Economic Policy Branch
Department of Sustainability & Environment, Victoria
Working Paper presented at 2011 AARES Conference

Contracts for environmental outcomes: the use of financial contracts in environmental markets

Veronika Nemes, Andrea La Nauze & James O'Neill
January 2011

Abstract

In environmental markets, parties frequently exchange obligations through environmental contracts. These contracts imply a distribution of risk between parties. The main focus of our paper is to identify contracts that enable risk in environmental markets to be reduced, distributed at least cost, or managed efficiently. The risks that we consider are: moral hazard risk, price risk, exogenous environmental risk, measurement risk and production risk. The first section of our paper outlines some of the contracts currently utilised in financial and insurance markets to achieve these objectives. These are: futures and options contracts, spread contracts, weather contracts and catastrophe bonds. We then provide a snapshot of current applications of these contracts both in real markets and in the literature. Finally we discuss some possible applications in the environmental sector and indicate how the use of these contracts may alter the way government manages environmental assets and responsibilities. We also suggest a staged process to the introduction of contracts that recognises the current limitations faced by government. This paper does not propose new or novel contracts for tackling the problems of risk in exchange. Rather it extends the application of existing contractual arrangements to a new type of problem: environmental markets.

Corresponding author: veronika.nemes@dse.vic.gov.au

1 Introduction

In recent years, policy makers have looked to new mechanisms such as Market Based Instruments (MBIs) for tackling environmental problems. At the most basic level, markets are institutions that facilitate voluntary exchange of goods and services between buyers and sellers. In the field of environment, MBIs attempt to mimic the features of markets to produce environmental outcomes efficiently. Environmental outcomes may include biodiversity, habitat for endangered species, carbon sequestration, improvements in river health, and reduction of certain pollutants such as nitrogen or sulphur dioxide. Transactions often occur because there is a regulatory requirement to maintain/reduce the level of pollution or emissions below a certain level (i.e. cap-and-trade schemes) or to reduce environmental impacts (i.e. offset schemes). Examples include the Regional Clean Air Incentives Market (RECLAIM, a sulphur oxides and nitrogen oxides cap-and-trade scheme) in California, the Regional Greenhouse Gas Initiative (RGGI) in the US, the Emissions Trading Scheme in the European Union (EU ETS), and the Victorian Government's native vegetation offset scheme. Environmental transactions also occur as the result of government procurement programs such as biodiversity auctions, grant schemes and other procurement tenders. Examples of these include the Victorian Government's BushTender and ecoTender programs, the New South Wales Hunter River Salinity Trading Scheme, and the Fitzroy Basin Association Biodiversity Tender.

In environmental markets, parties frequently transact by becoming parties to a contract. There are many different types of contracts. While in emissions trading schemes market participants buy and sell allowances (that specify the right to emit a certain quantity of pollutants within a period of time) or credits (that represents a unit of reduction in the pollutant below a certain baseline), in other markets a different type of contract has emerged. Typically, in procurement tenders like BushTender, environmental benefits are purchased via *input based* contracts. That is, the environmental outcome is procured through a contract that specifies the *actions* that a landholder commits to undertake for an agreed payment, usually over a period of time. With output based contracts, (such as emissions allowances and credits), payments are made for *delivery* of an output. In this type of contract the buyer is directly purchasing the good it is interested in (i.e. a unit of CO2 sequestered). Whether environmental benefits are established and purchased via input or output based contracts, various types of risks are implicit for buyers and sellers in the transaction.

The main focus of our paper is to identify contracts that enable risk to be reduced, reduced, distributed at least-cost, or managed efficiently. We also seek to demonstrate the applicability of various contractual forms in environmental markets. The first section of our paper contains a definition and a discussion about the types of risks that we have identified in environmental markets. The second section of our paper outlines the contracts currently utilised in financial, commodity and insurance markets to manage risks inherent in those transactions. These include futures and options contracts, spread contracts, weather contracts and catastrophe bonds. We then provide a snapshot of current applications of these contracts both in established markets and in the literature. We then discuss some possible applications in the environmental sector and demonstrate how the use of these contracts may alter the way government manages environmental assets and responsibilities. The novelty of this paper is to extend the application of existing contractual arrangements currently widely used in the financial sector to a new type of problem: to help reduce, manage or distribute various types of risks involved in transactions in environmental markets.

2 Risk and the role of contracts in environmental markets

Contracts, whether they are input or output based, can take a myriad of forms. A contract is an agreement between parties for the exchange of certain goods or the promise of certain actions. A contract is legally binding and sets out the obligations of both parties in an agreement. Without contracts, government or other purchasers have no mechanism to secure either the agreed management actions or the environmental benefits of their investment. Without a contract the supplier therefore has little incentive to deliver on the agreed terms. At the same time, without contracts landholders do not have any security regarding agreed payments for actions or goods and services they may produce. This leaves them exposed. Whilst contracts provide some security or certainty to both parties, they are most often incomplete. Implicit in these contracts is therefore risk.

