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Tradable Permit Systems for Natural Resource and Environmental Management

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1. Introduction

Tradable permit systems are increasingly being considered by policy makers as a means of addressing environmental or natural resource problems. While tradable permit systems have been the subject of much theorising, to date very few tradable permit systems have actually been implemented.

Natural resources possess unique characteristics in terms of the measurability and predictability of the supply of, and demand for, the resource. As a consequence, tradable permit systems need to be customised to suit the unique nature of each resource and to effectively manage the issues surrounding its use. Hence, the design of tradable permits in renewable natural resources is heavily influenced by contextual factors and the suitability of these systems should be considered on a case-by-case basis (James 1997). In this paper we plan to highlight the role of contextual factors in the design of tradable permits in natural resources by describing examples of tradable permit systems in relation to water allocation, water quality, salinity, fisheries, biodiversity, air pollution and weather.

2. Tradable permit systems

Tradable permit systems are generally classified into two types of programs – ‘credit’ programs and ‘cap and trade’ programs. Credit programs are formulated in terms of individual rights of access to a resource. The aggregate supply of the resource is the sum of individually defined rights of access. The difference between an individual’s actual use of the resource and their access can be traded. Cap and trade programs involve defining an aggregate supply of the resource and allocating individual rights of access to the resource as shares in the aggregate supply. Shares in the aggregate supply can be traded. The difference between the two types of programs is illustrated in the following example based on restrictions on emissions.

With a credit program an individual emission limit is set for each discharger within a defined area. If a credit holder reduces emissions below the limit they earn credits equivalent to the difference between the limit and the reduced level of emissions. These credits are tradable between dischargers within the defined area. A credit holder with emissions below the limit earns credits which can be sold to another discharger with emissions above the limit (Stavins 2000). In theory, this trading mechanism allows the target level of abatement to be achieved at lowest cost to society by facilitating the reallocation of emissions away from dischargers facing relatively low abatement costs towards dischargers with relatively high abatement costs.

A cap and trade program sets an allowable aggregate level of emissions, the cap, for a particular area. Dischargers are then allocated or are able to buy permits entitling them to a share of this aggregate level of emissions. The permits specify the exact amount firms are allowed to discharge. These permits are tradable and, in theory allow the aggregate level of emissions to be achieved for the lowest social cost of abatement (Stavins 2000).

Generally speaking, tradable rights to natural resources are classified into two forms. One is the right to discharge emissions into the environment (as is the case for water quality) the other is the right to access or consume a resource (as is the case for fisheries). The distinction between the two is more apparent than real as the right to discharge emissions can be interpreted as implicitly assigning rights to access the assimilative capacity of the environment. As a rule, cap and trade programs have been employed to manage emissions into water resources while credit programs are generally used to manage emissions into the atmosphere. To our knowledge only cap and trade programs have been employed to manage access to natural resources such water resources and other “renewable resources such as forestry and fisheries” (James 1997, 65).

There are three key advantages of tradable permit systems over other approaches to managing natural resources. One advantage is that, theoretically they allow environmental standards to be achieved at the lowest cost to society. The second is that transferable permit systems transform the right of access to a natural resource into a capital asset such that, in principle, the resource is allocated to its highest valued use. The third advantage is they create an incentive for permit holders to achieve environmental standards but allow permit holders the flexibility to make their own decisions as to how best to achieve those standards (James 1997).

The two key disadvantages of tradable permit systems relate to how the volume of trading is regulated and the allocation of permits. First, the effectiveness of a tradable permit system does depend to some degree on the number of participants that are eligible to trade in the market. In ‘thin’ markets the number of participant and trades is relatively low. This can increase information and search costs for market participants as a higher level of effort is required to identify potential trading partners. In a ‘thick’ market, in contrast, the number of participants and trades is relatively high. This may create a very complex market which, in itself, can make trading difficult. If participant numbers are more than optimal this may make co-ordination difficult and increase transaction costs. Either type of market can hinder the achievement of efficiency gains while the high costs of maintaining such markets can also diminish the programs effectiveness (James 1997).

The second disadvantage, which is a particularly difficult issue with any type of tradable permit system, is the initial allocation of permits. James (1997, 55) states that “equity problems are unavoidable with any allocation system”. Every method of allocating permits entails a redistribution of wealth by defining who is eligible to receive a permit, which is a capital asset, and by defining the degree of access to the resource the permit allows, the size of the asset. With tradable permit systems the allocation of permits requires explicit acknowledgment and consideration of equity issues. Other means of achieving environmental outcomes such as the imposition of regulations or voluntary codes of conduct also entail the redistribution of wealth among members of a community. However, equity issues are often less visible and less likely to be considered in detail.

In the following pages we present and describe a variety of credit and cap and trade programs covering a range of natural resources involving both emission rights and access rights.

3. Tradable rights to water

Tradable permit systems are increasingly common for water resources with markets in water entitlements well established in Australia for example. Water resources such as rivers, lakes and reservoirs exhibit two key characteristics from the perspective of designing a tradable permit system. One characteristic is that both the supply of, and the use of, water resources is measurable. The second is that, in varying degrees, the supply of water is unpredictable. The unpredictability of supply creates uncertainty and risks for resource users and resource managers.

The unpredictability of supply means that any method of allocating access to water needs to be sufficiently flexible to allow water use in aggregate to adjust to changes in the supply of water, thereby ensuring water is not overallocated. This can be achieved with a cap and trade program based on variable cap or take limits (Tietenberg 2003). In the Australian context, for example, water users are allocated (or purchase) water entitlements which define access to a specified volume of water. Each year an announcement is made specifying the volume of water that is available for use as a percentage of the total water entitlements that have been issued. For example, a user may hold an entitlement to withdraw up to ten megalitres of water in a year. If the announced allocation in a particular year is eighty percent then they are restricted to eight megalitres in that year (i.e. eighty per cent of their entitlement). This annual announcement provides a mechanism which allows resource managers to adjust water take to actual water supply levels.

Within this type of program water entitlements are not linked to land ownership and can be traded as a commodity (James 1997). This facilitates more efficient allocation of short term risk among water users. Different water users have different abilities to respond to unpredictable changes in water supplies in the short term. Horticulturalists, for example, have a limited capacity to reduce their use of irrigation water without severely reducing yields. Dairy farmers, on the other hand, have the capacity to reduce their use of irrigation water on pastures by substituting grains and concentrates in animal feeds. Horticulturalists, by leasing of water entitlements from dairy farmers, can secure supplies of irrigation water sufficient to maintain their tree crops in years when the supply of irrigation water is limited. In the longer term, trading in water entitlements allows water to shift towards the highest valued uses where the highest rates of return on water inputs are gained (James 1997).

Uncertainty about the security of supply can also be managed by other mechanisms such as a banking system that allows water users to carry forward the unused portion of their entitlement for use in the next period. In principle, uncertainty about the supply of irrigation water within a season can be managed using instruments such as futures and options. This would mean, for example, that an agreement is made in which one entitlement holder agrees to buy some agreed proportion of another users entitlement at sometime in the future subject to certain conditions being filled. These conditions may relate to allocation announcements and market prices for water at some point in the future.

Markets for water often do not function as freely as theorists would like as restrictions are often applied on trades by water management agencies. Restrictions may relate to spatial constraints on trades, volume controls, environmental considerations and prevention of monopoly behaviour in the market for permits (James 1997).

3.1 Water trading in the Oroua Catchment

The Manawatu-Wanganui Regional Council developed an Oroua Catchment Water Allocation and River Flows Regional Plan which incorporated a transferable water permit system to allocate water within the catchment (Ministry for the Environment et al 1997). The inclusion of the permit system in the Plan enabled the Council to meet the Resource Management Act requirement “that local authorities consider alternative ways of achieving the sustainable management of natural and physical resources” so as “to promote selection of the most efficient and effective means of achieving environmental objectives” (Ministry for the Environment et al 1997, 4).

“The Oroua River drains a 900 square kilometre catchment on the western side of the Ruahine Ranges” with a “mean annual flow of 9058 litres per second” (Ministry for the Environment et al 1997, 6). Agriculture is the predominant land use in the catchment with the main water users being the Manawatu District Council for town water supply, the Manawatu Beef Packers Plant and agricultural irrigators (Ministry for the Environment et al 1997, 4). The Plan was formulated in response to the fact that “a very high demand for water abstractions [leads] to unnaturally low flows during dry periods” (Ministry for the Environment et al 1997, 6).

