Trading Efficiency in Water Quality Trading Markets: An Assessment of Trade-Offs

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Abstract

Declining water quality as a result of increased nutrient leaching is a serious and growing concern, both internationally and in New Zealand. Water pollution issues have traditionally been addressed with command-and-control type regulation, but market-based nutrient trading schemes are becoming more widespread. In New Zealand, a cap-and-trade system has been implemented in Lake Taupo and another has been designed for Lake Rotorua. Despite the importance placed on avoiding transaction costs in water quality trading markets, there has been little discussion in the literature of practical policies to decrease these transaction costs, or any real assessment of when it is and is not optimal to decrease transaction costs. This paper begins to address these issues. We find that strong efforts to control time-of-trade transaction costs are most likely to be worthwhile in schemes with heterogeneous participants and large expected values and volumes of trading. The trading inefficiency that results from search and bargaining, and trade registration costs can be minimised at some cost. Regulators can reduce trade approval costs if they establish baseline leaching levels for all participants and design standardised leaching monitoring systems as part of the set-up of the system, and monitor all sources equally regardless of whether participants trade instead of estimating and approving changes in traders' leaching at the time of each trade (as occurs in a baseline-and-credit system). Finally we find that while regulators may be tempted to restrict trading or increase measuring and monitoring requirements to increase the environmental certainty of a scheme's outcome, environmental risk may be better addressed through a less certain but more stringent environmental target.

JEL codes

Q53, Q15, D23,

Keywords

Water quality markets, transaction costs, nutrient trading markets, trading ratios

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1. Introduction[1]

Declining water quality as a result of increased nutrient leaching is a serious and growing concern both internationally and in New Zealand (Ministry for the Environment, 2007).[2] While these water pollution issues have traditionally been addressed with command-and-control type regulation, attempts to deal with the issue through market-based nutrient trading schemes are becoming more widespread (Selman et al., 2009).[3] In New Zealand, a cap-and-trade system has been implemented in Lake Taupo (Duhon et al., 2011) and another has been designed for Lake Rotorua (Kerr and Lock, 2008). For water quality trading markets to efficiently and effectively achieve environmental goals, participants must be able to easily and cheaply trade allowances. This paper theoretically investigates the extent to which regulators should pursue this trading efficiency, and discusses policies which will enable them to achieve it.

Previous work in this area has approached the issue under the general umbrella of transaction costs in environmental markets. A useful survey by Krutilla and Krause (2011) presents a thorough overview of work and conclusions in this area. Stavins (1995) shows analytically that in the presence of transaction costs, the cost-effective equilibrium of equalised marginal control costs will not be reached in an environmental allowance market. Kerr and Maré (1998) provide evidence for this contention using data from the US Lead Phasedown Tradable Permit Market, while papers by Gangadharan (2000) and Fowlie and Perloff (2008) address this question using data from the Los Angeles Regional Clean Air Incentives Market (RECLAIM). Further work by Solomon (1999) and Falconer (2000) also emphasise the importance of considering transaction costs when designing environmental markets. Papers by Nguyen and Shortle (2006), Fang et al. (2005), Schary and Fisher-Vanden (2004) and Prabodanie et al. (2009) extend this investigation into the specific context of water quality trading markets.[4]

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[1] This paper has been written as part of the Nutrient Trading and Water Quality research programme which is being led by Motu Economic and Public Policy Research in Wellington, New Zealand. The programme aims to design and simulate a prototype nutrient trading system for the Lake Rotorua catchment, in conjunction with a group of stakeholders and scientists with specialist knowledge of the region. An overview of the initial prototype design is published as Motu Working Paper 08-02 (Lock and Kerr, 2008b), with full information available at www.motu.org.nz/research/detail/nutrient_trading.

[2] The most recent report on the State of the Environment released by New Zealand's Ministry for the Environment (2007) reported that more than a third of New Zealand's lakes have poor water quality, and that rivers throughout New Zealand have seen significant increases in nutrient levels over the past two decades.

[3] The recent overview paper by Selman et al. (2009) found 57 nutrient trading schemes worldwide (of which 26 were in active operation, 21 in development and 10 inactive) and that the prevalence of market regulation as a response to water quality issues was increasing. New Zealand currently has one operating nutrient trading scheme (Lake Taupo).

[4] The largely parallel literature on water allocation markets offers little further insight into trading efficiency. One of the few exceptions is found in two papers by Zhang (2007) and Zhang et al. (2009) which examine barriers to effective water allocation markets in the Heihe River basin of northwest China. These papers

The exact definition of transaction costs has also seen significant discussion. McCann et al. (2005) and Krutilla and Krause (2011) both argue that shifting definitions of transaction costs within the environmental markets literature hamper its development. To avoid perpetuating this we explicitly follow Stavins (1995) and use a narrow definition of transaction costs that focuses solely on the costs that are faced by a participant as a result of deciding to trade in the market.[5] Time-of-trade transaction costs include the costs of gathering information, bargaining, decision making, any costs of trade approval borne by participants, and, if only faced by participants who trade, the cost faced by participants in baseline setting and monitoring. We do not consider the behavioural or sociological barriers to trade efficiency that are considered in Breetz et al. (2005). This definition also does not include programme set-up or ongoing administration costs which will affect both regulators and participants. These costs are considered in the discussion of trade-offs required to achieve low time-of-trade transaction costs. Trading efficiency is defined as the inverse of time-of-trade transaction costs: trading efficiency is maximised by minimising time-of-trade transaction costs.

The initial conclusions of the literature are clear: transaction costs decrease the effectiveness and efficiency with which environmental markets can achieve environmental goals. However, despite the importance placed on avoiding transaction costs in water quality trading markets, there has been little discussion in the literature of practical policies to decrease these transaction costs, or any real assessment of when it is and is not optimal to do so. This paper assesses existing schemes and the literature to investigate when trading efficiency should be increased, and how it can be done.

We find that maximising trading efficiency by minimising transaction costs faced by participants at the time of trade has significant benefits for the operation of trading markets, but that its attainment can be costly, and requires careful consideration to ensure that trading efficiency and the benefits it brings are achieved at least cost. Gains from improved trading efficiency will be greatest in schemes with high expected volumes and values of trading; that is, those with heterogeneous participants and an inefficient initial allocation of allowances. Trading efficiency is largely determined by the underlying design of the trading scheme and the timing of monitoring, but it can also be affected by ongoing interventions. We find that regulators can reduce time-of-trade transaction costs if they establish cap and trade schemes with baselines set for all participants rather than voluntary baseline and credit schemes, and use standardised ex-

also find that transactions costs and trading inefficiency decrease the effectiveness of trading markets in achieving an efficient allocation of allowances.

[5] To avoid any confusion we refer specifically to "time-of-trade transaction costs" for the rest of the paper.

post monitoring rather than requiring ex-ante approval of individual trades. Trading efficiency can be further maximised in an ongoing way by encouraging liquidity in the trading market, ensuring that participants have good information, and by providing market participants with relative certainty about the future of the scheme by explicitly planning for future scheme changes.

This paper also contributes to the literature by formal exploring the trade-off between trading efficiency and environmental certainty that regulators face when considering restricting trading or increasing measuring and monitoring requirements in a water quality market. We find that while regulators may be tempted to restrict trading to increase the environmental certainty of a scheme's outcome, environmental risk may be better addressed through a less certain but more stringent environmental target.

The paper proceeds as follows. We begin by explicitly outlining the regulator's decision of whether and how to increase trading efficiency. Section 2 discusses the first part of this decision, and considers the characteristics of schemes where the benefits of increasing trading efficiency will outweigh the costs. In section 3 we explore how trading efficiency can be improved, this is split into two sections. Section 3.1 investigates how trading efficiency can be maximised at setup: here we compare the time-of-trade transaction costs faced in baseline and credit schemes with cap and trade schemes, and compare ex-ante and ex-post monitoring. Section 3.2 examines how trading efficiency can be increased in existing schemes. The role of information flows, certainty and market liquidity are outlined. In section 4 we discuss the trade-off between environmental certainty and trading efficiency, and develop a formal model to explore this trade-off. Section 5 concludes.