At least five types of risk can be identified in environmental markets: *moral hazard risk*, *measurement risk, exogenous environmental risk*, *price risk* and *production risk*. *Moral hazard risk* refers to the risk that the producer will apply little effort when fulfilling their contractual obligations. *Measurement risk* is the risk that the scientific tools and human error involved in the assessment of environmental outcomes may be subject to error. *Exogenous environmental risk* refers to the risk that an event beyond the control of parties to the contract will result in a reduction of environmental outcomes (for example because a fire or a drought wipes out the environmental gains that have been made by a landholder). *Price risk* is the risk associated with changes in the market price over time (where both buyers and sellers are price takers). *Production risk* is the risk that actions or inputs will not produce the desired environmental gains. Depending on how the contract is structured, the parties to the contract will share these risks amongst themselves or will use some form of insurance to transfer this risk to a third-party outside of the contract.[1]

Risk is important because it imposes costs on the parties who bear it. For example, input based contracts typically create risks for the buyer in the event of some external interruption to the contract (*exogenous environmental risk*) or if the inputs

[1] Although not considered here, a range of mixed contracts with payments for inputs and outputs (for example using performance bonuses) can also be designed using the techniques of contract and incentive theory. Bardsley et al (2009) for example have shown that the optimal contract design will differ in regulatory and procurement environments.

specified in the contract do not achieve the outcome (*production risk*). Transactions in output based contracts closely resemble other well-developed markets: in these contracts sellers receive payments for their actual production levels, there is no *moral hazard risk*, and the *exogenous environmental risk* and *the production risk* are borne by producers (sellers). Contracts also have an important time dimension to them. Which party bears the *price risk* depends on the timing and conditions of the transaction. This risk is important both for producers of environmental outcomes (who may be making forward production decisions) and for buyers of environmental outcomes (who may wish to ensure that a certain quantity of environmental outcomes can be purchased from a given budget).

Unfortunately it is impossible or costly to eliminate all risks. Eliminating or reducing *production risk* for example requires improved scientific understanding of the production of environmental outcomes or experience through time. As knowledge of the production function is expected to improve over time and with research and experience, it is possible that distribution of this type of risk will also change over time. That is, the production risk may initially be better placed with those who have knowledge through research but may be better transferred to those who build experience over time. Similarly, *measurement risk* is also expected to decrease with better measurement tools and by building capacity in the environmental sector to carry out accurate measurements.

Prices and the environmental outcomes that result from these markets will reflect the way the risk is shared between buyers and sellers. The distribution of risk implicit in contracts will therefore have important implications for the functioning of environmental markets. The next section of this paper briefly outlines a range of contracts used in the financial, commodity, and insurance sector that have developed to reduce, distribute or manage various risks in the exchange of different goods and services. We then go on to discuss how these contracts might be used in environmental markets and finally we discuss how establishing these contracts may also change the role of government in managing environmental assets.

3 Contracts used to manage risk in exchange

Various contracts have developed in financial and commodity markets to reduce distribute or manage the risks inherent in the sale of various goods and services. In this section we describe some of these contracts and give examples of how they are applied currently.

3.1 Futures Contracts

A futures contract allows people to buy and sell assets at a pre-determined price for delivery on a specific future date. This differs to buying and selling assets in the spot market, where the assets are traded instantly at current prices and physical delivery of the asset takes place immediately. By locking in a price today, futures contracts allow market participants to make investment decisions based on price certainty, without being exposed to future price changes.[2]

Specifications:
In order to formulate a futures contract, the following parameters have to be specified:
1) a unit of an asset (e.g. a bushel of wheat)
2) price (paid for the unit of asset at expiry)
3) expiration date (e.g. May 2012)

Example:
A wheat farmer is concerned the price of wheat may fall in the coming months. Prior to entering into wheat production, the farmer calculates that in order to make a profit, he needs to sell the wheat for at least $8.5 a bushel. He decides to enter into a futures contract to ensure he is protected in the event of a dramatic fall in the price of wheat. The current (August 2012) spot price is $10 a bushel, whilst the futures price in December 2012 is $9 a bushel. Satisfied with such a price, the farmer enters into a contract to sell 10 000 bushels at $9 for December 2012 expiry.

3.2 Options Contracts

Another example of a contract is an option. An option gives its owner the right, but not the obligation, to buy or sell an asset at a pre-agreed price. This is thus more flexible than a futures contract, which obliges the contract holder to buy or sell an asset.