After public consultation and the development of a Proposed Catchment Plan, submissions were received that led to the incorporation of a tradable permits system in the Plan to allocate water within the minimum flow regime that had originally been proposed. It was thought that the system would work well given “the history of co-operation between irrigators” in the area, with “the potential to help maintain a strong sense of rural community” (Ministry for the Environment et al 1997, 8).

3.1.1 Definition of permits and trading

The system is a cap and trade system with threshold points that determine the level of water abstractions that is allowed, whether trading is allowed and who can participate in trades. A two-tier system was developed to give “preference to existing permit holders without precluding new holders” (Ministry for the Environment et al 1997, 9). This system only allows trading during periods of low flow and only between members of the irrigators group (Ministry for the Environment et al 1997). While trading of permits at times other than low flows is recognised as a possibility, such trades are not permitted as yet.

The first threshold in the tier was set at 30 per cent of the mean monthly river flow. Trades can only occur once the flow in the river falls below this point (Ministry for the Environment et al 1997). New permit holders must stop abstractions of water at this point while existing permit holders must “apportion their take within a specified total water budget” (Ministry for the Environment et al 1997, 9). Within this budget abstractions are set out by a roster to ensure that take limits are not exceeded (Ministry for the Environment et al 1997). The second threshold in the tier is the minimum flow level and was set at 10 per cent of the mean monthly river flow. Once this is reached all abstractions must cease.

The two-tier system provides existing permit holders with some security of supply as they know that they are able to “continue abstracting until the stated minimum low flow is reached” whereas new permit holders are prevented from abstracting once the first threshold is reached (Ministry for the Environment et al 1997, 9). The design of this system is based upon a prior rights approach where the environment is deemed to have prior rights to be satisfied before water allocation decisions are made for consumptive uses. In this way, allocations are made to the environment “without payment of compensation to other water users as they only hold a right to that not needed for environmental purposes” (Siebert, Young, & Young 2000, 2).

The Oroua transferable permit system was limited to agricultural irrigators to protect against farmers’ fears of a ‘buy-out’ of permits by other interests. Separate negotiations for water abstraction limits would occur for non-agricultural users such as the beef packers and town water supply (Ministry for the Environment et al 1997).

3.1.2 Allocation of permits

Land owners who already possessed water permits were viewed as having paid for their access to irrigation water as the existing water permits were attached to land title and therefore the value of these permits had been implicitly incorporated in land values (Ministry for the Environment et al 1997). In recognition of this tradable permits were grand-fathered, or gifted to, agricultural land holders with an existing water permit (Ministry for the Environment et al 1997).

New entrants, or people seeking to increase their water allocation, have two options under the Plan. One option is to purchase transferable permits from existing holders. The other is to apply for a non-transferable permit from the council (Ministry for the Environment et al 1997, 9).

3.1.3 Issues

The system began operation in 1995. During the first two years of operation river flows did not drop below the first threshold. Consequently, no restrictions were implemented and no trades between irrigators were permitted. Despite this, many irrigators involved in the system still renewed their irrigation permits during this period as they were concerned to maintain the security of their water supplies (Ministry for the Environment et al 1997). Landholders were concerned that the declaration of a minimum flow regime and the possibility of further restrictions on irrigation takes would mean that their water supply would be less certain under the new Plan than it had been under the previous Plan. This prompted some farmers to take a number of expensive measures to increase their water use efficiency (Ministry for the Environment et al 1997). Concern over the security of future water supply meant some permit holders were reluctant to trade water, preferring instead to keep their full water entitlement as a reserve in case of future unexpected needs (Ministry for the Environment et al 1997).

In terms of trading, participants found that negotiations were complicated as they were uncertain of an appropriate price for permits. Participants found it difficult to settle on a price for water permits as permits were not traditionally seen as a tradable commodity.

A concern persisted among irrigators that prices for permits might rise so much that only large and very profitable irrigators could afford them. Adding to price concerns was the belief that some land holders were holding water permits but were not irrigating and did not have any intentions to trade. The perception was that these permit holders would take unfair advantage of high prices fuelled by high demand in the event of a drought (Ministry for the Environment et al 1997).

A number of options were discussed to overcome the lack of familiarity with, and mistrust of, a tradable permit system. These included the Council providing proactive encouragement of trades and the acting as a broker for trades; education to increase understanding and encourage trades; and close consultation with all affected parties during plan preparation and after the plan is implemented (Ministry for the Environment et al 1997). Operation of this program revealed that community perceptions are vital for any scheme’s success and it can take some time for permit holders to understand tradable permit concepts (Ministry for the Environment et al 1997).

4. Tradable rights to water quality

This section focuses on water quality with an emphasis on tradable permit systems for emissions in the form of nutrients discharged into rivers and lakes. Emissions of nutrients may be related to the activities of both point and non-point sources. The right to discharge nutrients into a body of water can be interpreted from a natural resource perspective as a right to access the assimilative capacity of that particular body of water.

Nutrient discharges from point sources are usually measurable and tend to be reasonably predictable which simplifies the design and implementation of a tradable permit system. However, non-point source discharges are rarely measurable or predictable which creates problems for designing a tradable permit system in particular and the management of the resource generally. The movement of nutrient discharges from a diffuse source through the environment and into a particular body of water usually depends on complex and quite lengthy biophysical processes. This means it is impractical, if not virtually impossible, to establish a causal link between activities on land and water quality in the body of water of interest. Furthermore, non-point source dischargers may be unable to directly control the timing and volume of nutrients discharged from their land in the short term. Hence they have limited capacity to influence their use of the resource in the short term which constrains their ability to respond to restrictions on discharges and economic incentives promoting abatement activities.

In principle, a tradable permit system for nutrient emissions can be designed to take advantage of the differences that occur in abatement costs and capabilities among dischargers. The supply of assimilative capacity as a resource can be fixed by setting either individual limits on emissions or by setting an aggregate limit on emissions within a specified area. Emission credits or permits respectively can then be defined. Trading in these credits or permits should encourage over time the transfer of the resource to its highest valued use. Those credit or permit holders who face relatively low costs of abatement will, in theory, invest in inexpensive abatement measures and sell their credits or permits to dischargers facing relatively high abatement costs. Dischargers facing relatively high abatement costs will purchase credits or permit to maintain their emissions levels and avoid investing in costly abatement measures.

Banking procedures can be incorporated into a tradable permit system for nutrient emissions to mange variability in emissions. These procedures allow the unused portion of a credit or permit be carried forward to cover future emissions or discharges in excess of current entitlements to be offset against future entitlements.

4.1 Nitrogen trading in Long Island Sound

Nitrogen was found to be a primary pollutant causing severe hypoxia to occur in Connecticut's Long Island Sound each summer (Rocque 2001a). In response a trading system based on a credit program was designed to reduce nitrogen emissions from all sources into the Sound. The foundations of the program are a General Permit authorising discharges and specifying annual discharge limits, and a Total Maximum Daily Limit which defined "how much nitrogen needs to be removed from the wastestream to meet state water quality standards" (Rocque 2001a). This Daily Limit consists of a point-source wasteload allocation, a non-point source load allocation and a safety margin.

The nitrogen wasteload allocation for each point source specifies how much nitrogen they are allowed to discharge, specified in pounds per day (Rocque 2001b). Similarly, the non-point source load allocation defines discharge limits for non-point sources. The safety margin acts as an environmental buffer to protect against seasonal variations, inaccuracies in the estimation of load limits, and other unforeseen occurrences to ensure water quality standards are met (Rocque 2001c).

The Program was implemented for point source emissions from public treatment works in 2001 with the intention of reducing emissions each year through to 2014 (Rocque 2001c). Written into the conditions of the program is the need to have a "periodic review and updating at five year intervals" (Rocque 2001c). The purpose of these reviews is to ensure that the Daily Limit accurately reflects changes in knowledge, technology, management practices and the state of the underlying resource (Rocque 2001c).

Despite discussions about including non-point sources in the program, at this stage trading only occurs between point sources. This puts most of the burden of reducing nitrogen emissions upon point sources; particularly publicly owned treatment works (Rocque 2001d).

