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PART II

Chapter 10

Quasi-option value

Another aspect of uncertainty is quasi-option value (QOV) where the notion of precaution is made more formal. Again the starting point here is that costs and benefits are almost never known with certainty. But the insight in QOV is that uncertainty can be reduced in some situations by gathering information. Any decision made now which commits resources or generates costs that cannot subsequently recovered or reversed is an irreversible decision. In this context of both uncertainty and irreversibility it may pay to delay making a decision to commit resources. The value of the information gained from that delay is the QOV. This chapter explains how QOV arises, what it adds to the approaches outlined in Chapter 9 and addresses some of the terminological issues that have arisen in the literature. The concept of QOV can make a significant difference to decision-making especially as it serves as a reminder that such decisions should be based on maximum feasible information about the costs and benefits involved, and that includes "knowing that we do not (currently) know". If this ignorance cannot be resolved then there is nothing to be gained by delay. But if further information can resolve it, then delay can improve the quality of the decision. How large is this gain is an empirical question.

10.1. Some terminology

Intuitively, most people would argue that a decision that involves the irreversible loss of an asset should be made more cautiously than one where the asset is lost but can be recreated if it is later judged that there has been a mistake. The argument seems especially relevant when there is uncertainty about the future benefits of the asset. Environmental assets are good examples of assets about which we have only limited information: for example, many millions of species have not been screened for their full information, no-one is sure what exists in the canopy of rain forests, or in coral reefs. In such contexts, the CBA rules do not seem quite appropriate: benefits are uncertain, their loss may be irreversible and the scale of the loss could be substantial. CBA appears to ignore the combination of uncertainty and irreversibility. There may also be irreversibility on the cost side. We can imagine an investment decision that requires us to commit resources to the investment such that, if conditions change, there is little or nothing to be done to reverse the investment costs. This will be the case, for example, with "dedicated" investment expenditures – expenditures on capital equipment which has only one specific use and which cannot be readily converted to other uses. In the natural resources literature, the example of fishing fleet investments is often cited. So, both benefit streams and investment or policy costs may be irreversible.

In fact the CBA decision rule can be reformulated to take account of the combination of uncertainty and irreversibility, so long as there is also a third element present – the opportunity for learning more, i.e. gathering new information.[1] This involves the notion of *quasi-option value* (QOV), which was introduced and developed by Arrow and Fisher (1974) and Henry (1974). QOV is the value of information gained by delaying a decision to commit to some irreversible action. Confusingly, in the financial and investment literature, a related concept is called *option value*, or *real option value* (Dixit and Pindyck, 1994). Traeger (2014) shows formally that these two concepts – QOV and "real" OV – are distinct but relate to one another in a demonstrable way.[2]

It is important also to distinguish both these concepts from yet another notion of OV in the environmental economics literature. This latter concept is the difference between *option price* and the *expected value of consumer's surplus*. Option price is the maximum willingness to pay for something in a risky world in which one does not know for sure what the outcomes will be. Option price is an *ex ante* concept, i.e. a willingness to pay know for a future state of affairs which is uncertain. This option price can differ from the expected value of the consumer surplus, and the difference is known as option value. Note that option price and option value arises in contexts where individuals are risk-averse. As we shall see, QOV arises in contexts of both risk aversion and risk neutrality. In general:

$$OP = E(CS) + OV$$

Technically, OV can be positive or negative. In other words, using E(CS), which is what CBA does in practice, could introduce an error in CBA estimates. The problem is that OV cannot be estimated without some knowledge of the underlying structure of preferences of

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the individuals in question (their *utility functions*). In practice, it is unclear that the error is significant, i.e. making assumptions about the nature of preference structures, the evidence suggests that no major errors are introduced by using E(CS) alone.

This notion of OV is not considered any further here. It may be important in some contexts, but the focus is on the QOV = real OV concept since this is more likely to affect the way CBA is conducted.

To summarise:

1. OV in environmental economics tends to refer to the difference between option price and the expected value of consumer's surplus
2. QOV in environmental economics refers to the value of information secured by delaying a decision where outcomes are uncertain, where one or more benefits (or costs) is uncertain, and where there is an opportunity to learn by delay.
3. OV or real OV in the financial literature refers to the value of information secured by delaying uncertain and irreversible investments, although in somewhat different ways.