There are two main types of options. When exercised, a call option gives the holder the right, but not the obligation, to *buy* an asset at a certain price. Similarly, when exercised, a put option gives the holder the right, but not the obligation, to *sell* an underlying asset at a certain price. The purchaser of an option has to pay an initial sum of money, called the *premium*, to the seller of the contract. There are two main option styles: European style options, which can be exercised only on the date of expiry, and American style options, which can be exercised on or before the date of expiry.

Specifications
In order to formulate an option contract, the following parameters have to be specified:
1) unit of an asset (e.g. a ton of steel)
2) contract type: put or call
3) contract style: European or American
4) agreed price (price paid for the unit of asset if exercised)
5) premium (cost of the contract itself)
6) expiration date (e.g. May 2012)

[2] Futures contracts are traded on a centralised futures exchange. A futures contract is similar to a forward contract however a forward contract is a non-standardised private agreement between two parties and is not exchange traded.

Example:
A company is currently (August 2012) deciding whether to expand its operations, with a decision to be made by the end of 2012. If the expansion goes ahead, the company will need to purchase 1,000 tonnes of steel. The company is concerned about rapidly increasing steel prices but does not want to lock itself into buying the steel unless it is sure the expansion will go ahead.
The company therefore decides to purchase an American style call option to buy steel anytime before the contract expires in December 2012. The company pays a premium of $20 for each of the 1,000 Dec 2010 call option contracts that gives the company the right to buy a ton of steel at a price of $550 per ton.
As this is an American option, the company has the right to exercise the option (i.e. purchase the steel) at any time until the contract's expiry in December 2012 at the price of $550 per ton. It may decide not to do this if the expansion does not proceed. Even if the expansion does proceed but the price of steel falls below $550 per ton, the company can choose to buy the steel at the spot market rather than exercising the option.
In December, the company decides to expand its operations. The December spot price for steel ended up being $650 per ton. As this is greater than the $550 price specified in the contract, the company decides to exercise the option and purchase the steel.

3.3 Spread Contracts

A spread contract is an agreement between two parties to exchange payments if an index is outside a pre-specified range at the time of expiration. A seller of a spread contract quotes the purchaser a 'spread' (i.e. a range of the index). This spread represents the values of the index where no money will be exchanged between the parties. The contract specifies which party (buyer or seller) pays or receives a payment if the index is outside the pre-specified spread during the contract period. The contract also specifies the amount to be exchanged between the parties for each point of movement above or below the spread. Each party stands to profit if the indicator moves beyond the spread in the direction that favours them, and to pay if the indicator moves in the other direction. This contract ignores movements in the market that are within the pre-specified range and changes in the index only become important if the movement is above or below the spread. A greater movement in the indicator will result in a greater potential gain or loss for the parties.

Specifications
In order to formulate a spread contract, the following parameters have to be specified:
1) index (e.g. FTSE 100, ASX 200)
2) direction (e.g. increase or decrease)
3) spread (a range of the index, e.g. between 3995 and 4005 points)
4) the amount of money paid or received per point
5) expiration date (e.g. May 2012)

An investor believes the Dow Jones Industrial Average will suffer heavy losses during the day's trading. She decides to ask a spread contract agency for a quote on the Dow Jones's movements for the day. She is offered a spread of between 9995 and 10005 points. She decides on a tick of $10 per

point and will stand to gain money if the Dow Jones falls below 9995, and lose money if it goes above 10005.
At the end of the day's trading, the Dow Jones has indeed fallen to 9850. The investor therefore receives $10 for every point it fell below 9995. As the index ended the day 145 points below the spread, the investor receives 10 x 145 = $1450.

3.4 Weather Contracts

A range of contracts have been developed to address other kinds of risk. One such non-standard contract (often referred to as an 'exotic' contract) is a weather derivative. These contracts were developed to enable parties to manage and mitigate the threats posed by *exogenous environment risks* such as adverse weather events. A weather derivative consists of a contract between two parties that details how payment will be exchanged depending on certain meteorological conditions (e.g. temperature, precipitation, snowfall and wind-speed) during the contract period. Like spread contracts, weather derivatives have special attributes that set them apart from other commodity derivatives. The main conceptual difference is that these derivatives do not trade an underlying asset: one is not purchasing weather. Rather, participants exchange payments based on a state of the world described explicitly in the contract. In this sense this contract is a substitute to an insurance product. One of the advantages of weather derivatives is that they cannot be manipulated by individuals. Hence these types of contracts do not suffer from the same *moral hazard* problems as other risk management products such as insurance. As with any other transaction, a person willing to sign a weather contract requires a counter-party. This counter-party either has an inverse upside (i.e. they gain when you lose and vice versa) or they are better able to spread their exposure to risk (e.g. they can sign contracts across areas that have inversely correlated risks).