4.1.1 Definition of credits and trading

A Nitrogen Credit Exchange Program was established in June 2001 to be directed by a Nitrogen Credit Advisory Board (Rocque 2001a). Under the tradable credit program amounts of nitrogen removed below the required Daily Limit earns nitrogen credits which can be sold, using the Department of Environmental protection as an intermediary, to other dischargers for whom it is cheaper to buy the credit than to implement abatement measures. The sale of credits decreases the capital cost for nitrogen removal (Rocque 2001d).

A key component of the exchange program is the General Permit for nitrogen. General permits apply throughout the State of Connecticut and became effective from January 1, 2002 with an expiry of December 31, 2006 (Rocque 2001b). These permits regulate the emissions of nitrogen from all publicly owned treatment works by setting an annual allowable discharge limit for each facility. These general permits are not tradable. They provide the authorisation to discharge nitrogen into the Sound and specify an annual limit on those discharges.

Nitrogen credits are expressed as pounds of nitrogen per day and can be earnt or purchased by treatment plants to stay in compliance with the General Permit (Rocque 2001b). Credits are earnt if treatment plants reduce their discharges below the Daily Limit and are purchased by the Department of Environmental Protection (Rocque 2001a). Treatment plants must purchase credits from the Department to offset any discharges in excess of their Daily Limit. The Nitrogen Credit Exchange retains credits for sale in the event that the production of credits does not meet the established targets (Rocque 2001d).

Nitrogen can have different effects on the dissolved oxygen levels in the Long Island Sound depending on where it originates (Rocque 2001d). To address this, the general permit framework incorporates an equivalency factor that operates as an exchange rate. Exchange factors vary depending on the geographic source of credits sold and the location of the purchasing plant (Rocque 2001d). When an application is made to trade a nitrogen credit a credit equivalency factor is applied to allow for the different effect nitrogen has in different areas. “For example, credits exchanged between New London and Norwalk would apply a 0.18 exchange factor. So if New London had a target of removing 100lbs of nitrogen per day from their discharge, they would need to buy only 18lbs of nitrogen per day of Norwalk’s excess. This would help Norwalk defray the cost of their nitrogen removal project and save New London the cost of removing a large load of nitrogen at the same time. And the oxygen benefit for Long Island Sound would be the same as if New London removed their own nitrogen” (Rocque 2001d).

The price of equivalent nitrogen credits are published annually by the Department of Environmental Protection no later than March of each calendar year. Prices are set by the Department considering the cost to facilities of reducing discharges by following the procedures established under Public Act No. 01-180 (Rocque 2001a). Over a fifteen year period the price per pound of a nitrogen credit is expected to range between $2 and $30.

By March of each calendar year each treatment plant is notified of their nitrogen credit balance. To remain in compliance with their General Permit each plant that has a deficit must buy the nitrogen credits needed to cover its emissions and achieve a zero balance by July 31 (Rocque 2001a).

The Program allows for a restricted form of credit banking. Unused nitrogen load allowances can be banked, at the most, for use within a twelve month period so as to ensure that the twelve month average discharge level remains below nitrogen reduction targets (Rocque 2001d).

4.1.2 Allocation of credits

When the program was established the nitrogen load for the entire State was grandfathered or gifted proportionately to each treatment plant based on their average emissions over the period 1997-1999. The decision to allocate permits to each treatment plant in this way was regarded as being fair to treatment plants who may have introduced new technology or activities to reduce discharges immediately prior to the introduction of the program. At the same time, this allocation procedure was not perceived as undeservedly rewarding treatment plants that may have been operating less effectively immediately prior to the introduction of the program (Rocque 2001e).

4.1.3 Issues

The Program relies on significant levels of self-monitoring and reporting. The frequency of monitoring and reporting depends on the size of the discharge flow rate specified in the General Permit. The threshold level is set at 10 million gallons per day. Below this facilities are required to monitor their final effluent at least weekly while plants operating above this rate must monitor at least twice each week (Rocque 2001a). “Facilities may monitor nitrogen more frequently, however, all samples collected and analysed during the month must be used to calculate the monthly average concentration of total nitrogen” (Rocque 2001a).

For more information on the TMDL or Nitrogen Credit Exchange see the Connecticut Department of Environmental Protection Bureau of Water Management website: http://dep.state.ct.us/wtr/index.htm.

4.2 Selenium trading in Grasslands

The Grasslands Drainage Area is an agricultural region on the western side of California’s San Joaquin Valley where the soil contains naturally high levels of selenium (Austin 2000). Selenium is a concern as “high concentrations of selenium can be toxic to birds and other wildlife”, (Austin 2000). Agricultural drainage water in the region is collected in tile pipes buried beneath the fields and then pumped out through sumps (Austin 2000). The water in these sumps contains selenium hence emissions of selenium can be measured in the sumps. This establishes a link between land use and water quality.

Several irrigation and drainage districts in the area came together and formed a group known as the Grassland Area Farmers “to exercise common powers for the purpose of managing agricultural drainage” (Austin 2000). The San Luis Drain is the outlet for the group’s drainage water and is privately owned. A five year use agreement exists between the group and the drain owners governing the use of the drain by the Group (Austin 2000). Part of this agreement sets a cap on the total allowable amount of selenium to be discharged into the drain which limits the supply of the resource, in this case the assimilative capacity of the drain. The cap decreases across the final three years of the project (Austin 2000).

To address the issue of reducing selenium discharges in line with reductions in the cap a tradable loads program has been established for non-point sources within the Grasslands Drainage Area. The objective of the program is to equitably distribute the costs of reducing selenium discharges across the region (Austin 2000).

4.2.1 Definition of permits and trading

A cap and trade permit system was designed and implemented (Austin 2000). A total annual allowable selenium load, subject to monthly discharge limits, is specified for the region and is allocated across member irrigation and drainage districts. This is done through a Selenium Load Allocation which is a tradable commodity that is specified in pounds of selenium discharged (Austin 2000). Districts are expected to either meet their Allocation by reducing discharges or by purchasing Allocations from other districts to cover discharges in excess of their Allocation.

Penalties apply to any party discharging more than their monthly or annual Allocation in the form of Use Agreement Incentive Fees (Austin 2000). Participants who discharge less than their Allocation receive rebates which are paid on a monthly or annual basis. The revenue for this rebate is derived from the penalties paid by parties that discharge more than their allowed Allocation. Rebates are paid in proportion to the amount of Selenium discharge variance. Penalties are not applied to discharges above the Allocation that are declared to be caused by an “extraordinary storm event” (Austin 2000).

For more information on the operation of fees and rebates in the trading system see: http://ageco.tamu.edu/faculty/woodward/et/grassland.htm.

4.2.2 Allocation of permits

A mixed measurement approach was taken to the allocation. Participants were gifted their Allocation based on their proportion of tillage acreage and total acreage in a district, and historical discharges for the district (Austin 2000).

4.2.3 Issues

The tradable loads program began operating in the Grassland Drainage Area in 1998. Each year a rule is adopted which re-establishes the program and its conditions for the coming year. The program was not particularly successful in its first year as the El Nino weather pattern prevailing at the time yielded the heaviest rainfall for fifty years and farmers exceeded their regional selenium load targets even when they were not irrigating (Austin 2000). Consequently, it was determined that 'uncontrollable and unforeseeable events' caused the discharges and the penalty fees were waived (Austin 2000). Only one trade took place in the first year. However, the second year of the program was more successful with eight trades taking place (Austin 2000).

Annual selenium discharges have continually decreased since the programs implementation and "selenium load targets were met every month in water year 1999" (Austin 2000). The program appears to be operating effectively especially as "the Grassland Area Farmers continue to seek new ways to curb selenium discharges" in response to the Program (Austin 2000).

4.3 Nitrogen trading in Port Phillip Bay

Excess nutrients and salt in inland and coastal waterways has become a problem in Port Phillip Bay, Victoria. Nutrient pollution occurs in the area from both point and non-point sources. Major point source dischargers include fish farms, sewage plants and storm-water drains; while non-point sources are mainly farms such as vegetables and grapes (NAPSWQ 2002).

A tradable emission permit scheme has been proposed to manage nutrient pollution in the Bay. Currently in the experimental phase the scheme focuses on managing nitrogen discharges with a cap limiting the amount of nitrogen allowed into the Port Phillip Bay area. The scheme is based on a cap and trade permit design with adjustments to include non-point source emissions, at least in principle. The proposed cap is 10,000 tonnes of nitrogen per year (NAPSWQ 2002). Direct trading of permits between point and non-point sources of emissions is not envisaged. Instead, non-point source participants can perform land management or environmental services which represent a tradable commodity to offset discharges.