1.1. The Nature of the Problem

The overall goal of any regulator introducing a water quality trading market is to minimise the cost of achieving an environmental goal. The cost of achieving this goal is made up of costs from three major areas: mitigation costs, time-of-trade transaction costs, and administration costs. Mitigation costs are the actual costs of reducing nutrient run-off, be this through the application of specific technologies or changes to production. Time-of-trade transaction costs refer to the costs faced by participants participating in the nutrient trading market. Administration costs refer to the costs of establishing and running the trading scheme; these can be further split into set-up costs (the costs of designing and implementing a trading scheme), the effort and cost of reducing time-of-trade transaction costs, and the ongoing costs that regulators will face.

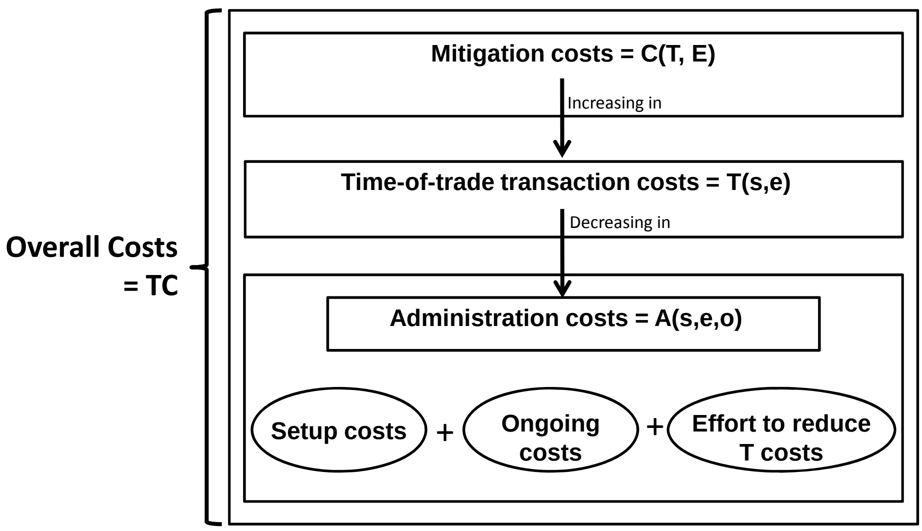
The regulator's goal can be expressed as:

$$\min TC_{s,e,o} = A(s,e,o) + T(s,e) + C(T,E) \quad (1)$$

$$s.t.\ E \geq E^*$$

The regulator's goal is to minimise total costs (*TC*) by optimally choosing set-up costs (*s*) and making an effort to reduce time-of-trade transaction costs (*e*) and ongoing costs (*o*), subject to meeting the environmental goal (*E*) of exceeding a given level of water quality (*E**) (*E≥E**). Total costs are the sum of administration costs (*A*), time-of-trade transaction costs (*T*), and mitigation costs (*C*). Time-of-trade transaction costs are decreasing in the amount of resources spent on system set-up, *s*, and effort by the administrators to reduce time-of-trade transaction costs, *e*. Mitigation costs are increasing in transaction costs, which are inversely related to trading efficiency, and increasing in the stringency of the environmental goal. The nature of the relationship between each of these individual costs is shown in Figure 1 below.

Figure 1: Relationship among costs



When set out as above, the problem faced by a regulator becomes clear: will the gains from increasing trading efficiency outweigh the costs? Increasing expenditure on setup and expending effort to lower time-of-trade transaction costs is clearly only worthwhile if it brings about a decrease in the overall cost of the system. Given this, how can regulators set up a scheme to maximise trading efficiency, and what ongoing policies should they enact to ensure that time-of-trade transaction costs faced by participants are minimised? These questions are addressed in the next two sections.

2. When is Increasing Trading Efficiency Worthwhile?

Any effort to improve the trading efficiency of a system will be worthwhile only if the improvements are expected to decrease the overall cost of achieving the environmental goal. The degree to which improved trading efficiency will decrease overall mitigation costs will differ from scheme to scheme, and depends on the expected value and number of trades. This is in turn determined by the heterogeneity of participants, the efficiency of initial allocation and the distribution of the expected size of trades. The scope of the scheme – the choice of the type and coverage of sources to include– will also affect the potential gains from trading efficiency.

The absolute gains from improved trading efficiency will be larger in schemes with a larger expected value of trading. If transactions costs are partly fixed costs per trade rather than proportional to the size of the trade, gains from improved trading efficiency will also be larger in schemes with a high number of expected trades: holding the total value of trades constant, gains from trading efficiency will be higher in a system with a high number of low value trades than in a system with a low number of high value trades.

Schemes with high trading values and volumes are characterised by heterogeneous participants and inefficient initial allowance allocation. Newell and Stavins (2003) conclude that systems with highly heterogeneous participants (in terms of mitigation costs and baseline discharges) will have more gains from trading. This heterogeneity of participants depends not only on differences before any regulation, but also differences that remain after any initial allocation of trading allowances: trading efficiency gains will be greatest in schemes with an inefficient initial allocation of allowances. This is most easily understood if the alternative, an efficient initial allocation, is considered. In this case the right to pollute will have been allocated to those who value it most and as a result we would expect no trading to occur. A highly inefficient initial allocation is most likely to occur if regulators have little knowledge of dischargers' mitigation costs or if free allocation is motivated by equity rather than efficiency concerns. An inefficient initial allocation of allowances is unlikely to occur if allowances are auctioned instead of freely allocated; as a result we would expect to see less trading in a scheme with auctioned allowances, and would accordingly expect less total gains from improved trading efficiency.

The distribution of mitigation costs that underlies participant heterogeneity is also important. Participants will trade with each other if the gains from trading outweigh the costs of doing so. As a result, gains from improving trading efficiency will be greatest in schemes where a slight decrease in transaction costs results in the gains from trade subsequently outweighing the costs of trading, leading to significant efficiency gains from a small increase in trading efficiency. This situation is most likely to occur in schemes where a large number of participants have heterogeneous mitigation costs (which would require a number of small value trades to achieve equalised mitigation costs), rather than in a scheme where only a few outlying participants have different mitigation costs (and only a few large trades would be needed to equalise those costs).

2.1. Scope

The choice of a scheme's scope – its comprehensiveness and the types of sources it covers – will also determine the heterogeneity of participants and, as a result, the benefits of improved trading efficiency. Regulators choose the scope of a scheme. They can choose to add participants if they expect the resulting cost of their inclusion will be outweighed by associated lower mitigation costs.

The scope of existing schemes differs considerably worldwide due to the different goals and approaches of regulators in different water catchments. The most obvious difference between schemes is whether they include only point sources of pollution, only non-point sources, or both. Point sources (PSs) discharge pollution at a specific location, for example the outflow pipe at a water treatment plant. Non-point sources (NPSs) pollute less directly, for example via diffuse run off from land.

Water quality regulation has traditionally set limits only for pollution from PSs. NPSs are more challenging to regulate because NPS nutrient loss is difficult to measure and is subject to seasonal and weather-related variation (Stephenson and Bosch, 2003). As a result the inclusion of NPSs may increase uncertainty about actual environmental impacts; we discuss the trade-offs between environmental certainty and trading efficiency in section 4. Despite these issues, the incorporation of NPSs of nutrient discharge is often crucial to achieve environmental aims, as NPSs often cause the majority of discharges.[6] Lock and Kerr (2008a) explore the impact of scope on liquidity and market power, and discuss the issues raised above in greater detail.

[6] Carpenter et al. (1998) report that 82% of nitrogen and 84% of phosphorus entering USA waterways comes from NPSs. This is also true for our prototype New Zealand trading scheme; NPSs are the primary origin of nutrients entering Lake Rotorua (Kerr and Rutherford, 2008).

3. How Do We Increase Trading Efficiency?

If regulators decide that the gains from increasing trading efficiency are large and worth pursuing, what policies should they consider? Time-of-trade transaction costs include search and bargaining costs of finding trading partners, and the costs of trade approval and trade registration. These transaction costs are largely determined by the fundamental design of the scheme: that is, whether the scheme is a cap and trade or a baseline and credit scheme, and also on the timing and intensity of participant monitoring. Regulators can also seek to minimise transaction costs in schemes that have already been established.