10.2. A model of QOV[3]

Most expositions of the QOV concept are intricate and involved. Here we attempt to understand the basics.

Consider a forested area which can either be preserved or converted to, say, agriculture. Call the conversion process "development". Let the current period be 0 and the future period be 1, i.e. for simplicity, there are just two periods. It is immediately obvious that if the forest is converted now, period 0, it cannot be preserved in period 0 or in the future period 1. But if the forest is preserved now it still leaves open the choice of converting or preserved in period 1. Suppose that the agricultural development benefits are known with certainty, but the preservation benefits are not known with certainty. This seems fairly realistic – we can be fairly sure what the forest land will produce by way of crops but we still do not know much about the nature and value of ecological services from forests. By converting now, certain benefits of D_0 and D_1 are secured (D_0 and D_1 can be thought of as present values). By preserving now, there is a conservation value of V_0, plus an uncertain conservation value of V_1 in period 1. Keeping the analysis simple, let these uncertain values in period 1 be V_{high} and V_{low}. V_{high} might correspond to some very valuable genetic information in the forest. V_{low} would arise if that information turns out to be very much less valuable. Let the probabilities of V_{high} and V_{low} be p and $(1 – p)$ respectively. The expected value (i.e. probability weighted) of preservation benefits (EP) in both periods, arising from the decision to conserve now, is therefore:

$$EP = V_0 + pV_{high} + (1-p)V_{low} \qquad [10.1]$$

A moment's reflection shows that if the forest is converted in 0 the expected value of development benefits will be the same as the certain value of the development benefits:

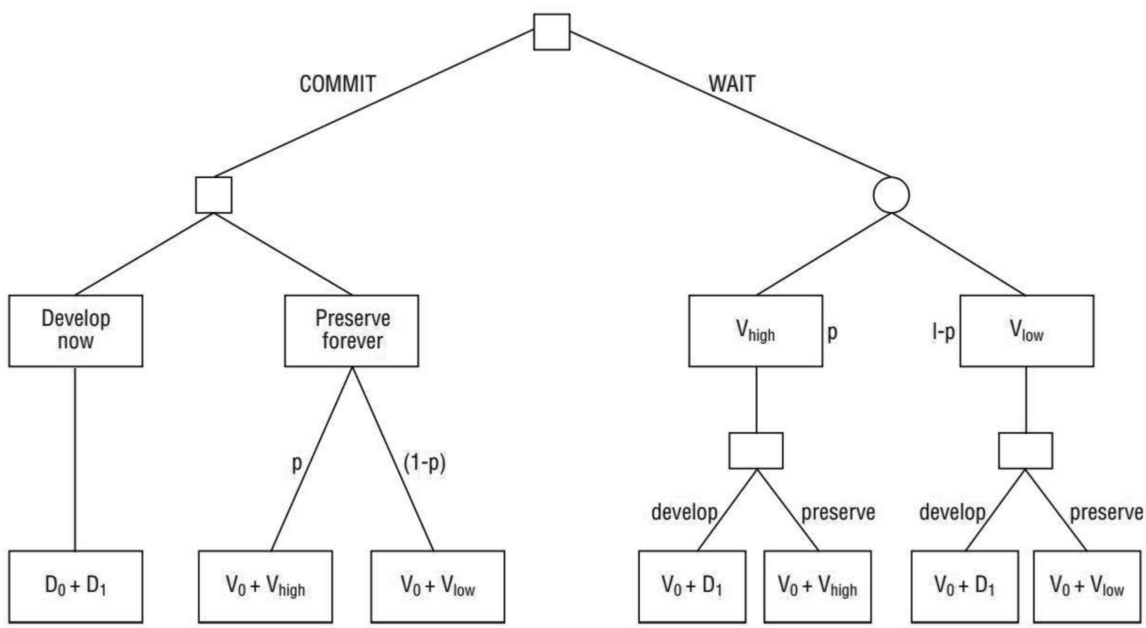
$$ED = D_0 + D_1 \qquad [10.2]$$

If the decision to preserve or develop has to be taken now, then a simple comparison of [10.1] and [10.2] will suffice. Thus, the forest would be developed if:

$$ED > EP, or, [D_0 + D_1] > [V_0 + pV_{high} + (1-p)V_{low}] \qquad [10.3]$$

This is how most cost-benefit studies would proceed: the expected value of the development (which, in this case, is certain) would be compared with the expected value of preservation. The relevance of QOV is that it changes the cost-benefit rule by allowing for postponing a decision. While political factors may dictate an immediate decision, it is often possible to postpone decisions, i.e. to wait before making the final choice of preservation or development. To see the possible choices, it helps to construct a *decision tree* such as the one shown in Figure 10.1.[4] A decision tree shows each stage of the decision process assuming certain events occur and certain choices are made. In Figure 10.1 the "trunk" of the tree is connected to various "branches" via *decision nodes* (marked as a square) and *probabilistic occurrences* (marked by circles). The analysis begins with a decision node which is either to decide now ('commit') or wait. The decision to commit involves either developing now or preserving now and forever. If the choice is to develop, then the outcome is clearly net benefits of $ED = D_0 + D_1$. If the choice is to preserve then the expected value of benefits is $EP = V_0 + pV_{high} + (1-p)V_{low}$. In other words, committing now is formally equivalent to the comparison of the two expected values, which we noted was how cost-benefit analysis normally proceeds.

Figure 10.1. **A decision tree**



Now consider the decision to wait. This involves moving down the right hand side of Figure 10.1. Waiting means that the decision to develop or preserve is postponed until period 1. Benefits of V_0 this occur in period 0. What happens next depends on whether "high" or "low" preservation benefits occur. Under either scenario, the decision is whether to preserve or develop in period 1. Hence there are 2 x 2 possibilities: if the high preservation benefits occur, developing in 1 will produce a sequence of $V_0 + D_1$ and preserving will produce sequence $V_0 + V_{high}$; if the low preservation benefits occur, the two sequences will be $V_0 + D_1$ and $V_0 + V_{low}$. Notice that we have ruled out the option of development in 0 and preservation in 1. This is because development is regarded as being *irreversible*: once it occurs, it cannot be reversed. This is a useful way of thinking about many problems, but, in practice, there are many gradations of irreversibility. The destruction of a primary forest

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through agricultural conversion does not, for example, necessarily rule out the recreation of a secondary forest which may well look just like the lost primary forest, although with different ecological features. And, one day, the *Jurassic Park* scenario of recreating extinct species may be realisable.

To see which option is best – from the point of view of expected values – it is convenient to attach some hypothetical numbers to the probabilities and outcomes in Figure 10.1. This avoids "getting lost" in the elaborate equations that otherwise emerge.

Let: $V_0 = 20, V_{high} = 300, V_{low} = 40, p = 0.4, (1-p) = 0.6, D_0 = 60, D_1 = 120.$

Compare waiting and committing. Waiting entails

[a] $V_0 + D_1 = 20 + 120 = 140$, or

[b] $V_0 + V_{high} = 20 + 300 = 320$, or

[c] $V_0 + V_{low} = 20 + 40 = 60$

Committing entails

[d] $D_0 + D_1 = 60 + 120 = 180$, or

[e] $V_0 + V_{high} = 20 + 300 = 320$

[f] $V_0 + V_{low} = 20 + 40 = 60$

Note that outcomes [e] and [f] are the same as outcome [b] and [c].

Which is the best decision? The analysis needed to answer this question is in two stages. Ultimately, the optimal choice requires a comparison of the expected values obtained by committing to immediate development (ED), the expected value obtained by immediately committing to preservation for all time (EP), and the expected value obtained by waiting (EW). However, to calculate EW we must first consider the optimal course of action after we decide to wait. What is the best decision after deciding to wait? It depends on whether V_{high} or V_{low} occurs. If V_{high} occurs, the decision should be *wait and preserve* because 320 > 140, but if V_{low} occurs the decision should be *wait and develop* because this decision produces 140 compared to 60 from wait and preserve. But how do we know if high or low preservation values will emerge? The point about waiting is that it gives us the chance to *find out* which of the two preservation values will occur. Put another way, waiting (postponing) generates *information* and this information can greatly improve the efficiency of decision-making: it reduces the uncertainty of the benefits of preservation. QOV links these important features of decision-making in many environmental contexts:

a) uncertainty

b) irreversibility

c) waiting and learning.