Specifications
In order to formulate a weather derivative contract, the following parameters have to be specified:

1) weather index (e.g. mm of snow, km/h speed of wind, mm of rain, C degrees in temperature)
2) the threshold where payments begin
3) the amount of money paid or received per point if the index is above/below the threshold (e.g. $250 per degree above 30 degrees)
4) premium (the cost of the contract itself)
5) expiry date (e.g. August 2012)

Example:
A winemaker is concerned that long range forecasts of snowy weather may damage his vineyards. He decides to purchase a weather derivative contract to manage this risk.
The farmer pays a premium of $5000 to purchase the weather derivative. On each day till the expiry of the contract (August 2012), the winemaker receives $100 for each cm of snow above a threshold of 5cm.

3.5 Catastrophe bonds

Catastrophe bonds (also known as CAT bonds) are contracts that transfer a specific risk from the seller (e.g. government or insurance company) to the buyer. The buyer accepts the risk in return for interest payments. If no catastrophic event occurs, the seller pays interest to the bond holder (e.g. the current interbank lending rate plus a premium). If, at any time prior to the expiry of the bond, specified trigger conditions are met (e.g. a hurricane, earthquake or other catastrophic event), the principal initially paid by the buyers would be foregone, and instead used by the seller to pay claims to policyholders. Catastrophe bonds are typically used by insurers as an alternative to traditional catastrophe reinsurance.[3]

Specifications
In order to formulate a CAT bond, the following parameters have to be specified:

1) principal (e.g. $1000)
2) interest rate (e.g. 15%)
3) catastrophe type (e.g. earthquake, flood, volcanic eruption)
4) index (to measure the degree of catastrophic event)
5) trigger condition that if met, the premium is kept by the seller of the bond
6) expiration date (e.g. December 2020)

Example: An insurer is concerned about its exposure to earthquake risk in the Sydney area. It decides to issue a CAT bond to investors. The principal payment is $1000. The bond has an interest rate of 10% per annum, an expiration date of December 2015 and a trigger condition of any earthquake in the Sydney metropolitan area that measures above 5.5 on the Richter scale. In the event of no such earthquake occurring, investors would receive 10% of the principal each year (ie. 0.1 x 1000 = $100 per year) as well as the principal on expiration. If an earthquake of sufficient magnitude were to occur during the time period, the insurer would keep the principal and use it to pay claims to policy holders.

4 Discussion

In this section we demonstrate the way in which contracts described in the previous section may be used to reduce, manage or distribute risks amongst market participants. We then provide a brief overview of some of the current and proposed applications of these contracts in areas related to environmental policy. Finally we describe how these contracts may be used to facilitate the participation of buyers and sellers in environmental markets and also to potentially redefine the government's role in managing environmental assets over time.

[3] One of the advantages of a CAT bonds for investors is that CATs show no direct correlation with equities or corporate bonds, meaning they provide a good diversification of risks.

4.1 Reducing, managing and distributing risks

All contracts discussed in this paper are based on outputs. One of the advantages of such contracts is that they eliminate *moral hazard risk*. Output based contracts however rely on effective measurement of the good or service in question. Over time, measurement and quality rating systems have evolved to allow relatively homogenous goods and services to be measured, grouped and traded with ease. For example, an ounce of 24 carat gold is such that it allows buyers and sellers to enter into contracts with each other knowing exactly what they trade.

In order to facilitate transactions in environmental markets, scientists have in recent years designed a range of Environmental Benefit (EB) metrics in the form of indices and units to measure, model or score the relative quantity and quality of environmental benefits or their indicators. For example, a biodiversity index may score the relative diversity of species present in an area[4]; a salinity index may score a unit change in salinity based on modelled outcomes; a river health index may model changes in aquatic functions.[5] These indices increasingly allow contracts to be directly related to an environmental outcome. They enable the current condition of outcomes to be measured or scored and may also model or predict changes (either gains or losses). However these tools also suffer from *measurement risk.* The inherent risk in measuring the environmental outcome will have implications for the contract and for parties' willingness to transact. *Measurement risk* can be greatly reduced over time through increased collection of information, the use of multiple measurement systems, improved technology, piloting and refining measurement tools and well-trained field officers.

In addition to accurate systems of output measurement, output contracts will be more successful if there is greater knowledge of the production function associated with the environmental good or service. The existence of significant *production risk* is one of the primary reasons for the use of input based contracts in infant environmental markets. Input based contracts distribute production risks to the buyer, who is most often the government in these markets. As these markets mature, the balance of production knowledge shifts from government to producer, who can gain experience through 'learning by doing'. Hence it may be appropriate to consider shifting some of the *production risk* to producers. If *production risk* continues to be borne by purchasers of environmental goods and services, producers have no incentive to invest in trialling new and better production methods or research and development.