Different system designs are discussed in section 3.1. This includes an explanation of both cap and trade and baseline and credit schemes, and ex-post and ex-ante monitoring, and the trading efficiency implications of these options. Section 3.2 outlines options available to regulators who want to improve the trading efficiency of existing schemes. Examples of potential approaches are explained under the heading of improved information flows, maximised participant certainty, and liquidity.

3.1. System Design

Trading efficiency can be maximised by designing systems where participants do not face trade approval and baseline-setting costs at the time of trade, and instead face them either at the time of establishment of the system, or as an ongoing cost that is faced by all participants, not only traders. Participants considering whether to trade will consider only the costs they face as a result of trading; they will not consider any prior sunk costs faced at scheme set-up, or costs that are independent of the trading decision.

While this shifting of cost timing will be an effective way to decrease a scheme's transaction costs, it is not clear that it will be efficient. This shift is worthwhile only if the mitigation and time-of-trade cost savings as a result of the improved trading efficiency are expected to outweigh the increased set-up costs; that is, if the total cost of achieving the environmental target decreases. Shifting trade approval and baseline-setting costs to the time of establishment will potentially result in overall savings due to the economies of scale that are possible when dealing with all participants at once.

If a regulator decides that minimising transaction costs in this way is worthwhile they will need to focus on two fundamental policy design choices: the choice of a cap-and-trade or baseline-and-credit system, and the choice of an ex-ante or ex-post monitoring system. These choices largely determine whether trade approval costs are faced at the time of trade or not.

3.1.1. Cap-and-trade versus Baseline-and-credit Systems

There are two basic types of nutrient trading markets: cap-and-trade systems, and baseline-and-credit (also known as offset) systems. Cap-and-trade markets involve setting a comprehensive cap on the allowable discharge of a given nutrient over a catchment or watershed, and dividing this cap into individual, tradable allowances. These allowances are then distributed to market participants, and participants must obtain and regularly remit an allowance for each unit of nutrients entering waterways from their property. Further trading rules can be written to ensure that the environmental goal is not compromised by trading.

In a baseline-and-credit market not all sources of nutrient discharge are regulated. Baseline-and-credit systems involve some regulated participants facing a cap (individually or as a group with allowances allocated to individuals) in the same way as in a cap-and-trade system, but also include a voluntary component. Voluntary sources outside the regulated group can opt into the system and participate by decreasing their nutrient discharges in exchange for credits. For sources to participate, a baseline level of nutrient losses must be set, generally by estimating nutrient leaching under best practice or business as usual. If this voluntary participant discharges less than its allotted baseline it can sell credits equivalent to its discharge decreases to the regulated cap-and-trade section of the system. When the system works as intended, these voluntary reductions act as a substitute for nutrient reductions in the cap-and-trade segment of the scheme, and the environmental goal will still be met.

Differences in the trading efficiency levels of cap-and-trade and baseline-and-credit schemes stem largely from whether the monitoring is ex ante or ex post (this is discussed in the next section). The two systems also have other advantages and disadvantages. Cap-and-trade schemes offer greater environmental certainty because participation is compulsory and the schemes regulate and monitor a much larger group of sources. The fact that all nutrient sources are treated alike also has some attractions in terms of equity. However, it can be politically difficult and costly to introduce a cap-and-trade scheme which includes all sources. Baseline-and-credit systems are more easily and cheaply established at a small scale than cap-and-trade schemes, largely because the political cost of allocating allowances (equivalent to setting clear baselines for each source) is deferred. The flip side of this is that the cost of baseline setting is faced by participants at the time of trade, so trading efficiency is low. If only a small proportion of sources is expected to need to trade in order to efficiently achieve the environmental outcome, a baseline-and-credit system will probably be more efficient.

A key disadvantage of using baseline-and-credit schemes is that including fewer sources reduces market efficiency and raises the cost of achieving the environmental goal, as participants have fewer trading partners with consequently less variation in individual mitigation costs. Not including all sources of nutrient discharge also introduces the risk of leakage, where decreases in pollution by regulated sources within the catchment leads to pressure for more production and hence increases in discharges by unregulated sources. Moreover, baseline-and-credit schemes are liable to face a significant problem of adverse selection.

Adverse selection occurs as a result of the difficulties faced by regulators in accurately setting a business-as-usual baseline for participants, combined with the voluntary participation element of baseline-and-credit schemes. If baselines are estimated accurately for all potential participants, then any participants that opt in will do so because they can profit by reducing nutrient losses at a low cost and then selling the accrued credits on the nutrient market. However, if participants have better knowledge about their baseline discharges than regulators (asymmetric information), and as a result baselines are estimated with error known to the participants, then there can be a second reason for sources to opt in. If a source ends up with an erroneously generous baseline, then this source can choose to participate and collect credits for apparent environmental savings without doing anything to reduce their leaching. The spurious credits that they accrue from this participation are not environmental substitutes for nutrient reductions by regulated sources, as no actual reductions have occurred. These credits unintentionally increase the level of the cap, and as a result, if this is not controlled for, they will result in violation of the environmental goal.

There is no balancing out of these environmentally harmful credits; if a voluntary source is instead attributed an erroneously stringent baseline, then they will simply choose not to opt in. This also has a negative impact: efficiency will be lost if those who could offer some cheap mitigation do not because of an ungenerous baseline. This adverse selection was a reported outcome of voluntary participation in the USA Acid Rain Program (Montero, 1999). The compulsory participation of cap-and-trade schemes avoids adverse selection as all participants are included in the scheme and cannot opt-in to take advantage of the erroneous generosity or out as a result of the erroneous stringency of their allocation. While individual errors will still occur, on average these will balance each other out.

Clearly, the choice between a cap-and-trade scheme and a baseline-and-credit scheme has a large impact on the effectiveness and efficiency of the regulation. This choice also has significant flow-on effects on other characteristics of the system. In particular it largely determines the type and level of monitoring and enforcement that is implemented, a characteristic that also has implications for the trading efficiency of the system.

3.1.2. Monitoring and Enforcement

Any regulation (with or without trading) must specify how and when emitters are monitored, and whether discharges are "monitored" in advance (ex-ante control) or once they have occurred (ex-post monitoring). The method of determining emissions for regulatory compliance is critical for the environmental integrity of the system as well as for the flexibility individual participants have in how they comply and the certainty they have about the effect of their actions on their compliance. Monitoring requirements can also have a large impact on the trading efficiency of any nutrient trading system.

Monitoring is considered ex ante when a scheme requires individual assessment of participants before any changes to their discharge levels or trades are approved. Most baseline-and-credit systems use this approach.[7] Ex-ante monitoring is generally used to prevent non-compliance; unfortunately this approach also greatly increases transaction costs and decreases trading efficiency (Schary and Fisher-Vanden, 2004). Every time participants change discharge levels on their farms in order to trade they have to first submit to individual estimation and approval of any changes they plan to make. As a result, these ex-ante monitored systems place the cost and uncertainty of this monitoring only on those who change their operations (including all buyers and sellers of allowances). This decreases the flexibility and the net benefit of trading for all participants, and subsequently decreases the trading efficiency of the system.

Participants in ex-ante baseline-and-credit schemes face any costs of participation in the system only if they choose to trade and opt into the system. These costs are borne as transaction costs. If a discharge source in a baseline-and-credit system chooses not to trade then they will not have to adapt in any way to the market regulation – they can avoid the costs of learning the new system, and obviously any baseline setting, measuring, monitoring and registering costs that they would have to face if they opted into the system and traded. These costs will greatly decrease the overall benefits of trading for optional participants in a baseline-and-credit scheme, possibly to the extent that they decide not to participate even if they could have provided low-

[7] They could theoretically use ex-post schemes but the biggest attraction of an ex-ante scheme – low set-up costs – would be undermined by the costs involved with establishing standardised monitoring systems. Indeed, ex-ante baseline-and-credit schemes are the most prevalent water quality trading schemes worldwide, particularly for those schemes that incorporate non-point sources (Selman *et al.*, 2009).

cost mitigation.[8] The low number of trades reported in many nutrient trading schemes are consistent with this being an issue (King, 2005).

