred by the pumps, induces most farmers to use water sources beyond their regeneration capacity, thus bringing about the depletion of the groundwaters.

Furthermore, these markets are frequently characterized by monopolistic structures which generate high prices, and result in, higher costs for smaller farmers. In many small villages, generally just one farmer is able to buy a water extraction pump and it is therefore, just one holder who can sell these rights to the other smaller farmers in the village. As a consequence, the lack of competition between farmers on the product market (caused by the disparity of size and wealth between the main farming firm and the others) also results in a lack of competition on the water rights market.

In Mexico the borrowing and selling of water resources between farmers for seasonal transfers has also existed for many years, even when these types of transactions were not encouraged, and sometimes even declared illegal. From 1992, however, the reform of the Federal Water Law also sanctioned, from a legal point of view, the possibility to carry out transactions on the water market between individual farmers and farming associations (Hearne and Trava, 1997).[16]

Bank. (Ferragina, 2003).

16 The reform was accompanied by other measures of liberalization directed at stimulating the economic growth through private investment in the agricultural sector, amongst which: (I) the removal of agricultural aid, (II) the elimination of some agencies and public banks for agriculture and (III) the North American free trade agreement (NAFTA).

The renewable water usage rights, with a variable duration of between five and fifty years, are assigned by a national committee according to historic levels of usage, the type of farming activity carried out and the surface area to be irrigated. The concessions for use are written in registers which are on public view: this strongly reduces the uncertainty for the interested parties involved in trading, as it allows them to control the amount of water allocated; it provides legal certainty regarding the rights to the resource; it facilitates the planning and programming of the use of this resource and constitutes an immediate consultation tool for all users which can be used as "rights" in the case of controversy.

The water law of 1992 certainly represents an important step forward for the Mexican water market, as it stipulates precise trading conditions although, the number of transactions is currently limited due to the selling restrictions between the various districts.[17] Moreover, the trading between associations is frequently dictated by political rather than economic criteria. This was proved in the case of the irrigation district of Alto Rio Lerma (Central Mexico) where the presence of a shared political interest by all of the associations of the district induced the vendors of water resources to provide water to the purchasing associations at very advantageous prices, thus changing the functioning of price-usage as a market signal (Kloezen, 1998).

17 Every water transaction outside of a district must be approved by the National commission and by at least 2/3 of the users with the right to vote.

Conclusions

Over the last few years tradable permits have generated a strong debate between supporters and critics regarding market intervention in the management of natural resources. The idea to implement this instrument on water resources has, until now, been flatly refused, due to the ethical argument that the quality and the use of water are common goods owned by the community, therefore in assigning individuals the power to pollute or exploit the resource would be to deprive the community of an inalienable right (Hahn and Hester, 1989; Goodin, 1994). On the other hand, this right can become worthless if interventions are not implemented, capable of reducing free riding behavior which the community itself tends to adopt when it is not given a direct role in the management of the natural resource. From this point of view, the tradable permits can constitute a useful tool to assign a price to the resource and apply the Polluter Pays Principle (PPP), which is at the very foundation of environmental policy. In order to better understand this type of intervention and the limits of its implementation in the water context, it is opportune to examine the advantages and disadvantages, both on a theoretical level and in using policy experiences developed up to now. As shown in the analysis conducted in this paper, the tradable permits system represents a competent tool in dealing with the problem of pollution and overexploitation of the water resources, but it also presents some significant limits which could obstruct the practical realization of the potential benefits. The permits have an important advantage over the other economic instruments -where the banking and borrowing of permits is consented- as the firms, the private agents and the government authorities can buy and sell permits allocating them in the best way according to an inter-temporal situation. In attributing a price to the usage or pollution of the resource, the water markets help the users to allocate and use the water more efficiently, stimulating buyers and sellers to treat this natural resource as any given economic good. As a result, the users are encouraged to select the water use which has the highest value between the various possibilities (where the water resource is strictly necessary) and which has the least environmental impact. Another important advantage derives from the establishment of water markets, which can increase the flexibility of the farmer's response to the fluctuating prices, leading towards the reduction of problems linked to irrigation practices which are not sustainable from an ecological point of view.[18] Finally, if the market is sufficiently contestable the establishment of a water permit system enables one to enter the market and buy the rights in question, a viable option for those who use the water resources for recreation, or even environmental groups who intend to safeguard the resource. In this way the permits can increase the stakeholders capacity to influence the realization of economic policy objectives and speed up the transition towards environmentally friendly technologies. It is not by chance that some of the most successful applications of tradable permits (for example the pollution permits along the Hunter River in Australia or the usage permits in the western states of the US) have seen the active participation of stakeholders to the permits system and its regulation.