[4] For example, the habitat hectare (HHa) is a widely used metric to score habitat (a proxy for biodiversity) in Victoria. It consists of a measure of the quality and the area of a vegetation type. The BushTender, ecoTender, and the native vegetation offset program all use HHa to measure the losses and gains in environmental outcomes.

[5] In general, environmental outcomes may be measured on a continuous or discrete scale. For example, water or air quality may be measured on a continuous scale. On the other hand, a threatened species is either present or not. For a literature review on the various aspects to be considered in designing appropriate environmental indices to support environmental outcomes, see Collins & Scoccimarro, 2008.

Option contracts can help manage *production risk*. Put options give the right but not the obligation to sell at a pre-specified price within a period of time. If the production function was poorly estimated and the output was lower than expected or did not eventuate, the put option holder can simply decide not to exercise it. In exchange for a premium, the put option holder can create a safe 'trial' environment where their effort (if successful) could be rewarded by a pre-specified price. Otherwise, no further payment (other than the initial premium) takes place.

A spread contract can also create a safety zone where no payments are made unless the index moves out of this range. In this instance, *measurement* and *production risk* are distributed between buyers and sellers. This sharing is represented and priced by the spread. Payments are only made if the movement in the environmental outcome is either positive or negative but 'large enough' that it cannot be attributed to measurement error or some mistakes in the production estimates alone. Whilst risks such as *measurement risks* and *productions risks* can be greatly reduced over time, it is unlikely they will ever be completely eliminated.

The contracts described in the pervious section are frequently used to support markets that trade a range of goods and services. In agricultural production for example, producers commonly manage *price risk* through futures contracts. Futures contracts specify the price to be paid and the delivery date in a future time period. These contracts are essential for the exchange of goods and services where delivery is at some future date. They provide future price certainty and hence facilitate decision-making in the present. Spread contracts eliminate *price risks* for both buyers and sellers because the amount of money paid or received per point is pre-determined at the point of entering into the contract.

In the same way a farmer might enter into a futures contract for wheat, she can enter into a futures contract to produce environmental outcomes. For example, a farmer may estimate that she can produce 2 units of Habitat Hectare (HHa) by June 2015. The farmer estimates the cost of her effort over a period of time and decides it is only worth entering the biodiversity market if she can secure a price of at least $1200 per HHa produced. The farmer turns to the futures market to find a party who is willing to pay at least $1200 per HHa with an expiry date of June 2015 or later. If the farmer finds a suitable contractual partner, then through the futures contract she locks in the price ($1200 or higher), the expiry date (June 2015 or later) and the units of HHa to be delivered (up to 2HHa). Until a suitable contractual party is found, there is no obligation on the farmer to produce HHa. The futures contract allows the farmer to manage *price risk* by specifying the sales price prior to any investment decisions.

Options contracts also manage price risks but they also offer some added flexibility by allowing the holder to make a decision whether or not to exercise the contract (i.e. to buy or sell at the pre-specified price). Continuing on from the previous example, instead of a futures contract, the same landholder could purchase a put option (for a premium of $100) which gives her the right (but not the obligation) to sell 2HHas at a price of $1200 or higher. Once the HHa is produced prior to contract expiry, the landholder can exercise the put option and be entitled to the agreed price.[6]

Suppliers of environmental outcomes also face a range of uncertainties that impact upon their ability to produce. Climatic variability, droughts, flood events, fire, hail, and other extreme weather conditions are only some of the examples that may affect production. Unlike *measurement risk, production risk* and *moral hazard risk*, these *exogenous environmental risks* cannot be reduced or eliminated but can only be managed or distributed. Put option contracts can also help manage *exogenous environmental risk.* If the above mentioned landholder fails to produce the 2 HHa within the specified contractual timeframe due to unforeseen climatic variability, she loses the premium ($100) but there are no further consequences and no further payment takes place. Historically, the agricultural sector has addressed the *exogenous environmental risks* through the use of insurance products, such as crop insurance. However weather derivatives (on a small scale) and CAT bonds (on larger scales) are well placed to help manage and distribute these risks. These products have some distinct advantages over insurance products that seek to assist producers to manage the same risk. Firstly, they are not subject to *moral hazard risk;* secondly, if participants are able to find a party with the exact inverse of their risk profile then they may be able to hedge their risk without the cost of a premium.