Cap-and-trade systems can have either ex-ante or ex-post monitoring systems; there are existing examples of each world-wide (Breetz et al., 2004).[9] Ex-post monitoring systems require all participants to self-report their nutrient discharges, and compliance is established on a periodic basis (often annual) after any changes and trades have taken place. As a result, instead of requiring individual assessment of each trade, an ex-post system allows participants to change management and trade freely according to pre-set rules, models and precedents. This approach to monitoring and measuring is expensive to set up, as it requires the establishment of models or systems that robustly estimate discharges using the supplied data. However, the economies of scale available when setting up these systems for all participants at once will potentially reduce the average cost, relative to an ex-ante scheme. Once established, this ex-post monitoring system will be relatively cheap for regulators to operate. Also, as under an ex-post scheme all participants, regardless of whether they have traded, must provide verifiable data to regulators, this monitoring cost becomes independent of the trading decision. This decreases time-of-trade transaction costs.

Ex-post cap-and-trade systems have high set-up costs but very low time-of-trade costs and high trading efficiency. In comparison, ex-ante cap-and-trade schemes, such as the Lake Taupo nutrient trading scheme, face significant set-up costs and also face significant and uncertain time-of-trade costs. However, they do provide regulators greater opportunity for oversight and as a result may be appropriate to ensure environmental outcomes in schemes where enforcing compliance may be difficult (Environment Waikato, 2009).

These dimensions are summarised in Table 1, where the arrow shows the direction of greater trading efficiency. The timing of monitoring is largely a function of whether the trading system is cap-and-trade or baseline-and-credit (offset).

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[8] In contrast, participants in ex-post and ex-ante cap-and-trade systems face these costs of baseline setting as part of set-up, and face the ongoing monitoring and registration costs regardless of whether or not they trade (to ensure that they are in accordance with their allowed discharges). As a result these costs do not enter in their decision of whether to trade: transaction costs are lower and trading efficiency higher.

[9] Our proposed Lake Rotorua nutrient trading scheme is an ex-post cap-and-trade system. See Lock and Kerr (2008b).

Table 1: Comprehensiveness of Monitoring

Basis and timing of monitoring		**Sources only monitored if they trade**	**All sources always monitored**
	Ex-ante monitoring– (prescribed plan or activities)	Ex-ante baseline-and-credit	Ex-ante cap-and-trade
	Ex-post monitoring– (nutrient losses modelled based on verifiable information)	Ex-post baseline-and-credit (rare)	Ex-post cap-and-trade

Greater trading efficiency

The question of whether ex-ante or ex-post monitoring will have a lower overall cost for a given level of environmental gain is less clear, and depends on the specific characteristics of trading scheme. These characteristics are largely similar to those discussed in section 2: the cost of setting up an ex-post scheme is more likely to be offset by decreased mitigation costs in systems with high expected behaviour change and volumes and values of trade, whereas if changes in behaviour and trade are expected from few sources and penalties for non-compliance are weak, then the lower set-up costs and enhanced ability to prevent non-compliance of an ex-ante system may make it the preferred option.

3.1.3. Impacts on Innovation

A final issue that should be considered when deciding on the monitoring system to use in a trading market is the impact that the scheme will have on innovation and the development of new technologies and mitigation methods. An oft-cited benefit of environmental markets is that, unlike simple regulation, they can promote innovative responses to environmental problems (Jaffe et al., 2001).[10] However, this will occur only if innovations in management or mitigation can be easily and cheaply incorporated into the nutrient trading scheme; if the cost of measuring the environmental impact of new mitigation methods is high then innovation will not be especially promoted. Streamlining the inclusion of new mitigation methods while minimising the cost of investigating these methods requires careful consideration on the part of regulators, and

[10] Tietenberg (2006) also discusses the relative strengths of this claim. The literature indicates that this claim is stronger under some circumstances and assumptions than under others; namely, if allowances are auctioned and marginal costs of production are increasing. In any case, decreasing the costs of incorporating new innovations into a system will increase innovation.

their decisions will need to feed into the choice of the monitoring process (Kerr and Rutherford, 2008).

Incorporating new innovations into a system with ex-post monitoring will be more difficult and time consuming than in an ex-ante system, but will provide greater certainty. In an ex-ante system, regulators can take an ad hoc approach where new methods and techniques are recognised individually at the time of each trade approval. This is a relatively cheap and straightforward process for regulators, but may have negative impacts on the uptake of new innovations due to participant uncertainty: participants will have to go through the expense of a trade approval process before they know whether their innovative mitigation methods will be recognised. In comparison, in an ex-post scheme new innovations would have to be tested and incorporated into the models that are used to estimate discharges for all participants before it can be used by participants. This method will be slower and more expensive, but is likely to offer more certainty for participants, who will know before applying any mitigation techniques the impact that this will have on their recognised discharges.

3.2. Further Minimising Time-of-trade Transaction Costs

While the trading efficiency of a trading system is largely determined by its setup, it can be improved by providing participants with good and trustworthy information, certainty, and by ensuring adequate liquidity in the market. Methods to achieve this are discussed here, with examples from existing schemes.

3.2.1. Information Flows

Trading efficiency is supported through traders having ready access to high-quality information. In particular, the transaction costs of search and bargaining and of re-organising and optimising production under the new regulation can be minimised by providing good information to participants. Good market design can improve the types and quality of information available to those who require it, either through expert third parties or through improved electronic access to information.

Brokers and similar third parties make information gathering and decision making more efficient by accumulating knowledge of the trading framework and streamlining the trading process (Stavins, 1995). These organisations, in turn, require clear governing frameworks to ensure they are trusted and effective. Some markets have a single intermediary, known as a clearinghouse, which handles all allowance sales. This approach reduces search and bargaining costs. The disadvantage of this approach is that there is no competition to encourage greater efficiency. Nevertheless, Selman et al. (2007) list as a success the implementation of a clearinghouse for the Great Miami River Water Quality Credit Trading Program in Ohio.[11]

Online and automated trading facilities can also help to reduce decision making and search and bargaining transaction costs. NutrientNet (World Resources Institute, 2007) is a set of web-based tools to facilitate water quality trading. NutrientNet allows participants to connect with other possible traders, and to list credits for sale or bid on available credits. It also allows administrators and the public to access (confidentialised) trades and prices over time, and administrators to keep track of credits and compliance records, all at minimal cost. The system has been used for four trading programmes in the US, across five states (Selman et al., 2007).

NutrientNet's calculation tool, and a New Zealand counterpart, OVERSEER®, allow farmers to run relatively complicated nutrient models to estimate their discharges and consistently compare different mitigation methods and their effect on nutrient leaching. These models allow participants to more effectively and cheaply optimise their operations to changing market conditions and hence decide how much to produce, mitigate, and trade. The New Zealand OVERSEER® model has been built to compute nutrient budgets and to estimate nitrogen and phosphorus loss from pastoral land using data that can be reasonably easily obtained by farmers or consultants, whilst still giving thorough and dependable output.[12] The Lake Taupo Trading Program uses OVERSEER®, in part for this reason (Selman et al., 2007)[13]. The information that such models provide to participants can greatly decrease the costs of choosing optimal production under the new regulation and increase trading efficiency.

Information flows are also likely to change over time. A case study by Woodward (2003) investigating the first trade carried out in the Lake Dillon reservoir in Colorado, USA, suggests that over time participants have a better understanding of the system and also a greater knowledge of possible trading partners. Both of these factors work to reduce search and information costs and transaction costs as a whole, which increases the trading efficiency of a system over time.

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[11] The Miami River clearinghouse purchases allowances from agriculture using reverse auctions and allocates these to "investor" companies (who require credits to meet environmental regulation) in proportion to their level of investment.

[12] For example, the OVERSEER® pastoral farming model uses data on a farm and block level, and computes outputs based on farming region, animal shelters and feed pads, effluent management, animal species and their management and stocking rate, supplements, nitrogen inhibitors and wetland areas, topography, climate, soil and pasture type, and irrigation, along with soil analysis and fertiliser inputs (AgResearch, 2009).

[13] The proposed Lake Rotorua trading scheme would also use Overseer (Lock and Kerr, 2008c).