In spite of the decided advantages in systems of tradable water permits, the case studies analyzed also faced some significant difficulties practicing their implementation.

One of the main problems to have emerged from the analysis (e.g., in the application of TWPR in Wisconsin, Colorado, California, or the TWAR in Chile) concerns the difficulty to establish a sufficiently developed market (sometimes described as "weakness" of the market), which is a sufficiently high number of transactions to create efficiency gains. The low number of participants which characterizes the permits market in reality makes it far from the textbook perfect competition market which is able to efficiently allocate water resources. In fact, as seen in the experiences of some countries, (cf. the case of TWPR on the Fox River or the TWAR in the southern Asian countries) it is possible that in some markets, one or more participants can dominate the market and in this way distort the prices where trade occurs, preventing

18 If the farmer has to face higher costs for the usage or pollution of water, then he is likely to modify his choices more quickly, moving his business activities towards those farming methods which minimize water use or pollution.

the leveling out of the marginal costs of abatement required to maximize the benefits in terms of efficiency.

Another important limitation of permits underlined here, concerns the transaction costs, which in some cases (e.g., Chile) can be very high. In this case, the Coase theorem (1960), which inspired the tradable permits as an instrument of internalization of the externalities, no longer holds true. However, even when the transaction costs are limited, it may be impossible to reach an agreement between the demand and supply of the permits due to the inequality which exists between the agents or the unequal distribution of revenues from the transfer which can obstruct co-operation, even though trade would be mutually advantageous.[19] Where it has been possible to overcome this criticality, the tradable permits program represents a valid instrument in reducing ecological problems such as the emissions of point and nonpoint sources (e.g., on the Tar-Pamilico basin), selenio pollution (on the Murray Darling basin or along the Hunter river) or the water scarcity of some areas (as in the case of usage permits employed in California).

Nevertheless, the success of tradable permits in some contexts cannot be easily repeated elsewhere. Both the planning and the implementation of these programs must take the local context into consideration; from the climatic, environmental, economic, social and legal point of view. For this reason every country must develop its own implementation strategy and find institutional solutions where the permits market can develop and allow adjustments from region to region. Although this makes it difficult to obtain general indications from applications in specific contexts, it is however, possible to identify some essential requirements for the existence and functioning of tradable water permits from the analyzed case studies. As far as water rights are concerned, they must be clearly defined, their distribution must be suitably established and their implementation must not damage third parties' rights. The same conditions are a necessity for the successful functioning of a water permits system; the water basin must be clearly identifiable and in this way also facilitating the identification of users and/or polluters of the basin who are potentially interested in the permits market. In the case of pollution permits, a sufficient number of point and nonpoint sources are a necessary requirement, together with wide differences in abatement costs; as in the case of water permits for abstraction the purchasers (farmers, industry, hydroelectric or water treatments plants) must be sufficiently ample and heterogeneous.