4.2 Current and proposed applications

Futures and options contracts are used in everyday transactions in the electricity market, mainly to mitigate *price risks*. Electricity use is highly dependent on weather and weather contracts are now a common tool for electricity retailers to protect against *exogenous environmental risks* such as the consequences of abnormally high or low temperatures.[7] CAT bonds have also been introduced in the US and Australia for very low probability but extremely costly events (e.g. earthquakes).

Options contracts have also been nominated (though not adopted) as a means for water utilities to ensure secure water supply for urban water users (see for example Michelsen & Young, 1993 and Hansen et al, 2008). With a call option, a water utility could secure water allocations from rural water license holders if and when needed. Under this scenario, the water utility has the right, but not the obligation, to

[6] If at the time the landholder considers exercising the put option the spot price of the HHa is higher then the pre-specified price, the landholder may decide to sell the HHa at the market directly. The put option gives insurance to a minimum payment but does not prevent the farmer taking advantage of a higher spot price.

[7] Initially, there were a small number of locations where weather was measured for the purpose of derivatives. As weather derivatives became more common, the measurement stations have become more frequent and the product has become geographically more differentiated and therefore better at addressing local risk conditions. Dutton (2002) documents that timescales of weather derivatives are expanding towards both the shorter term (fractions of an hour for weather-induced electricity demand) and longer term (monthly or seasonal scales to manage weather risks in agricultural production). For climate change related risks, for example, contracts based on longer time horizons (5-10 years) may be more appropriate.

purchase the water. Similarly, Hafi et al (2005) suggested that an environmental manager could also exercise call options to secure water to deal with the risk posed by an *exogenous environmental risk* such as drought, e.g. buy back rural water allocations for environmental flows. The above-mentioned examples represent an alternative risk management strategy to the traditional and costly approaches of building greater and greater infrastructure or introducing command-and-control style water restrictions to manage availability of water or the effects of drought.

Gorddard et al (2008) reports on an auction for the conservation of three threatened ground nesting bird species in the Murray Catchment: Bush Stone Curlew, Plains Wanderer and Brolga. The auction, called NestEgg, required landholders to choose between an input based contract and an output based contract. Landholders bid by specifying the upfront payment (i.e. the premium) they require in order to enter into the contract. The output contracts pay an annual bonus to landholder when a 'habitat benchmark' and/or a 'bird species benchmark' is achieved. Input based contracts pay an annual management payment for undertaking certain conservation actions. The tender results indicated that all landholders chose output based contracts.

Mandel et al (2009) suggest applying the CAT bond approach to endangered species conservation to address *exogenous environmental risks*. If the species or the species' habitat declines to a predetermined threshold, the principal the buyers paid would become available for species/habitat recovery initiatives. Similar to other uses of CAT bonds, this instrument creates an immediately available fund to address species recovery. A CAT bond requires the monitoring of the species need to be based on an objective measure. It is also possible for such a contract to align private incentives with the interests of endangered species.

There are also cases where these types of contracts are used in novel ways by firms. Zeng (2000) for example, documents a case where a snow blower retailer offered its customers a payment if the total snowfall for the coming winter was less than a threshold. This innovative sales technique can be looked at as if the retailer provided a weather contract with each sale. This weather contract assists customers in managing the probability of high and low snowfall and partially compensates them for the investment in a snow blower in case the snowfall turned out to be low. It is assumed the retailer included a premium in the price of the snow blower for offering the payment.

Spread contracts have developed, primarily for use in financial markets, to manage risks of a stock portfolio but until today, spread contracts have not been utilized in the environmental context.

4.3 Government as environmental manager

Government currently plays a crucial role in managing environmental assets, in procuring environmental goods and services from landholders, and in imposing obligations on private parties to ameliorate environmental damages. It has many tools at its disposal to achieve outcomes and manage risks. We argue that the contracts described in this paper could become a valuable part of government's policy tool kit. Because of its pervasive role in environmental markets, we also argue that government has a role in facilitating the use of these contracts by private parties. By continuing to adopt input based contracts, governments may crowd out private risk management providers from the market such as weather contract providers. If participants can reduce, distribute and manage the risk they face, output based contracts have the potential to improve the efficiency of environmental production, and to achieve greater environmental outcomes at lower cost. We also acknowledge that it is not feasible for such contracts to become standard practice immediately. Rather, we suggest a gradual but deliberate approach to their use. We characterise this gradual approach in the four steps below. We then go on to elaborate on how government may recast the way it undertakes environmental management.

Step 1: reduce measurement risk and production risk.

The reduction of these risks to a tolerable level (i.e. where the marginal cost of reducing the risk is equal to the marginal benefits of reducing it) is crucial to the adoption of output based contracts. Output based contracts are themselves a pre-requisite for a large proportion of the contracts discussed in paper.