In addition to nutrient management, the impacts of market structure within cap and trade system design are to be investigated. Another issue to be explored is whether tradable permit schemes needed to be modified to account for the impact of large dischargers with high levels of market power. Also to be studied was the occurrence of any information problems associated with nutrient and salt emission problems (NAPSWQ 2002).

4.3.1 Definition of permits and trading

The project combines tradable emission permits for point-source dischargers with auctions for non-point dischargers to provide environmental or land management services (NAPSWQ 2002). These environmental services are likely to be provided by land owners to offset their discharges which are not directly under the landowner's control.

Trading in permits and auctions of off-set services is intended to allow participants to discover the lowest cost method to manage emissions. Participants may choose to reduce emissions, purchase a permit to cover emissions, purchase land management services to offset emissions, or provide land management services. Permits are traded between point source participants while contracts for land management services may be exchanged between non-point and point source participants (NAPSWQ 2002).

4.3.2 Issues

An experimental study into market power and information issues arising from a trading scheme similar in design to the Port Phillip Bay experiment found that market power had less of an impact on market performance than previously thought (Cason, Gangadharan, & Duke, 2002).

4.4 Nutrient trading in the Hawkesbury-Nepean

Within the Lower Hawkesbury-Nepean Rivers there are many point and non-point sources of nutrient discharges which are creating water quality problems in the region. The large volume of nutrients being discharged from sewage treatment plants is a particular concern (James 1997). A pilot pollution reduction trading scheme has been proposed to reduce loads of nitrogen and phosphorus in the rivers. The trading design is expected to take advantage of large differences in marginal abatement cost's that are thought to exist between plants in the area (James 1997).

4.4.1 Definition of permits and trading

A cap and trade scheme was designed to control aggregate nutrient loads within a specified area or 'bubble' as opposed to a credit program regulating emissions on an individual basis (James 1997). The bubble trading scheme proposed uses existing regulations to place a cap on nutrient discharges and improve the level of accepted practice for non-point sources in the pilot area (NAPSWQ 2002). Aggregate load limits are to be reduced substantially over an eight year period (James 1997).

Credits and offsets are used to achieve emission limits. New sources of nutrient discharges in the area can either perform some kind of land management or environmental activity to offset their discharges or purchase the equivalent amount of permits (NAPSWQ 2002). Credits and offsets are to be tradable and defined in terms of equivalent emissions of phosphorus or nitrogen (NAPSWQ 2002). It is anticipated that both existing and new point source participants would purchase offsets or credits as abatement measures are likely to be extremely costly. Sellers of offsets are likely to be non-point source participants who are believed to face relatively low abatement or offset costs.

4.4.2 Issues

Information problems arose with the proposed scheme as the efficiency of abatement measures for non-point sources was unknown. To address this it was proposed that, in close consultation with stakeholders, current abatement measures would be monitored to develop estimates of the efficiencies of different abatement measures (NAPSWQ 2002). Furthermore, it was highlighted that to help smooth the operation of the scheme, an internet tool needed to be developed to estimate the load of pollutants required to be offset under the pilot (NAPSWQ 2002).

4.5 Salinity trading in the Hunter

The Hunter Valley in New South Wales contains a mix of heavy industry, coal mining and power generation, pastoral farming, and irrigated dairy farming and viticulture. The Hunter River is naturally saline but the salinity of the River is intensified by saline discharges "by coalmines, power stations, irrigation and other industry in the catchment" which impose "external environmental costs on various groups in the community" (James 1997, 55). Analysis of river flows and salinity levels found that periods of relatively high flows were accompanied by an initial flow or spike of very saline water. After such a spike a period of hours or days of very low salinity levels passed. This raised the possibility that saline water could be discharged from mines with minimal impact on the environment (Smith 2003).

The Hunter River Salinity Trading Scheme was developed to promote the discharge of saline water from coal mines during these periods of high flows in the river when salinity levels are correspondingly low, with the phasing out of discharging saline water under low river flow conditions (James 1997). The scheme manages saline water discharge from licensed point sources "and was introduced in 1995 on a trial basis" (James 1997, 56; NAPSWQ 2002).

4.5.1 Definition of credits and trading

The trading scheme is based on a variable cap and trade program with tradable credits that describe opportunities to discharge saline waste water which are specified in megalitres. Total emissions at a point in time are capped based on the rivers' flow and by defining the maximum salt allowable concentration in the river to be 900EC (Smith 2003).

Credits can only be held and traded among holders of licenses to discharge saline waste water within the catchment (NAPSWQ 2002). The river is divided into three sections - an upper, middle and lower section with "each license holder … associated with a relevant sector" (James 1997, 56). A daily total daily allowable saline water discharge limit is set depending on the size of water flows in a particular section of the river and the concentration of salt in that section.

Water flowing through the river is divided in to 'blocks'. Each block represents the "body of water that passes the Singleton gauging station during any 24 hour period" (James 1997, 56). Licence holders possess credits, sometimes referred to as proportional discharge credits, which entitle the holder to discharge 0.1% of the daily load limit (James 1997). One thousand credits have been issued each with its own unique registration number (James 1997, NAPSWQ 2002). Credits have a one to two year lifespan under the pilot scheme which is likely to extend to ten years under the full scheme (NAPSWQ 2002).

Credits are tradable between licence holders but "trades must be for whole credits and for whole blocks … the EPA reserves the right to refuse approval of a trade if it detracts from the effective environmental operation of the scheme" (James 1997, 57). The scheme was initially confined to coal mines and an electricity company in the Valley. In principle there is the potential to involve diffuse sources into the scheme (James 1997).

4.5.2 Allocation of credits

Initially credits were grandfathered among the existing license holders although twenty percent of the total number of credits was retained by the Environmental Protection Authority as an environmental buffer (James 1997). Credits were issued with different life spans with 200 credits expiring in two year intervals beginning 30 June 2004. Every two years 200 new credits are created to replace those expired, each has a 10 year life span (Smith 2003). New credits are sold by public auction to reveal the price of credits (Smith 2003). The discharge value of the credit depends on the pattern of water flows and the ambient salinity of the water in the river over time.

4.5.3 Issues

After the trial phase the scheme is now operating on a full cost recovery basis. Participants pay an annual contribution for services provided to allow the scheme to function such as monitoring of flows and salt concentrations along the River. Total scheme costs are split between discharge license holders and credit holders (Smith 2003).

High levels of monitoring are required to ensure the right amount of water is discharged at the correct location in the river and the right point in time. Monitoring for volume and conductivity is required at discharge locations during discharge and real time monitoring must also be conducted upstream and downstream of the discharge point. Licence holders are responsible for monitoring and all monitoring data must be submitted to the Environmental Protection Agency (James 1997). In terms of reporting all “permit holders must prepare and submit quarterly reports to the EPA and keep records for two years (James 1997, 57). Regular audits of the scheme will be conducted by the Environmental Protection Agency.

5. Tradable rights to fisheries

Fisheries are a particularly difficult resource to manage to prevent excessive depletion of stock due to over-fishing and uncertainty about the size and dynamics of fisheries.

Problems in defining property rights to fishery resources is a major hurdle in the way of effective and sustainable fishery management. Without restrictions most fisheries are an open access resource where everyone helps themselves to the resource on a first-in first-served basis (James 1997). As fish aren't 'owned' until they are landed and it is virtually impossible for one user of the fishery to prevent other users from fishing, the incentive is to harvest the resource as quickly as possible and over-invest in the fishery. The inability to establish exclusive private rights of access to fishery resources means that the economic rents generated by consuming the resource are dissipated in excessive numbers of boats and over fishing (James 1997).

Historically, efforts to manage fisheries have depended on input controls such as restrictions on fishing effort and timing. Unfortunately, these have proven to be inefficient and ineffective leading to over-fishing, resulting in severe stock depletion and over-investment in boats and equipment. Consequently, there has been a change in focus towards controls over outputs and a rise in popularity of management systems based catch quotas. Such systems are a step closer to the optimal regulation of fishing which is achieved by limiting the annual fish "harvest to a level that maximises the value of the resource" (Straker, Kerr, & Hendy 2002, 6).