3.2.2. Certainty

Certainty in the context of a nutrient trading system refers to certainty in the definition of an allowance and its properties, and to certainty in the regulatory, political and scientific elements of the trading environment. Participants need certainty in these areas to mitigate and manage their nutrient leaching with confidence. Uncertainty will make it more difficult for participants to plan and invest for the future, and will result in defensive, and inefficient, trading behaviour. While an in-depth exploration of all of these uncertainties is beyond the scope of this paper, this section briefly outlines these uncertainties and how policy design can seek to avoid them.

Clearly defining an allowance and its properties is an important step for efficient trading. An allowance determines the holder's ability to discharge nutrients, how much, when and where. A clear definition should state how nutrient discharges will be estimated, whether the allowance is to be used once or for a flow of discharges each year, whether it can be banked for use in future periods, whether it can be changed by the regulator (for example the amount of nutrient discharge associated with it could be reduced by a percentage or the allowance could be cancelled without compensation) and whether the location of the discharge is restricted.

Whether regulators, policy makers, and politicians will remain committed to the nutrient trading system is a major concern for trading efficiency.[14] Changes in political priorities could see politicians introducing new regulations or relaxing existing ones. Participants who anticipate these actions may choose to hoard or sell at a loss any allowances they hold. A stakeholder process can help minimise the likelihood of political uncertainty by generating widespread political support for a scheme. Selman et al. (2007) advocate both education and ongoing dialogue with stakeholders to ensure a system is implemented smoothly and with greater certainty.[15]

Finally, the scientific information used to measure and address water pollution is subject to change, and provides another level of uncertainty for traders. However, restricting scientific uncertainty can stifle incentives for innovating of new mitigation methods. Balancing this trade-

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[14] A recent paper by Karpas and Kerr (2011) illustrates the cost of political uncertainty in a trading market, the forestry component of New Zealand's emissions trading scheme. They find evidence that this uncertainty is a key reason for low levels of participation in the market.

[15] The appendix in Selman et al. (2007) lists educational resources for communicating relevant information to a range of stakeholder groups. Breetz et al. (2005) draw on social embeddedness theory and concludes similarly: building trading market participants trust and understanding through education and the leveraging of existing social networks is crucial to ensure participation and the ongoing success of any nutrient trading scheme. As a practical resource, Motu's environmental trading game is designed to introduce the principles of nutrient trading to a non-technical audience (this can be found online at www.motu.org.nz/building-capacity/environmental_trading_game).

off requires regulators to treat new scientific information like any other potential change in regulation: uncertainty can be avoided through clear specification of which elements may be subject to change and a declared mechanism for transferring liability (or unexpected gains) to allowance holders (Kerr and Lock, 2009).

As a general rule, certainty in all of its dimensions can be maximised by the inclusion of well developed processes for managing any future change. It is highly unlikely that any trading scheme will continue unchanged indefinitely; planning for the almost certain future changes will be the most effective method to promote certainty within a system.

3.2.3. Market Liquidity

Ensuring that nutrient markets have adequate liquidity is essential to minimise search and bargaining costs, and to avoid any risk of market power. It should be relatively easy for a willing and able buyer to find allowances they can purchase, and vice versa.

To maximise this liquidity, designers of nutrient trading systems should examine how much flexibility a region's hydrology can handle. For example, the period for which participants are able to bank credits might be restricted to the mean residence time of a water body. In the Greater Miami River, Ohio, participants may purchase only allowances generated upstream from their point of discharge (Selman et al., 2007). This helps to avoid "hot spots" of pollution, but limits liquidity as it means that buyers can trade only with a subset of potential sellers.

Liquidity can also be encouraged by holding regular auctions of allowances. Regular auctions enhance price discovery and increase the transparency of the market, and ensure regular availability of allowances for participants (Matthes and Neuhoff, 2008). Using auctions rather than free allocation also encourages participants to actively participate in the market rather than simply comply using their free allocations, which will also encourage liquidity (Matthes and Neuhoff, 2007). Auctioning of allowances occurs, for example, in the Hunter River Salinity Trading market, Australia.

Allowing trading across more than one pollutant can also significantly increase allowance liquidity. Stephenson and Bosch (2003, p. 11) draw on the emissions trading literature to state that "cross pollutant trading could be a practical alternative in many watersheds". The Rahr Malting Company trading programme, Minnesota, USA, allows phosphorus, nitrogen, and sediment to be traded for one another according to trading ratios (Breetz et al., 2004). While this type of cross-pollutant trading increases liquidity, if the environmental impacts of the pollutants are not similar, or adequately controlled for, it will adversely affect the environmental integrity of the trading scheme. This trade-off between environmental impacts and trading efficiency is explored in section 4.

4. Trade-off: Environmental Certainty and Trading Efficiency

The issue of trading efficiency in environmental markets is made more difficult by the trade-off between environmental certainty and low time-of-trade costs. This trade-off and its implications are discussed and formalised in the following section. Examples of trading restrictions from existing systems are also explored.

As discussed in section 3, maximising trading efficiency and minimising transaction costs requires that trading is made as flexible as possible. While this approach ensures that allowances can cost-effectively move from initial holders to those who value them the most, if there is any difference in the environmental impact of nutrient discharge cuts, then this free trade can also result in an uncertain net environmental outcome.

This environmental uncertainty has the same impact whether the uncertain environmental outcome is due to true scientific unknowns or is a result of known and accepted variability. Immeasurable uncertainty occurs if the actual impact of any nutrient discharges or reductions on the final environmental goal is not totally certain. For example, this is the case if regulators cannot be sure that a decrease in discharges by one participant will exactly offset an increase in discharges from another participant (as is often the case when including non-point sources in a trading scheme). Environmental uncertainty also results from known variability in environmental impacts. To establish a workable trading scheme an "enabling myth" of homogeneity of impact may need to be assumed.[16]

This environmental uncertainty is likely to be a larger issue in a flexible trading scheme (baseline-credit or cap and trade) than in a command and control regime (where regulators require dischargers to meet specific discharge limits or employ defined technologies) for two reasons. First, scientific understanding and the modelling of nutrient discharges are based on status quo activity and discharge levels. Policies that result in large shifts away from status quo levels of activity will shift further away from accepted scientific understanding and will be associated with an increase in the uncertainty of the environmental outcome. Second, flexible trading schemes are more likely than command and control schemes to result in significant

[16] Kerr et al. (2004) discuss the potential for systematic bias leading to underachievement of the environmental goal. This can occur if low cost mitigation is correlated with a positive error in measurement. In the context of water quality markets, it may occur if participants whose mitigation is modelled erroneously high are more likely to mitigate than others with the same modelled mitigation. This might further motivate management of environmental uncertainty.

movement of discharges around a catchment and greater variation of discharge levels, with increases at some sources and decreases at others.

The environmental uncertainty discussed here differs from the uncertainty discussed by Weitzman (1974). Here, uncertainty occurs as regulators do not know the exact effect of any environmental targets set (due to uncertain errors in the modeling of discharges); in Weitzman uncertainty occurs as regulators do not know how much benefit any increase in environmental target will bring (due to uncertainty around the benefit from environmental improvements). The inefficiency that results is the same, but the solutions available are different.

This issue of environmental uncertainty is also touched on in the literature on "hot spots", which also outlines some regulatory attempts to decrease them (Tietenberg, 1995). Hot spots occur when unacceptably high levels of pollution occur in a localised area within a wider trading market. While the literature has shown that the occurrence of hot spots has not been high (Swift, 2000), avoidance of these hot spots is another possible motivation to restrict trading.[17] Tietenberg (2006) provides a summary of possible policy responses to avoid hot spots. Hot spots, however, result from variability in impact of a known level of emissions; we are here more concerned with unobservable variability in the true level of emissions.

4.1. Formal Depiction of Trade-off

We first set out the cost of environmental uncertainty. Regulators can either accept this environmental uncertainty and bear its cost, or can attempt to decrease (the cost of) uncertainty, for example by introducing trading rules and increased monitoring and measuring at the time of trade. While this will increase environmental certainty, these regulations also act as transaction costs and decrease trading efficiency. Indeed, if regulators are especially risk averse and apply particularly stringent trading restrictions, then the high costs of trading could inhibit all trades. Even small restrictions on trade will have a cost.