Step 2: adopt flexible contract forms.

Contracts that allow for some tolerance of measurement and production risk (such as options and spreads) become feasible once measurement and production risk have been reduced. A premium is paid for a more certain environmental result; encouraging producers to bear and manage risk.

Step 3: widespread use of output based contracts alongside other contract forms.

Output based contracts become standard practice in environmental markets. Parties to transactions utilise a range of contract forms to manage their risks.

Step 4: recast the role of government as a manager of environmental outcomes.

Government recasts the role of an environmental manager to enable the use of a range of contracts to achieve efficient outcomes and in response to changing circumstances.

In Section 4.1 we concentrated on the applications of contracts currently used in financial markets by producers of environmental goods and services. We now turn to the implications of these contracts for how government might eventually discharge its environmental responsibilities.

How government might use these contracts is likely to differ from how landholders might use them. Government has different objectives and may be affected differently by risk. For example government may be better able to aggregate and spread localised exogenous environmental risks than individual landholders. At the same time, whilst put options allow flexibility for landholders, these contracts do not guarantee that specific environmental objectives are achieved (e.g. that a threshold level of EB is achieved or the overall environmental quality is maintained across a region). Futures contracts offer more certainty to the government as the landholder is obliged to deliver the environmental outcome by the contract expiry date. This means the landholder may have to enter the market as a buyer in order to 'make good' the environmental contract. This also relies on government enforcing its contracts with landholders. If it is in any way reluctant to do so the benefits of these contracts decline. An independent authority tasked with achieving outcomes may be better placed than government to make use of contracts that require enforcement.

There are various exogenous events (e.g. bushfires) that may require the government to speedily recover losses. In order to have a stock of environmental outcomes on 'stand-by', the government may enter into a call option contract with landholders for the delivery of environmental outcomes. This type of contract requires the government to pay a premium to the landholder to be prepared to sell environmental outcomes when required but gives government flexibility in making the decision to call upon them.

For example, the government may be concerned with the biodiversity loss resulting from a bushfire but equally concerned with the consequences of a possible drought on aquatic functions. The probability of occurrence of either a fire or a drought (or both) is not known with certainty. In order to prepare for the possible events, the government may decide to pay a premium to a landholder for biodiversity options and to pay a premium to another landholder who, if and when needed, can supply aquatic outcomes. If a bushfire occurs, the government exercises the biodiversity call option (i.e. purchases the biodiversity outcomes at the pre-agreed price). If on the other hand, drought occurs, the government exercises the aquatic call option (i.e. purchases the aquatic outcomes at a pre-agreed price). If neither of these events occurs the only loss to the government is the premium paid to landholders to be on "stand by". Both buyers and sellers know with certainty the price that is paid for the environmental outcomes delivered.

With this approach, both the landholder and the government have eliminated *price risk* and the government has an effective management tool to respond to *exogenous environmental risks* (i.e. only exercises the call option if the state of the environment changes such as a bushfire or drought). Hence these contracts are an effective risk management tool for government and could therefore become an integral part of its toolkit. The flexibility of these contracts is likely to become increasingly important as government faces the unknown but highly variable impacts of changes in the climate.

Environmental responsibilities that are currently informal could also be made formal with the use of environmental contracts. For example, landholders currently have 'duty of care' obligations (i.e. a minimum level of environmental management) that specify minimum standards of land management. There is, however, no incentive for landholders to improve environmental quality above this minimum.

Spread contracts could prove useful for the government to provide additional incentives to avoid deterioration in environmental outcomes whilst also providing positive incentives to improve quality. The government may decide on a 'spread' of the environmental outcome and the amount that is to be paid or received if the index measuring the outcome is to move out of the spread's upper or lower threshold. If the index increases beyond the pre-determined threshold by the end of the contract period, the landholder would receive payments from the government. If, however, the index falls below a predetermined threshold, the government would receive payments from the landholder. The upper threshold would represent the minimum environmental improvement that can be attributed with certainty to improvements and is well beyond measurement uncertainty. The lower threshold can be thought of as the minimum level of 'duty of care'.

This contract can easily be compared to a government policy that imposes a penalty on landholders for not meeting their 'duty of care' or minimum regulatory obligations and rewards landholders who exceed them. In this case the penalty is not fixed but is dependent upon the severity of the loss (penalty is paid per unit of loss) just as any payments the landholder receives for gains also depend on the extent of improvement. The contract could be constructed so that the per-unit payment is different depending on whether a biodiversity gain or loss occurs.

Spread contracts would allow governments to better tailor incentives to suit specific situations, depending on whether their priority is to encourage improvements or avoid degradation. The contract also allows for some natural variability in the environment to be incorporated by setting the lower threshold of the spread at a value that tolerates it. Another advantage of this type of contract is that no up-front premium need be paid by either party in the transaction.