Tradable quota systems for fisheries are a form of cap and trade system of tradable permits. A cap is set nominating the total allowable level of catches across all resource users. The cap is based on the estimated maximum sustainable yield of that fishery which in turn is based on quantitative predictions of fish stock growth. Theoretically, the maximum sustainable yield occurs at the point where the rate of harvest from the fishery is equal to the growth rate of the stock (Straker et al 2002). Once the maximum sustainable yield has been determined and allowances are made for recreation and traditional catches a Total Allowable Commercial Catch can be set for commercial fishers. This Commercial catch is then allocated among commercial fishers in the form of a tradable quota for a particular species. Such quotas are usually specified in tonnes. By creating exclusive and secure access to a share of the resource the quota removes the incentive to over-harvest fish.

Quota entails ownership of the right to harvest a specified amount of a species of fish rather than ownership of the fish resource itself. Individual rights to harvest fish, that is, individual quota may be defined in a couple of ways. The most common way is to define quota as a share of the Total Allowable Commercial Catch. This allows the Commercial

Catch to be adjusted in response to changes in the supply of the resource. Alternatively, quota may be defined as a right to a share of the Commercial Catch together with a right to withdraw a specified amount of a species in a particular year (Tietenberg 2003). The former right represents a right of access to the resource while the latter right specifies actual amounts that may be harvested during a particular period. In this case a quota holder can sell the harvest right while retaining ownership of the right to access the resource in the future that is given by ownership of the share right (Tietenberg 2003). This is effectively equivalent to leasing the quota for a fixed period.

Generally speaking, quota is initially allocated to commercial fishers by grandfathering on a historical catch basis. Subsequent allocations may be made by auction.

A quota system requires high levels of monitoring, reporting and enforcement to ensure the integrity of the scheme. "Commercial fishers must monitor the volume of each species they catch from each fish stock and show that they own quota that match their catch. Fishers that do not have enough quota [will] face penalties" (Straker et al 2002, 7).

Many countries found that fishery stock numbers temporarily declined after implementing quota programs. These declines were due either to over estimating the sustainable yield of a fishery or illegal fishing activity due to ineffective enforcement (Tietenberg 2003). Estimating the optimal fishing level can be problematic because the stocks may be dynamically unstable and often there is very little data available for making predictions. In addition, the Total Allowable Commercial Catch "tends to be influenced by political and sectoral considerations" (Straker et al 2002, 8). Despite these drawbacks the evidence suggests that management systems based on quotas are superior to input controls as they efficiently reduce fishing effort and investment nearer to optimal levels while maintaining sustainable yields. Furthermore, in theory a quota system maximises the economic rent from a fishery for society as a whole (Straker et al 2002). Once implemented a quota system can be funded by the commercial industry through the application of a levy either on quotas holdings or per tonne of catch landed.

Problems such as highgrading and by-catch persist with quota systems. Highgrading describes the dumping of fish of lower commercial value when subsequent catches yield fish of higher commercial value. This practice is encouraged as the commercial fisher wants to ensure that they fill their quota with fish that will attract the highest commercial return they can achieve. Generally the discarded fish do not survive but the evidence of the overall effects of this practice on fish stocks is mixed (Tietenberg 2003). By-catch is where fish are caught when no quota is held for that particular species. That is, fish are caught other than the species that is targeted. By-catch fish may be discarded or illegally processed. Most quota systems usually have by-catch provisions that should make such steps unnecessary. These provisions may include the ability to land catches against another fisher's unused quota or allowing appropriate quota to be purchased after the catch is landed. By-catch is a problem that occurs regardless of the type of control that is used to manage a fishery and the information on exactly how by-catch has been affected by quota systems is mixed (Tietenberg 2003).

Highly migratory fish species, such as tuna, add another layer of complication to fishery management (Ministry of Fisheries 2004). When fish migrate across the fishing zones of two or more countries the cooperation of those countries is required to ensure sustainable management of the fishery. The impact of other countries fishing effort and resource management must be taken into consideration when setting caps for migratory species.

Quota systems can have significant benefits for the management of fishery resources. However it is important to recognise that such systems are not a stand alone solution to fisheries management. A quota system only "limits the total catch to a chosen level" (Straker et al 2002, 8). Additional regulations may be needed to cover other aspects of fisheries such as when, where and how fishing occurs as well as the acceptable size of fish caught (Straker et al 2002).

5.1 Fisheries trading in New Zealand

New Zealand introduced "transferable property rights, known as Individual Transferable Quota" as part of a quota system under the Fisheries Amendment Act 1986 which were applied "to commercial catches across all New Zealand's major fisheries" (Straker et al 2002, 23). New Zealand's quota system has become world renowned for creating over 257 simultaneous markets for 42 species of fish (Straker et al 2002).

5.1.1 Definition of quotas and trading

A Total Allowable Catch is set annually to limit catches across all users of the fishery resource. The Allowable Catch is based on estimates of the Maximum Sustainable Yield of the fishery and can be changed in response to changing biological conditions without "triggering legal recourse by the owner" (Tietenberg 2003, 408). After consideration of prospective non-commercial catches, the Total Allowable Commercial Catch is "set for each species or group of species in each defined area" (Straker et al 2002, 24).

The system has changed somewhat since its inception. Individual quotas were originally defined as fixed tonnages. However, the dynamic variability of fish stocks and subsequent declines in stocks resulted in the introduction of an Annual Catch Entitlement. The entitlement authorises the actual taking of fish by specifying how many tonnes the holder can take in a particular year (Straker et al 2002). The individual quotas have been redefined as quota shares which are property rights describing the owners share of the fishery (Straker et al 2002). The amount of quota shares owned by a fisher determines the amount of the Annual Catch Entitlement the fisher receives. "At the beginning of each fishing year, each quota owner receives an [entitlement] equal to their share of the TACC…trading [entitlement] is theoretically equivalent to leasing quota for a year" (Straker et al 2002, 41).

Fisheries are classified into a number of Management Areas. These areas were first established when New Zealand declared its 200 mile Exclusive Economic Zone in 1977. Fishery Management Areas were created by dividing the EEZ into ten regions (Straker et al 2002). With the creation of the quota system Quota Management Areas were introduced. These areas were "based on geographically sensible management areas that take into account the biology and known distribution of fishstocks, traditional fishing regions, as well as the cost of administration" (Straker et al 2002, 25). Generally a Quota Management Area will contain one or more Fishery Management Areas.

Under the Treaty of Waitangi Settlement Act 1992 "customary (traditional, non-commercial) fishing rights of Maori" are distinguished from commercial rights (Straker et al 2002, 51). A proportion of the Total Allowable Catch is set aside non-commercial fishers and for customary catches to reflect the traditional rights of Maori to harvest and gather seafood. Customary catch applies in areas that are significant to "iwi or hapu as a source of food or for spiritual or cultural reasons" (Straker et al 2002, 34). The catch in these areas is governed by traditional fishing customs and cannot be sold. Commercial fishing is generally excluded from fishing in larger areas which are important for customary food gathering (Straker et al 2002). The governance structure responsible for customary fishing, 'kaitiaki', must report customary catch information to the Ministry of Fisheries quarterly and any commercial catches within five days (Straker et al 2002).

5.1.2 Allocation of quotas

In a quota system the distribution of the value of the resource depends heavily on the method used to allocate quota. The government receives windfall gains when quota is allocated by auction. The industry receives windfall gains when quota is gifted.

When the quota system was established quota was allocated only to full-time commercial fishers who could prove that they were heavily reliant on fishing for their income. Quota was allocated by gifting based on catch history (Straker, 2002). A Provisional Maximum quota was allocated to commercial fishers based on the average of their two best fishing years selected from catches for the three years prior to implementation of the system (Straker et al 2002). When the provisional quota was allocated the Total Allowable Commercial Catch had yet to be finalised for any stock. Not surprisingly, the provisional quotas exceeded final estimates for the Allowable Commercial Catch for 20 of the 29 fish species originally included in the quota system (Straker et al 2002, 43). This meant that the provisional quotas were unsustainable. Consequently, the government implemented a provisional quota buy-back scheme which reduced the aggregate volume of provisional quotas to the desired levels after two rounds of competitive tendering (Straker et al 2002). Once the desired levels were achieved the provisional quota became guaranteed minimum tradable quota. The buy-back process proved to be "an integral part of the successful transition to a property rights based system of fisheries management" (Straker et al 2002, 44).