Where the number of participants is limited (e.g., due to the size of the basin or the characteristics of the local productive material), it is important to intervene with policies that look to in-

19 For a deeper theoretical approach to this aspect in regards to the Coase theorem, see Cooter (1982).

crease market competition. To this end, it is auspicious that the allocation of permits occurs through an auction system which is able to increase the effective competitiveness, rather than with a system of grandfathering which tends to sanction the status quo. The entry barriers should also be reduced in order to make the markets more contestable and thus, increase the competitiveness potential. It is also important to be in possession of sufficient accurate data with regards to emissions and pollution levels (in the case of TWPR), or regarding the abstraction levels and water usage (in the case of TWAR). An adequate institutional body is required, which gives incentives to the agents to participate and where definite rules regarding the monitoring and application mechanisms are outlined, as illustrated in the Californian permit system where the central role of the public structure was crucial to its success. The community must accept the chosen system, without perceiving it as an external imposition from an ethical and cultural point of view, where the opposite happens, as underlined in the Chilean application case, the market may not be able to "take off" even though the trading opportunities are potentially advantageous for the agents involved. Finally, when examining the case studies we see that the planning of water markets, the allocation of permits and the regulations regarding transfers must take the interactions between the environmental quality and the economic activity into consideration. For this reason, the integration of biological models with economical models is essential in order to understand how the changes in water flows can change the environment. We can derive therefore, that the planning of a successful permit system cannot be based on economic considerations alone, but requires the individualization of bioeconomical models which are able to integrate the biological information regarding the basin with those concerning the economic activities that take place along the same basin.

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Tradable Water Pollution Rights: Case studies

Water Basin	Application period	Type of pollutant	Results achieved
Fox River (Wisconsin)	1981-	Reduction in COD	just one transaction Non competitive market structure
Lake Dillon (Colorado)	1984-	Phosphorus	just one transaction Reduced eutrophication
The Gulf of Cherry Creek (Colorado)	1984-	Phosphorus	Low number of transactions Emissions still below limit
The San Joaquin Valley (California)	1999-	Selenium	Low number of transactions A reduction of emissions by a third during the first two years; improvement in water quality
The Hunter river (Australia)	1995-2002 2002-	Sodium chloride	Increasing number of transactions Reduction in salinity
The Murray-Darling basin (Australia)	1992-2001 2001-2015	Sodium chloride	Reduction in salinity
The Nanpan River (Cina)	1992- (not yet tradable permits)	Reduction in COD	Consented emission limits are not respected due to a lack of application regulations
The Tar-Pamlico basin (North Carolina)	Phase I (1990-1994) Phase II (1995-2004) Phase III (2005-2014)	Phosphorus & Nitrogen	Phase I: nutrient reduction by 28% Phase II: 2002 expected reduction of phosphorus (-33%) and nitrogen (-18%) Phase III: results are not yet available

Tradable Water Abstraction Rights TWAR: Case studies

Water Basin Or State	Implementation Period	Principal Purchasers	Results achieved
California, Idaho, Montana, Oregon, Washington, Arizona, Nevada, New Mexico, Colorado	Various start dates	Federal agents, private firms, environmental groups	Increase of flow in the main rivers Wide variability in the price of water from State to State Numerous transfers, particularly in California
Upper Snake River (Idaho)	1980-	Federal agencies	Increased river flow Ambiguous results on the protection of salmon in the rivers
The Murray-Darling Basin (Australia)	1989-	Idaho Electric Company	Significant success in the number of transfers (2 computerized centers are created) Temporary transfers and limited to the agricultural sector. (farming)
Chile	1979-	Main city representatives	Contradictory opinions in literature: economic growth but with a lower number of transactions than expected
Southern Asia (Pakistan, India, Yemen, Jordan, Palestinian territory)	Informal or illegal markets	Single farmers	Depletion of the water resource High prices due to the monopolistic character of the market
Mexico	1992-	Single farmers Small farmers Private Water companies Single farmers and water management associations	Limited number of transactions High variability between the districts for the quantity of water transferred and the quote in regards to the amount actually used.