The concept of a catastrophe bond could also be applied to assist managers of high value natural assets to deal with *exogenous environmental risk*. Consider the manager of a National Park who faces heavy costs to rehabilitate a popular tourist destination after a natural event such as a cyclone, fire, flood or storm. A catastrophe bond would provide this National Park manager (or their insurer) access to funds to assist in the rehabilitation of the Park in the same way they provide insurance companies access to capital to fund their liabilities. These contracts could also play a significant role in managing climate generated *exogenous environmental risk* as climate change is expected to increase the frequency and severity of extreme weather events.

5 Conclusions

Improvements in science increasingly allow us to measure and predict aquatic and atmospheric pollution levels, biodiversity, and other environmental outcomes of interest and to understand their importance for a healthy and productive society. At the same time new types of contracts are required to facilitate the emergence of market-based approaches to these problems such as emissions trading and offset schemes. Such contracts are a crucial part of a well-functioning market. They enable participants to effectively reduce, distribute and manage a variety of risks inherent in the production and exchange of all goods and services, including those in environmental markets.

This paper has considered the role that futures, options, spread contracts, weather contracts and catastrophe bonds can play in the development of more sophisticated and efficient environmental markets. It has given a snapshot of some relevant existing applications and posited some uses in reducing, distributing and managing several types of risk in environmental markets. Specifically, this paper has discussed *measurement risk, production risk, moral hazard risk*, *price risk* and *exogenous environmental risk* in environmental markets.

In the foreseeable future, government will continue to play a significant role in environmental markets. The above-mentioned environmental contracts may enable government to undertake its role with greater flexibility and precision and at a lower cost. Unlike in regular markets, where new types of contracts emerge through private innovation, in the environmental sector government may need to take, at least in the short term, a lead in facilitating the development and providing a regulatory framework for these new types of contracts. Access to a range of products that enable producers to manage their risks should reduce costs of participation. This may increase the viability of environmental production for private firms and in doing so deepen existing markets for environmental services. This may be a necessary condition for producers to see production in the environmental sector as a viable alternative to more traditional markets.

This paper advocates a staged approach to the introduction of the contracts described in previous sections. As a first step, we stress that addressing production and measurement risk is important. Second, flexible contracts such as options and spreads can be explored and trialled. Third, output based contracts can be trialled alongside mechanisms such as weather derivatives and CAT bonds. Once these contracts have become standard practice, government can recast the role of an environmental manager to achieve outcomes efficiently in response to changing circumstances.

6 References

Bardsley P., and Burfurd, I., (2009), Contract Design for Biodiversity Procurement, Paper presented at 2009 Australian Association of Agricultural and Resource Economics, Cairns, Australia.

Collins, D. and M. Scoccimarro (2008). Market-based Instruments Decision Support Tool. Market-based Instruments Capacity Building Programme, Market-based Instruments Pilot Programme and the National Action Plan for Salinity and Water Quality, Department of Natural Resources and Water, Brisbane, accessed from: http://www.marketbasedinstruments.gov.au/Portals/0/docs/Metric%20literature%20summary%20final%20web.pdf, August 2010.

Dutton, J.A. (2002), 'Opportunities and priorities in a new era for weather and climate services', Bulletin of the American Meteorological Society, 83(9).

Gorddard, R., Whitten, S., Stevens, D., Knight A , 'Designing auctions with outcome bonuses: An application to ground nesting birds in the Murray Catchment, Final Project Report for the National Action Plan for Salinity and Water Quality under the National Market Based Instruments Pilot Program June 2008

Hafi, A., Beare, S., Heaney, A.,& Page, S. (2005) Water options for environmental flows ABARE eReport 05.12, Prepared for the Natural Resource Management Division, Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, November.

Hansen, K., Howitt, R., & Williams, J. (2008), 'Valuing risk: options in California water markets', American Journal of Agricultural Economics, 90(5), DOI: 10.1111/j.1467-8276.2008.01227.x

Houthakker, H. S. and P. J. Williamson (1996). The economics of financial markets, Oxford University Press, US.

Mandel, J.T., Donlan, C.J., & Armstrong, J. (2009) 'A derivative approach to endangered species conservation', Frontiers in Ecology and the Environment, 8(1) 44–49, doi:10.1890/070170.

Michelsen A.M., & Young, R.A. (1993), 'Optioning Agricultural Water Rights for Urban Water Supplies during Drought', American Journal of Agricultural Economics, 75(4).

Zeng, L.Z. (2000), 'Pricing weather derivatives', Journal of Risk Finance, 2.