5.1.3 Issues

Originally the government bought back quota if a fishery continued to be over-fished or the allowable catch was found to have been overestimated. This changed with the Fishery Amendment Act 1986 which included a provision allowing for the proportional reduction of quotas with compensation for the quota holders based on the 'fair market value' of the [quota]" (Straker et al 2002, 36). Thus the government may reduce the allowable catch in a fishery by reducing quotas directly and paying compensation, or by purchasing or leasing quota (Straker et al 2002, 36).

Amendments to the Fisheries Act in 1999 saw the introduction of quota banking to protect fishers from catch uncertainty. Fishers are now allowed to carry forward for one year 10 per cent of any uncaught quota to be used in the subsequent year. Likewise, they are also permitted to catch 10 per cent more than they are entitled to by their quota. This additional catch is subtracted from the catch entitlement for the subsequent year (Ministry of Fisheries 2003).

The high level of reporting involved in the quota system has seen high levels of compliance. "Commercial fishers must provide (monthly) reports of their catch for each fish stock, which is matched against their [quota] holdings to ensure they do not overcatch their entitlement" (Straker et al 2002, 41). Catch and effort reports must also be completed for every trip and a "public register shows each fisher's holdings and catch to date" (Straker et al 2002, 41).

The New Zealand system is now operating on full cost recovery. Quota holders pay various fees and charges to cover the cost of running the system. The current cost recovery regime was introduced in 1994 to replace the previous resource rental regime. When setting fess and charges it is mandatory for the Minister of Fisheries to have regard for the under or over recovery of costs and make adjustments as necessary.

5.2 Fisheries trading in Australia

Individual Transferable Quotas similar to those used in New Zealand fisheries have been used to manage various Australian fisheries since 1984. Quota based systems have been used in the Southern Bluefin Tuna fishery, abalone fisheries in New South Wales, South Australia and Tasmania, and the South East Trawl fishery (James 1997).

The highly migratory nature of the Southern Bluefin Tuna complicates the design and implementation of resource management policy. The species is fished in the high seas outside of Australian waters as well as in New Zealand's Exclusive Economic Zone (James 1997). This means that stock levels are affected by other nations policies and fishing efforts which are beyond Australia's direct control. To address concerns about the sustainability of the fishery a series of catch agreements were signed in 1982 by Australia, Japan and New Zealand. International agreements such as these have reduced Australia's Total allowable Catch for the Southern Bluefin Tuna, thereby reducing the total volume of quota available to Australian fishing operators.

The Southern Bluefin Tuna fishery has been managed by a quota system since 1991. The introduction of a quota system was prompted by fears that increased fishing effort was depleting stocks and causing catch sizes to decline (James 1997).

"[Quotas] are fully transferable among operators in the Australian fleet" and may be used in joint ventures between operators from Australia and other countries (James 1997, 72). He observes that, at least for the Australian fleet, the quota system for the Southern Bluefin Tuna Fishery appears to have been effective "in controlling catch levels and achieving maximum economic returns from the resource" (James 1997, 73). Total quota restrictions have been met while the fishing fleet has restructured "using more efficient equipment and harvesting methods and higher revenues were earned" (James 1997). Furthermore, the price of quota has increased substantially since the quota system started (James 1997). However, uncertainty about the long-term population dynamics continues to be a major difficulty for the fishery and the industry (James 1997, 73).

The industry has experienced rationalised since the initial issue of quotas with noticeable distributional impacts. Port Lincoln became the main base of the fishery with South Australian operators purchasing the bulk of quotas (James 1997). The transfer of quotas to South Australia had "adverse regional economic impacts in some communities" in New South Wales and Western Australia as many marginal producers were forced out of the industry (James 1997).

6. Tradable rights in biodiversity management services

Biodiversity is a natural resource that is particularly difficult to define. Consequently biodiversity is exceptionally difficult to measure and value. While biodiversity in a particular ecosystem or location may be measurable there is much debate over procedures for rigorously comparing the significance of biodiversity in different ecosystems and locations. This constrains the design of policies, whether they be regulatory or market based, for conserving biodiversity when there are many ecosystems distributed among different regions on private land.

The situation is further complicated by the fact that biodiversity conservation activities on private land will impose costs on the landholder both in the form of actual expenditures and in the form of foregone economic opportunities. Yet biodiversity conservation benefits the wider community. This creates a need to devise a way for private landowners to derive value from conserving biodiversity so as to develop incentives to motivate private conservation action.

6.1 Bush Tender in Victoria

The Bush Tender project was designed to facilitate the management and preservation of areas of remnant habitat in the Victorian agricultural landscape. Public management of these areas is difficult as they are located on private land and there are inadequate incentives for private landholders to provide a service to the community by protecting remnant habitats. Without a means of valuing such services, and a mechanism allocating biodiversity services among possible suppliers, private landowners were unable to realise any economic gains from actions they may take to conserve remnants (Bardsley 2003).

The Bush Tender Trial was focused on developing the supply of conservation services to protect remnants and maintain biodiversity - it was assumed that the government demanded these services on behalf of the public (Bardsley 2003). Contracts for conservation of remnants were established with landholder in terms of service inputs instead of outputs due to the cost of accurately specifying and measuring output (Stoneham et al 2003).

6.1.1 Definition of tenders and trading

Ecologists constructed a metric to express preferences with respect to conservation of biodiversity while economists designed an mechanism, auction by tender, to reveal the opportunity cost of changing land use for biodiversity conservation (Stoneham, Lansdell, & Strappazzon 2003).

Landholders offered tenders to supply conservation management services. Note that landholders were required to "tender bids for management services that maintain or improve native vegetation *beyond the level* required by duty of care and currently permitted uses" (Parkes 2003). Prior to tendering landholders were advised of the significance of vegetation types, species or locations, on their property and witnessed an assessment of the vegetation on their property. The assessment provided the opportunity for an agreement to be reached about the management commitments needed to conserve the vegetation (Parkes 2003). After this visit the landholder received a map of potential biodiversity preservation sites, a summary of significant values of biodiversity services and a draft management plan and agreement (Parkes 2003). After considering this information the landholder then submits a sealed bid to provide the agreed draft biodiversity services (Parkes 2003).

A discriminating price, closed bid auction was used to induce competition and honest bidding as contracting with the government created incentives for landholders to overstate private costs (Bardsley 2003). The auctions were intended to reveal information about the true value of alternative land uses and biodiversity services while enabling landholders to "make mutually-acceptable, cost-effective deals" that would also ensure the better management of biodiversity resources (Parkes 2003). Price discrimination among the tenders was obtained by calculating a supply price which was the ratio of the expected biodiversity outputs (determined using a Biodiversity Significance Score and a Habitat Services Score) per dollar of investment (Stoneham et al 2003).

6.1.2 Issues

The trial was designed to overcome three major information problems related to conservation of biodiversity. These were the difficulty of valuing biodiversity services, asymmetrical costs of information and the difficulty of monitoring conservation activity (Bardsley 2003). The first problem was overcome through the development of a methodology to value biodiversity services (Bardsley 2003). The auction process addressed the second problem. Monitoring difficulties were overcome through inclusion of digital cameras in the landholder's contract with a schedule of photo points and dates for record keeping and evaluation (Bardsley 2003). This ensured that the landowner could be held accountable for the final outcome (Bardsley 2003).

7. Tradable rights in air emissions

The assimilative capacity of the atmosphere is an open access resource and the management of emissions into the atmosphere is subject to the same problems that troubles the management of other open access resources such as fisheries and aquifers. Emissions into the atmosphere may originate from point sources such as factories or non-point sources such as agriculture. Point source emissions are measurable and can be directly controlled. However, emissions from non-point sources such as emissions of green house gases from livestock are difficult to measure accurately and are less easily controlled.

A tradable credit program can be, and have been, designed to manage air pollution from point sources. However, the measurability and control associated with non-point source emissions means that including non-point sources in credit programs is not straight forward. In some situations models could be used, at least in theory, to estimate emissions which would allow non-point sources to participate in a credit trading scheme. Alternatively, an offset scheme could be developed where non-point sources earn credits for undertaking activities thought to offset a certain level of emissions. Again, models might be required to estimate the credit equivalents of offsets. This would also allow non-point sources to participate in a credit trading program.