Figure 2 shows the benefits and costs of mitigating discharges into a lake. The costs of mitigating are borne privately by the nutrient dischargers who do the mitigation and participate (or not) in the nutrient trading market. Their marginal costs of mitigation (MC) are assumed to be increasing as they mitigate more. This initial mitigation cost line illustrates the case where trading is unrestricted and monitoring requirements are not onerous. This results in mitigation

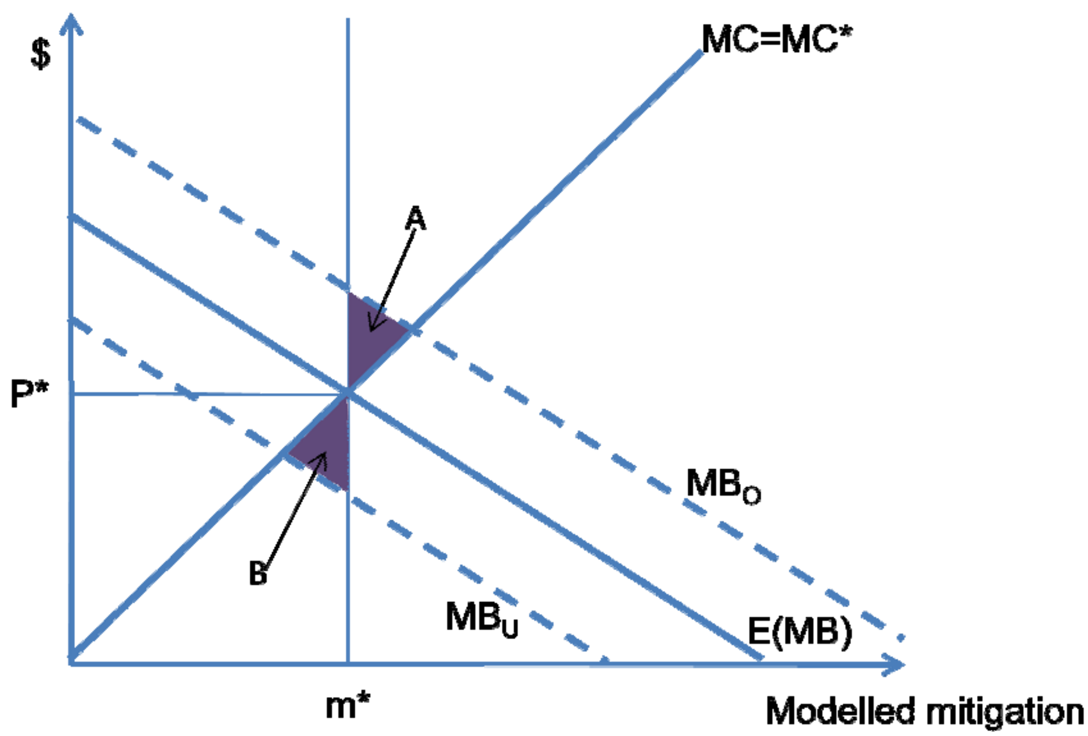
[17] A wish to ensure "environmental justice" may be another motivation to restrict trading. The flexible nature of a trading scheme could plausibly result in a shift of emission/discharge concentrations into lower socio-economic areas. A recent paper by Fowlie et al. (2009) uses evidence from the Southern California NOX program to investigate whether the trading scheme has resulted in emissions changes that differ by neighborhood demographics; they find no evidence of this.

being carried out by those who can most efficiently do so, at the lowest overall cost to society (MC =MC*).

Society benefits from increased mitigation of nutrient leaching (which decreases water pollution), but at a decreasing rate. Society cannot easily predict the exact amount of mitigation, but instead bases decisions on a best guess – this level of mitigation is given by m, and the expected benefit of this mitigation is given by the curve E(MB). Given the amount of information available to regulators, the optimal level of mitigation in our trading market (m*) is given by the intersection of these two curves. When the cap on nutrient leaching to meet the environmental goal is set so that required mitigation is m*, the price for the nutrient trading allowances is P*.

4.1.1. Option One: Accepting Uncertainty

Figure 2: Accepting Environmental Uncertainty



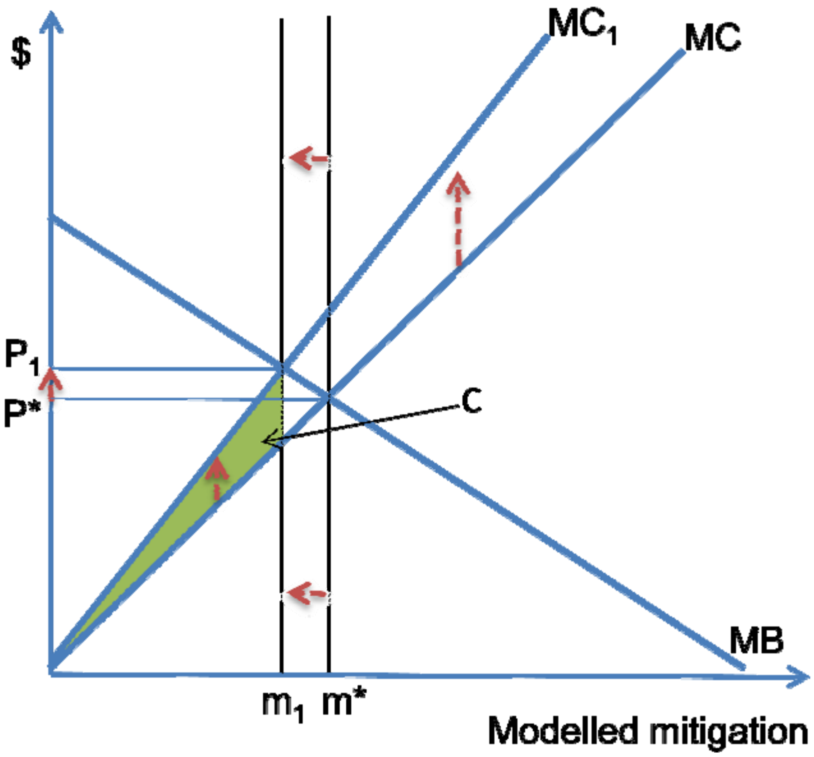
We assume that the regulator sets the mitigation target at m* to create a cap on leaching, distributes the trading allowances to participants, uses simple modelling, and allows free trading among participants. This is associated with low time-of-trade transaction costs, and will minimise the marginal cost of complying with the regulation for dischargers (MC=MC*). However, this is associated with environmental uncertainty: regulators cannot be certain that the modelled mitigation (m) is equal to actual mitigation. This does not affect the marginal costs of farmers (they are required to remit allowances equal to their total modelled level of leaching, not actual).

However, there is a real cost to society. If modelled mitigation is systematically less than actual mitigation across sources so the errors do not cancel out, the marginal benefit of mitigating more will be higher than the expected marginal benefit (curve MB_O). The cost of this is shown by triangle A: gains are forgone by not setting a modelled mitigation goal at m>m*. There is also a cost if modelled mitigation overestimates actual mitigation, as the true marginal benefit of mitigating will be lower than the expected marginal benefit (curve MB_U). Triangle B shows the cost of overstating the marginal benefit of modelled mitigation; gains could have been achieved if the environmental goal had instead been set m<m*. For illustrative purposes, we assume that the MB_O and MB_U are the true marginal benefit curves with a probability of 50 percent. Under this assumption the expected cost of the environmental uncertainty is ½(A+B).

4.1.2. Option Two: Limiting Uncertainty

Regulators may seek to avoid these costs of environmental uncertainty by restricting trading in some way, for example by limiting who can participate or by requiring extra monitoring and measuring. This will have two effects; both are illustrated in Figure 3. The first effect will be an increase in environmental certainty, which is shown as the disappearance of the uncertainty around the expected marginal benefit curve; such that E(MB)=MB. However, restricting trade in this way also decreases the trading efficiency of the scheme, which makes the achievement of any environmental goal more expensive. This is shown by a shift upwards of the marginal cost line from MC to MC_1. Marginal costs of mitigation are no longer at their lowest level, as the trading restrictions mean that the cost of mitigation is augmented by time-of-trade transaction costs (if those with low mitigation costs are not those with a shortage of allowances) and some of the cheapest mitigation options may not be taken. Society will now set the optimal environmental cap at m_1. The cost to society of the resulting transaction costs are shown by the triangle C.