Notice throughout that the decision rule is still based on expected values.

It is often argued that decisions about global warming control should be postponed because the science of global warming is advancing rapidly. Postponing decisions could prevent the irreversible commitment of resources to controlling global warming, resources that could be used perhaps to more social benefit elsewhere. Control decisions could be made later when information has improved. In fact the global warming context is more complex than this. While decisions are postponed, and if warming is a proven fact, then warming increases and any damage associated with it increases. Hence it is necessary to build into the decision tree the likelihood that the waiting option will increase damage if warming turns out to be a genuine phenomenon. There are two irreversibilities here –

unrecoverable costs of action, and irreversible warming. The decision theory approach appears capable of making allowance for this aspect of the decision. The other feature of global warming is that we have very little idea of the probabilities of the outcomes. For example, catastrophic events may be uncertain in their scale, the probability of their occurrence and the time when they might occur. Hence decision making may have to take place in the context of "pure uncertainty", uncertainty associated with no known probabilities. Even here, waiting may enable better information about those probabilities to be revealed, so the QOV framework remains relevant if this is the case.[5] Overall, it should be easy to see that QOV approaches improve the decision-making procedure compared to the simplistic comparison of expected values of costs and benefits in the "no waiting" – i.e. commitment – case. How far such approaches encompass the full range of problems embraced by uncertainty and irreversibility remains open to question, however.

It is possible now to write an expression for the expected value of waiting (EW). This is:

$$EW = V_0 + pV_{high} + (1-p)D_1 \quad [10.4]$$

To understand this expression, inspect Figure 10.1 again. EW is the value of waiting in period 0 and then choosing the best option in period 1. Waiting clearly secures V_0 in period 0. The numerical example tells us that $V_{high} > D_1 > V_{low}$. V_1 is random – it can be "high" or "low" – and is the value of preservation in period 1. If high preservation values occur we opt for preservation because $D_1 < V_{high}$. If "low" preservation values occur, we develop anyway since $D_1 > V_{low}$. is the weighted average of the high preservation value and the development value: $pV_{high} + (1-p)D_1$ which, when added to V_0 in period 0 gives the expected value of waiting shown in [10.4].

In terms of the numerical values in the hypothetical example, we have:

$$EW = 20 + 0.4(320) + 0.6(140) = 232$$

The value for $EW(232)$ is higher than the value for

$$EP = V_0 + pV_{high} + (1-p)V_{low} = 20 + 0.4(320) + 0.6(40) = 172.$$

Hence, in this example, $EW > EP$. In fact, it is always better to wait than to commit to preservation forever, so long as $D_1 > V_{low}$. This is because by waiting one can always secure the value of *EP* since waiting involves preservation in period 0 and this leaves open the option of preserving in period 1. Thus waiting allows a flexible choice: preserve in period 0 and preserve in period 1, and preserve in period 0 and develop in period 1.

The previous argument establishes that, under the conditions stipulated, it is better to wait than commit forever to preservation. What of waiting versus outright development? This requires that we compare *EW* with *ED*. We know that *EW* = 232 and $ED = D_0 + D_1 = 180$, so the expected value of waiting exceeds the expected value of outright development.