Under a tradable credit program an allowable level of emissions would be set for each emission source. The allowable level of emissions may be specified as a volume or concentration. Participants in the program would earn credits for reducing emission levels below this limit. Trading of credits would allow those participants with the lowest abatement costs to invest in abatement measures and generate credits which can be sold to participants with the higher abatement costs. In this type of program the risks associated with uncertainty in the supply of, or demand for, credits could be managed through risk reduction mechanisms such as credit banking or derivatives trading. When implementing a trading scheme to manage atmospheric emissions there is a concern that 'leakage' may occur. Leakage occurs when emitters, faced with new, stricter environmental policies, "move their polluting factory to a country with lower environmental standards" (Tietenberg 2003, 406).

7.1 Tradable rights in sulphur dioxide

The 1990 U.S. Clean Air Act Amendments included a goal to reduce annual sulphur dioxide emissions by ten million tons below 1980 levels (Stavins 2000; EPA 2004a). In response to this goal an Acid Rain Program was established which included a trading program for sulphur dioxide emissions (EPA 2004a).

Emission reductions were to be achieved in two phases. The first phase of sulphur dioxide emission reductions started in 1995 with a second phase of reduction to be started in the year 2000 (Stavins 2000). In the first phase individual emissions caps were assigned to 263 of the "most SO_2-emissions intensive generating units … after January 1, 1995, these utilities could emit sulphur dioxide only if they had adequate allowances to cover their emissions" (Stavins 2000, 21). The second phase commenced with the inclusion of most electric power generating units in the program. Some power units were not included as they were deemed to be already unusually clean or would have been severely disadvantaged by the potential restrictions on growth (Stavins 2000).

7.1.1 Definition of allowances and trading

The sulphur dioxide trading program implemented by the Environmental Protection Agency operates like a cap and trade program rather than a credit program (EPA 2004a). A cap sets the maximum amount of total sulphur dioxide emissions that may occur from all regulated sources during a compliance period. The cap was set lower than historical emissions to force reductions in emissions. Permits, termed allowances, authorise the holder to emit one ton of sulphur dioxide during a given year or any one year period thereafter (EPA 2004a). Allowances can "not be used for compliance prior to the calendar year for which they are allocated" (EPA 2004a). Irrespective of the amount of allowances held a permit holder cannot emit more than is allowed under the Clean Air Act and emissions are continuously monitored (EPA 2004c). An annual reconciliation at the end of each period ensures that all participants possess at least as many allowances as their emissions (EPA 2004a).

If a participant reduces emissions below their allowance they have a number of options. They can trade unused allowances with other participants in the program, they can sell the unused allowances to other utilities on the open market or through auctions sponsored by the Environmental Protection Agency, or they can bank unused allowances to cover emissions in future years (EPA 2004a). Any individual, firm or organisation can participate in trading with "some individuals and groups purchasing allowances as an environmental statement" (EPA 2004c).

Some utilities are required by law to participate in the Acid Rain Program and allowance trading. These utilities must install constant monitoring systems for sulphur and nitrous oxides. Other sources are able to participate in trading through an Opt-in Program. These sources enter on a voluntary basis and receive their own allowances. Like other participants, if they reduce their emissions below their allowance the unused allowances can be sold in the market. This can be profitable if the cost of reducing emissions is less than the revenue gained from selling allowances (EPA 2004c).

An annual auction is held for the small proportion of the new allowances made available for allocation each year from reserves held by the Environmental Protection Agency. The auction is thought to assist price discovery while also providing new sources of emissions with another avenue to obtain allowances (EPA 2004b). The auction is divided into two parts. A 'spot' auction for allowances to be used in the year of the transaction and an 'advance' auction for allowances usable for seven years after the transaction, though allowances can be traded earlier (EPA 2004b). This provides the units with security that they can continue a specific level of emissions into the future.

Private allowance holders can also offer their allowances for sale at the auctions. The auction operates by sealed bids. The Agency's allowances are sold first based on the highest bid price followed by the sale of privately held allowances. These are sold in ascending order based on lowest minimum price requirements (EPA 2004b). The auctions are run by the Chicago Board of Trade as delegated administratively by Environmental Protection Agency.

7.1.2 Allocation of allowances

Allowances have been allocated annually since 1995. Participants in the first phase were allocated annual allowances by the Environmental Protection Agency based on their historic fuel consumption and specific emission rates during the baseline period (1985-87) with bonus allowances available under a variety of reserves (Stavins 2000; EPA 2004c). Under Phase II total allowances are restricted to a total of 8.95 million tons annually (EPA 2004a).

Emission sources that began operating after 1995 onwards were not allocated allowances. These participants must buy allowances through the market or the annual Agency auctions (EPA 2004a).

Three reserves or special provisions were made for the allocation of allowances. The first reserve was made available during the first phase of the program and was allocated to utilities that did not originally participate in the program but became eligible by installing qualifying technology (EPA 2004a). Allowances from the second reserve are allocated to sources that achieve sulphur dioxide reductions by customer-orientated conservation measures or renewable energy generation (EPA 2004a). The third reserve contains allowances set aside for the auctions which are sponsored by the Agency (EPA 2004a).

7.1.3 Issues

As part of Environmental Protection Agency's role in recording allowance transfers and ensuring emissions equal allowances at the end of each period, the Agency operates an Allowance Tracking System (EPA 2004a). Each market participant has an account with the System and must notify the Agency of any transfers so that they are recorded on the System (EPA 2004a). Each account is divided into two sub-accounts; one is for allowances to be used for compliance in the current year while the other is for allowances to be used in years to come (EPA 2004a). The information in these accounts is available to the public. Note that the Agency does not have to be notified of allowance transfers until such time as the transfers are going to be "used to meet a unit's SO2 emission limitation requirement" (EPA 2004a).

A penalty of $2000 is charged per ton of emissions exceeding any year's allowance (Stavins 2000). Two methods may be used to offset excess emissions. Either allowances amounting to the excess are immediately deducted from the sub-account containing the following year's allowances or the utility can submit a plan to the EPA describing how the excess emissions will be offset in the following period (EPA 2004a).

Stavins (2000) reports that despite low levels of trading in the program's early years "trading levels [have] increased significantly over time" and "a robust market of bilateral SO_2 permit trading has emerged" (Stavins 2000, 21).

8. Tradable rights in weather derivatives

Weather conditions can have severe economic consequences for many businesses. Variables such as the temperature, rainfall, snow, wind speed and humidity can all cause damaging economic losses (see table 1). In spite of extensive research into weather forecasting methods and technology, weather patterns cannot be predicted with any accuracy more than a week in advance.

The inability to produce reliable weather forecasts has important implications for those whose profits are strongly influenced by the weather such as energy companies or ski resorts. Significant numbers of firms are affected by weather in some economic sense (Hunter, 1998). Trevor (2002, 8) quotes Muller and Grandi (2000) who "quantify the risk in the economy attributable to the weather to be in the region of US$9 trillion in 1999, spread across a diverse range of industries". Consequently, markets for weather derivatives have evolved to allow individuals and businesses to deal with, and minimise, risks associated with weather conditions. Market participants can be anyone who is involved in activities that are weather sensitive (Stern & Dawkins 2004).

The weather derivative market originated in the United States with the first transaction occurring in 1997 (Chance 2003). Early pioneers of the market were mainly large energy trading companies such as Enron, Aquila, and Koch Industries. The market has evolved from energy applications to include entertainment, retail, agriculture and construction applications (Climetrix 2004). Weather derivative markets have spread worldwide with transactions occurring in the United Kingdom, Australia, France, Germany, Norway, Sweden, Mexico and Japan. The market for weather derivatives market in the United Sates is the largest. Participation in the market for agricultural weather derivatives in Australia is currently limited to corporate grain and cotton growers and suppliers of agrochemicals (Rural Skills 2004).

8.1 Definition of derivatives and trading

"Weather derivatives are risk management tools" for hedging against the possible effects of weather factors (Climetrix 2003; Stern & Dawkins 2004; Rural Skills 2004; Lettre 2000). They are financial instruments based on a standard derivative structure where the instrument is derived from one or more independent measures of the weather factors of concern (Lettre 2000). Weather derivatives tend to cover low-risk, high probability events such as cool summers or warm winters (Lettre 2000). These derivatives are intended to stabilise earnings from weather dependant events by guaranteeing minimum levels of financial income before the event occurs or is completed (Rural Skills 2004). This is in contrast to weather insurance which generally covers high-risk, low probability events such as hurricanes (Chance 2003; Lettre 2000).