Figure 3: Limiting Uncertainty



Deciding whether to restrict trading or accept uncertainty should depend on a relatively straightforward comparison of costs: if C > ½(A+B) then regulators should accept the environmental uncertainty, and if C< ½(A+B) then they should act to restrict trading.[18]

While this model suggests that accepting environmental uncertainty may be the best option in some cases, examples of such acceptance are uncommon in existing water quality regulation worldwide. Instead, the vast majority of water quality problems worldwide are managed using significantly restricted trading schemes or less flexible regulation (examples are discussed in section 4.2 below). A potential explanation for this is that regulators and stakeholders are particularly concerned about environmental uncertainty under trading, and particularly the potential for underachievement of the environmental goal. We set up a model that fits these observations, and investigate the suitability of setting a more ambitious trading cap as an alternative to restrictive regulation.

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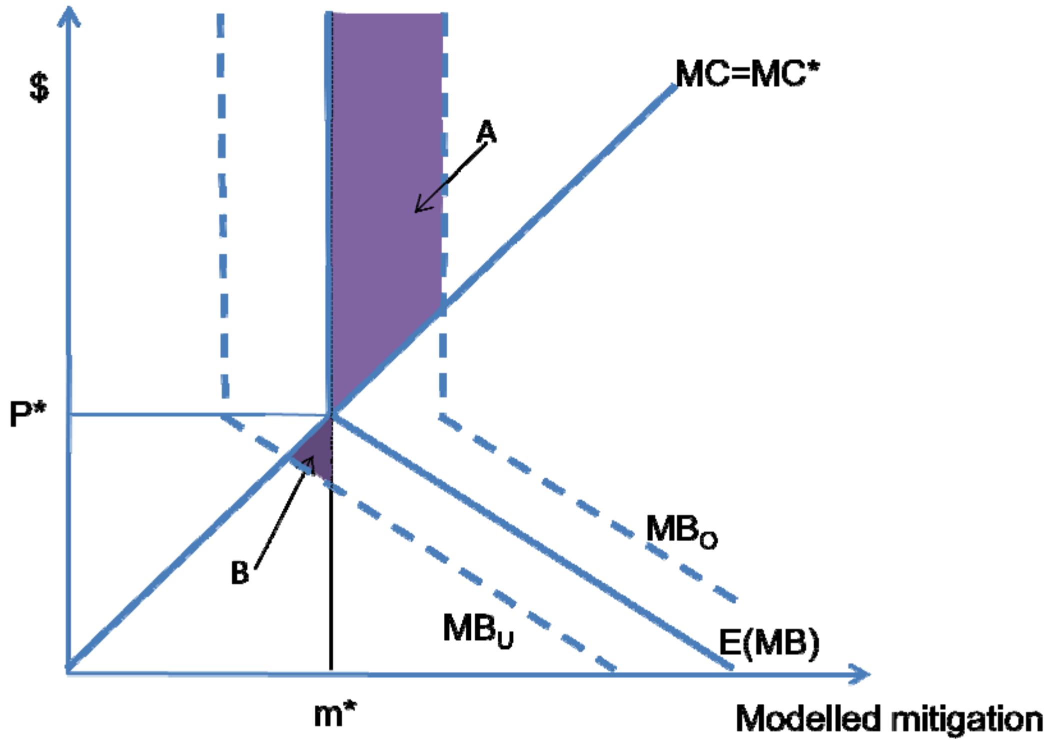
[18] This is not the optimal approach; the lowest cost option would be some combination of acceptance and increased monitoring and trade restrictions. This illustration compares the costs of the different approaches in isolation.

4.1.3. Option Three: Ambitious Environmental Goal

A particular aversion to underachieving (as opposed to overachieving) the environmental goal implies a kink in the marginal benefit curve. This situation is illustrated in Figure 4. The cost of environmental uncertainty here is significantly higher than that shown in Figure 2.

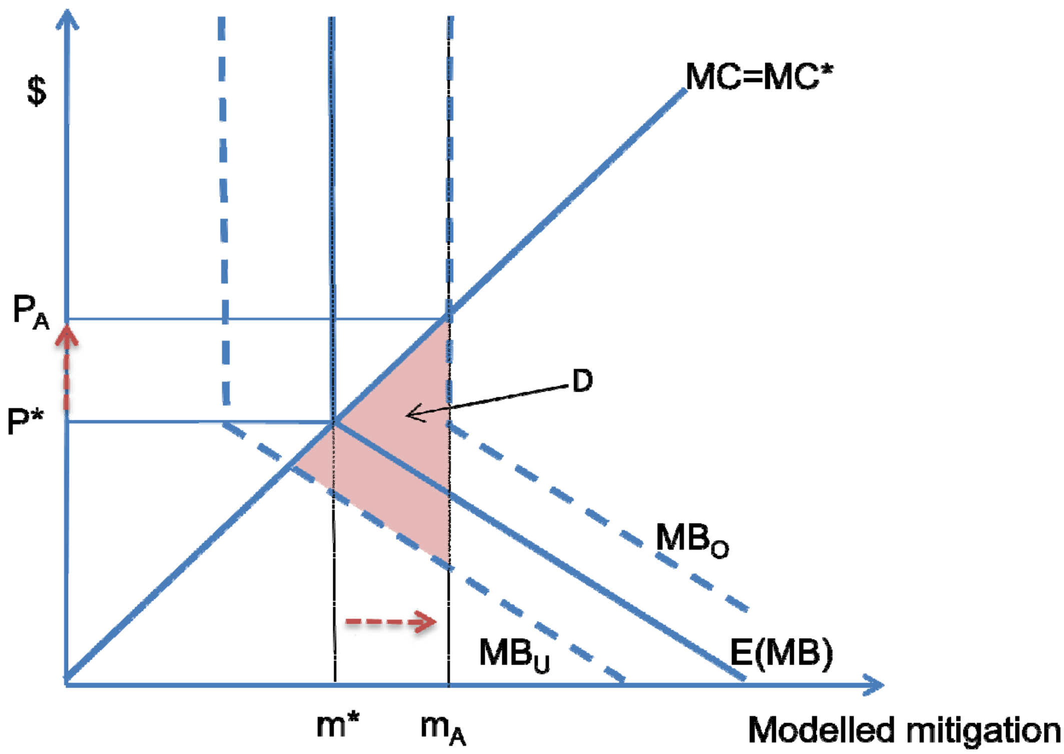
Figure 4: High Cost of Underachieving the Environmental Goal



Given this marginal benefit curve, regulators will be more motivated to restrict trading to minimise the likelihood of underachieving the environmental goal (and facing the cost illustrated by triangle A), as the cost of environmental uncertainty (½(A+B)) has grown relative to the cost of restricting trading efficiency.

However, given these social preferences, regulators can instead pursue a different approach to minimise the costs of environmental uncertainty. This approach, aiming for a more ambitious environmental goal but placing no restrictions on trading, is illustrated in Figure 5. Here, instead of accepting the cost of uncertainty or introducing restrictions and monitoring requirements to avoid it, regulators set a more ambitious environmental goal. Figure 5 illustrates the case where the goal (in terms of modelled mitigation) is increased so that even if the modelled mitigation underestimates the true level of mitigation (curve MB_O), the socially optimal level of mitigation is met (m_A). If modelled mitigation is instead an underestimate of true mitigation, the cost to society is the triangle D. Assuming an equal chance of modelled mitigation over- or under-estimating the true level of mitigation; the expected costs of this more ambitious target are equal to ½(D). Given this marginal benefit curve, regulators should choose the policy associated with the lowest out of ½(D), ½(A+B), or C. The gains of this approach may be reduced if the more ambitious environmental target is accompanied by increased lobbying by stakeholders. This rent-seeking could significantly increase set-up costs for regulators.

Figure 5: Ambitious Environmental Goal



It is likely that the optimal solution would be a combination of acceptance, a more ambitious target and a carefully chosen level of monitoring and trading restrictions. Trading ratios, a commonly proposed solution to the problem of uncertainty (that are discussed in the next section), are equivalent to a more ambitious target but imposed only when trades occur. If trading, that is to say moving mitigation between sources, is inherently more uncertain than changes in how mitigation is done within sources, this may provide a way to optimally adjust the target as levels of uncertainty change.

4.2. International Examples of Trading Limits

Examples of trading limits and restrictions that target the trade-off between environmental certainty and trading flexibility are plentiful in existing schemes worldwide. We present a number of international examples of trading restrictions below and discuss their implications for environmental certainty and trading efficiency.

If regulators are not confident that a trading scheme alone will ensure that nutrient mitigation in one area is a perfect substitute for mitigation in another area then additional rules or pre-approval of trades may be a sensible method to decrease any risk to the environment. Rules that restrict trading to between like sources are an example of rules that aim to restrict trading to increase environmental uncertainty. "Like sources" can be defined in a number of ways. The Pennsylvania Water Quality Trading Program looks to ensure that trading is restricted to "like sources" where "like" is defined as locating within the same watershed.[19] "Like" can also be defined by the same arrival time in the focal body of water: in the initial prototype Lake Rotorua nutrient trading scheme discharges must be matched by allowances appropriate to the year that nutrients arrive in the lake (a 'vintage' system) (Lock and Kerr, 2008c). A similar level of certainty of mitigation effectiveness can also group 'like' sources: the restriction of trading to metered point sources, such as in the Connecticut, U.S. Long Island Sound Nitrogen Credit Exchange Program, is an example of this. However, the most common appearances of these environmentally motivated trading restrictions are as uncertainty ratios.

Uncertainty trading ratios are commonly used in schemes which include NPSs. NPS discharge reductions are generally thought of as less certain and more variable than PS reductions, as their effectiveness depends on things such as the weather and storms (Selman et al., 2009). Uncertainty ratios are set such that for a NPS to get a credit equivalent to a one unit PS discharge reduction, the NPS would have to decrease their discharges by more than one unit. This approach is meant to work as a safety margin that ensures that even if NPS discharge reductions don't work as expected, water quality will not be negatively affected. While the use of uncertainty ratios may have some environmental benefit by ensuring that water quality is protected, they also impose clear costs on trading efficiency. The use of these uncertainty ratios decreases incentives for NPSs to participate in any trading system: any discharge reductions they make are worth significantly less than PS discharge reductions. This will work as a significant barrier to getting discharge allowances from the low-cost abaters (presumed to be NPSs) to those who face high costs of abatement (presumed to be PSs), which by definition will negatively affect trading efficiency. However, if this is balanced by a significant decrease in the uncertainty of the environmental impact, it may be justified.

In the Lake Dillon scheme in Colorado, USA, two units of discharge reduction by NPSs are required for any one unit increase in discharge by PSs (Woodward, 2003). The Pennsylvania Water Quality Trading Program places a 10% 'insurance' ratio on all trades to cover any

[19] The Pennsylvania scheme controls nutrient discharges across two watersheds, the Susquehanna and the Potomac. See (Pennsylvania Department of Environmental Protection, 2006).

mitigation that fails due to reasons outside of the credit seller's control (Pennsylvania Department of Environmental Protection, 2006). Uncertainty ratios are also present or proposed in many other schemes such as the Lower Boise River Effluent Trading Demonstration Project and the Minnesota River Basin trading program (Greenhalgh and Selman, 2008). The use of uncertainty ratios is also encouraged as good policy by the United States Environmental Protection Agency (United States Environmental Protection Agency, 2007).

Despite their impact on trading efficiency, the use of uncertainty ratios may be preferable to other, less certain mechanisms that are used to address environmental uncertainty. Complicated compliance systems may achieve environmental certainty but are associated with uncertainty for participants. An example of such a system is New Zealand's Lake Taupo Trading Program. In this scheme both the buyer and the seller must have any changes to their discharges individually assessed and approved before a trade can be carried out. This mechanism provides less certainty for participants to plan ahead, is costly, and as a result may significantly decrease trading efficiency. Under such uncertain approaches participants may choose to mitigate more than is efficient and over-comply (buy additional allowances or not sell) to reduce risk (Shimshack and Ward, 2008). This over-compliance comes with a cost.

Likewise, systems with onerous approval and monitoring may maximise environmental certainty, but the transaction costs involved participating in such schemes are likely to minimise participation. Breetz et al. (2004) describes a number of water quality trading schemes with onerous monitoring systems. An extreme example is given by the Kalamazoo River Water Quality Demonstration Project, Michigan USA. The project planning and approval required to certify discharge reductions by NPSs, which could then be traded with PSs, took on average 4-10 weeks, and up to 4-6 months.

In the numerous attempts worldwide to address the trade-off between environmental certainty and trading efficiency, regulators have generally opted to err on the side of environmental certainty. However, there are also instances where trading restrictions and limits have been introduced that decrease trading efficiency with no obvious gains in environmental certainty. While regulators may have other good reasons for introducing such regulations, it is important that the negative impacts of restricting and limiting trade are recognised. The negative impacts of restricting trading efficiency in this way can be large, and must be considered when designing policy.

4.3. Other Trading Limits

There are also many examples of trading rules and restrictions that limit trading but do not offer any related environmental certainty gains. In the Pennsylvania Water Quality Trading Scheme landowners can accrue nutrient credits for decreasing nutrient discharges through almost any nutrient mitigation method, but they cannot receive credits for land use change.[20] In the Connecticut Long Island Sound Nitrogen Credit Exchange Program trades are allowed only between PS participants and the central exchange board. The board also sets the price of credits based on an assumed average mitigation cost. This approach results in no market clearing, which leads to trading inefficiencies. The restriction of participation to PSs is another trading rule that decreases trading efficiency. This limitation is present in at least 13 of the 57 existing, proposed or inactive trading schemes worldwide (Selman et al., 2009).

Trading systems should also give participants the choice of whether or not to trade. While trading is expected to lower the cost of mitigation, in some cases nutrient discharges may be most cost effectively cut through onsite methods. Fang et al. (2005) criticise the Minnesota system because it requires PSs to purchase allowances from NPSs to comply – point sources are unable to meet their target through in-plant control methods.[21] This restriction potentially forgoes more efficient nutrient reductions. It also retains a high level of control for regulators, negating the "command but not control" philosophy of market-based instruments (Shabman and Stephenson, 2007).

Local circumstances and political processes can also lead to inefficient trading rules. An example is the interaction between existing or parallel command-and-control regulations and any trading scheme(King, 2005). If the scheme is not carefully aligned with any existing regulation, trading efficiency can be significantly hindered.

5. Conclusion

We have examined existing water quality trading markets worldwide and assessed the growing literature on transaction costs in environmental markets to address two key questions. First, under what circumstances should regulators try to reduce time-of-trade transaction costs in

[20] There was political concern in the lead up to the nutrient trading scheme that its introduction would result in farms stopping operations and selling or shifting to alternative land uses. As a result a clause was written into the law to ensure that farmers would not get credits by shifting land out of farming, even if this was the most cost-efficient method of nutrient reduction.

[21] The Minnesota scheme has this restriction as a result of the legal framework it is based on. See Fang et al., (2005).

a water quality trading market, and how should they do so? Second, what policies will successfully balance the competing goals of trading efficiency and environmental certainty?

Our discussion indicates that maximising trading efficiency should be a key consideration when designing a nutrient trading market, but that maximising trading efficiency can be costly. We offer a selection of policies that will effectively increase trading efficiency. A key insight of the discussion is the importance of designing schemes with trading efficiency in mind; a high degree of efficiency can be achieved, but only if the goal of trading efficiency is considered from the design stages. Any policy that decreases transaction costs participants face at the time of trade will increase trading efficiency. Improving the information made available for participants and maximising certainty (in all its spheres) for participants, and shifting the timing of costs to set up will all decrease time-of-trade transaction costs and improve trading efficiency. The appropriate level of effort to control transaction costs depends on the heterogeneity of actors and the stringency of the goal, and hence the volume and value of potential trades.

A final insight comes from our discussion of the trade-off between trading efficiency and environmental certainty. While regulators may be tempted to restrict trading or increase measuring and monitoring requirements to increase the environmental certainty of a scheme's outcome, this will have negative effects on trading efficiency. If regulators and the public can be convinced to accept some degree of uncertainty partly matched by a more ambitious goal, then a trading scheme will be able to achieve environmental goals at lower cost.

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