Pay outs with weather insurance scheme are based on actual damages whereas payouts with weather derivatives are "based on negotiated differences between a negotiated 'strike price' and the actual weather" (Lettre 2000, 3). The derivatives are "based on indexes that closely monitor the incidence of 'normal' weather patterns over a period of time" (Chance 2003) and the chosen index "governs when and how payouts on the contract will occur" (Climetrix 2004). A payment schedule is set after the study of the long term behaviour of the index and is based on the purchaser's anticipated revenues during the option period (Chance 2003). "Payments are triggered if there is a sufficient diversion from the norm that exceeds an agreed trigger" (Chance 2003).

Table 1: The link between weather and financial risk

(Climetrix: Weather Market Overview[1]):

Risk Holder	Weather Type	Risk
Energy Industry	**Temperature**	**Lower sales during warm winters or cool summers**
Energy Consumers	**Temperature**	**Higher heating/cooling costs during cold winters and hot summers**
Beverage Producers	**Temperature**	**Lower sales during cool summers**
Building Material Companies	**Temperature/Snowfall**	**Lower sales during severe winters (construction sites shut down)**
Construction Companies	**Temperature/Snowfall**	**Delays in meeting schedules during periods of poor weather**
Ski Resorts	**Snowfall**	**Lower revenue during winters with below-average snowfall**
Agricultural Industry	**Temperature/Snowfall**	**Significant crop losses due to extreme temperatures or rainfall**
Municipal Governments	**Snowfall**	**Higher snow removal costs during winters with above-average snowfall**
Road Salt Companies	**Snowfall**	**Lower revenues during low snowfall winters**
Hydro-electric power generation	**Precipitation**	**Lower revenue during periods of drought**

[1] Retrieved from: http://www.climetrix.com/WeatherMarket/MarketOverview/default.asp

The most common indexes used in the derivatives market are Heating Degree Days and Cooling Degree Days which “measure the cumulative variation of average daily temperature” from 18°C over a set period of time (Climetrix 2004). These types of indices are often used by the energy industries as they relate well to energy consumption (Climetrix). Common indexes for non-energy applications include average temperature, the intensity of a rainfall event, cumulative rainfall and snowfall exceeding a defined level (Climetrix 2004).

Key attributes of a weather derivative include the strike, tick size and limit. The strike is the value of the underlying index at which the contract starts to pay out while the tick size is “the payout amount per unit increment in the index beyond the strike” (Climetrix 2004). The limit is the maximum financial payout of the contract. To buy a weather option or derivative, the buyer “pays a premium to the seller that is typically between 10 and 20 per cent of the notional amount of the contract; though this can vary significantly depending on the risk profile of the contract” (Climetrix).

Derivatives come in two forms – put options and call options. When a put option is purchased the holder of the option is paid a certain amount for each unit the index deviates below the agreed strike value for the index. This type of option sets what is known as the floor price and establishes the minimum revenue the option holder will receive (Hunter 1998). As an option provides the right but not the obligation to follow through on the contract at a specific time, if the index remains above the strike value all that is lost is the premium (Hunter 1998). The second type of option is a call option. By selling a call option based on a high strike value a revenue ‘ceiling’ is created. In this way protection against extreme variations in revenue can be obtained (Hunter 1998).

A potential problem with derivatives is that there may be times when there is a poor link between the weather index selected and climatically induced changes in revenue (such a crop yield). Investigations are being carried out into index-based contracts and models linking rainfall to yield in order to address this problem (Climetrix 2004).

Most trading in weather derivatives occurs is customised although some standardised weather derivative contracts are listed on the Chicago Mercantile Exchange, the Intercontinental Exchange, and the London International Financial Futures and Options Exchange. A recent survey of the weather risk industry “found that more than 3900 transactions occurred during the year (a growth of 43% over the previous year) and that these transactions represented more than US$4.3 billion of notional exposure” (Climetrix 2004).

8.2 Weather derivatives in agriculture

In principle, weather derivatives allow a farmer to "take out protection against a weather event. For example, a derivative could be formulated to protect against certain conditions occurring at a designated recording station, such as receiving less than 300mm of growing season rainfall" (Chance 2003). A payout would be received for each millimetre of rainfall below 300mm up to an agreed amount. Therefore, in the event of a drought, a farmer could receive a payment to at least partially compensate for loss in yield (Chance 2003). Alternatively a contract could be designed so that the yield of a certain crop can be directly related to factors such as frost damage or increased pest activity due to high temperatures. In this case compensation would be paid based on the duration and degree of temperature extreme relative to an agreed level.

Trevor (2002) describes the concept of contracts based on Growing Degree Days and rainfall as potential weather derivatives for agricultural industries. Growing Degree Days represent the range of temperature required for optimal crop growth. The buyer of a contract receives a pay out per degree for every day that the temperature lies outside of the agreed range. Rainfall or precipitation contracts work in the same way with the basis of measurement being millimetres or centimetres of rainfall.

8.2.1 Issues

There are significant problems with rainfall based derivatives in agriculture. To begin with rainfall is spatially discontinuous. In other words, it may be raining in one location but another location close by may be dry (Trevor 2002). Consequently, there may be little if any correlation in rainfall between geographically close locations. Hence rainfall may need to be measured across a large number of sites (Trevor 2002). Accurately monitoring rainfall across a number of districts or region can be extremely expensive. This introduces the equivalent of a basis risk in futures markets into the derivatives market and reduces confidence in the contracts and the market (Trevor 2002). This risk decreases with long term contracts if there is a higher long term correlation in rainfall across sites (Trevor 2002). These complications have resulted in large risk premiums being applied to rainfall contracts making them unattractive to farmers (Trevor 2002).

There are pricing problems for agriculture weather derivatives as the assumptions underlying the commonly used procedures for pricing financial derivatives are unlikely to be approximated with weather derivatives (Trevor 2002). Alternatives do exist for both farmers and market makers to establish a 'fair value' for a contract. However, the two parties are likely to arrive at vastly different values as market makers add a risk premium and use in-house pricing models. This makes it hard for the farmer to understand and have faith in how the 'fair value' of a contract has been derived (Trevor 2002).

Trevor (2002) states that the ideal weather derivative contract for agricultural producers would contain multiple triggers for temperature and rain set for each month of the growing season. This would allow the "farmer to hedge all weather risk during the growing season without the administrative expenses incurred in the buying of multiple options" (Trevor 2002, 28). However, the short term nature of such contracts is likely to increase the risk premium applied. An alternative is a three month degree day contract and a three month rainfall contract. The degree day contract would contain no basis risk as it is only hedging against temperature. The three month term of the rainfall contract is likely to reduce its inherent basis risk (Trevor 2002). Trevor (2002) concludes that the three month degree day contract is likely to be useful and cost effective however the utility of the three month rainfall contract is unclear.

In conclusion, the literature on weather derivatives for agriculture indicates that though they might by useful they are unlikely to be cost effective for most farmers in their current form (Trevor 2002). This is due to difficulties in forecasting and modelling weather conditions as well as difficulties in formulating pricing models to accurately deal with climate complexities (Trevor 2002).

9. Conclusion

Tradable permit systems are increasingly being considered by policy makers as a means of addressing environmental or natural resource problems. While tradable permit systems have been the subject of much theorising, to date very few tradable permit systems have actually been implemented. In this paper we have presented examples of tradable permit systems in relation to water allocation, water quality, salinity, fisheries, biodiversity, air pollution and weather derivatives.

Natural resources possess unique characteristics in terms of their measurability and predictability. As a consequence, tradable permit systems need to be customised to suit the unique nature of each natural resource. We have highlighted the role of contextual factors in the design of tradable permits for managing natural resources in this paper. Predictability in the supply and use of natural resources does not appear to hamper the use of tradable permit systems. However, unpredictable variability in the supply of natural resources does create risks for both resource users and resource managers. While banking mechanisms have been incorporated into some tradable permit systems we believe other risk management instruments similar in kind to derivatives are worth exploring.

In our view the key factor constraining the use of tradable permit schemes in natural resource management is the challenge of measuring the use of resources by non-point sources. The common factor in the programs that we investigated that are either still in the proposal or pilot phase is the difficulty of establishing trades with non-point source users. The inability to measure the use of a resource means that the establishment of a direct link between economic activities and resource use is problematic.

We believe possible solutions to this issue lie in the development of common property rights (Kaine and Reeve 1993) and the use of quantitative models to predict resource use such those that are currently used to estimate resource supply in fisheries.

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