There are now two "rules" by which development and preservation can be compared. The first emerges from the previous analysis, the second from the conventional cost-benefit approach. Immediate development is justified if either $ED > EW$ or $ED > EP$. As long as $EW > EP$, the former rule will be harder for an advocate of development to meet. *Thus, allowing for waiting makes the irreversible development option more difficult to achieve (recall that "conventional" CBA would simply compare ED and EP).*

The final stages of the analysis permit us to identify the meaning of QOV more precisely. First, we rewrite *EW* as:

$$EW = V_0 + EV_1 + E\max(D_1 - V_1, 0) = EP + E\max[D_1 - V_1, 0] \quad [10.5]$$

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The proof of this is shown in the Annex to this chapter. The term $E\max(D_1 - V_1, 0)$ is to read as follows: it is the expected value of the maximum of $D_1 - V_1$ and 0 as seen from the standpoint of period 0. So, if $D_1 - V_1$ exceeds zero, the expected value of this is entered into equation [10.5] (recall that we do not know V_1 when in period 0, so it is random. We do know it when we move to period 1).

The condition for developing the land immediately was that $ED > EW$ and we observed that this was a stricter condition than simply comparing the two expected values of development and preservation, as would be the case in the conventional cost-benefit case. We can rewrite the condition $ED > EW$ in terms of the expression for EW in [10.5], so that development immediately is only justified if:

$$(D_1 + D_2) > EP + E\max(D_1 - V_1, 0) \quad [10.6]$$

In slightly different form, this is the equation derived in Arrow and Fisher (1994).

Since a lot of derivation has been presented, it is well to summarise the basic finding:

1. "Conventional" cost-benefit analysis would follow a rule that, for development to be justified, $ED > EP$;
2. The "options" approach requires a stricter rule, namely that $ED > EW$
3. EW and EP differ by an amount $E\max(D_1 - V_1, 0)$
4. So EP *understates* the "true" value of preservation by the amount $E\max(D_1 - V_1, 0)$

How should QOV be interpreted? In some analyses QOV would be identified with the last expression above – i.e. $E\max(D_1 - V_1, 0)$. *But it is more precise to think of QOV as the increase in expected value of benefits from waiting*. The expression for this would be:

$$QOV = EW - \max(ED, EP) \quad [10.7]$$

That is, QOV is the difference between the expected value of waiting and whichever is the larger of ED and EP. Equation [10.5] implies that if $ED < EP$ then QOV and $E\max(D_1 - V_1, 0)$ are the same. But if, as in the example above, $ED > EP$ then QOV is *less* than $E\max(D_1 - V_1, 0)$.

10.3. How large is QOV?

In some ways, asking about the "size" of QOV is not very sensible. What matters is whether consideration of waiting and learning will change the nature of the decision made to commit resources to some policy or project. If that process results in a changed decision relative to the "baseline" of making decisions as if delay was not an option, then QOV may be large relative to the resources committed to the decision. It is in this sense that the financial literature argues that what we have called QOV, and what in that literature is known as the value of an option[6], can be large (Dixit and Pindyck, 1995). In the financial literature, investing irreversibly "kills" the option because the decision cannot be reversed and the option of waiting for new information is also forgone. As a result:

> This lost option value is an opportunity cost that must be included as part of the cost of the investment (Dixit and Pindyck, 1994, p. 6).

Finding examples of estimated QOV in environmental economics applications is far harder. Box 10.1 outlines one study of forest conversion. Wesseler (2000) has suggested that QOV has a positive value in the context of postponing the introduction of genetically modified farm crops in Europe.

The discussion should be sufficient to underline an important feature of QOV: *it is not a component of total economic value (TEV)*. Rather, it is a reminder that decisions should be

Box 10.1. **The empirics of quasi option value**

It is not hard to envisage a range of environmental and resource concerns in which "quasi option value" (QOV) is both relevant and potentially significant. A natural question to ask then is the extent to which QOV can be demonstrated to be empirically important. A handful of studies have sought to answer this practical question. One early example was Bulte et al. (2002) for tropical forests in Costa Rica. Their empirical estimate of QOV illustrates that uncertainty about forest values justifies more forest conservation than in the case where values are known with certainty. Nevertheless, the authors also find that QOV turns out to be considerably less empirically important for the forest conservation/agricultural conversion decision than sorting out more conventional valuation issues, such as valuing global externalities and making judgements about the rising relative valuation of ever more scarce forestland.

Unfortunately, there seems to be a lack of evidence to consider further whether this is a general finding or not (although it is consistent with an even earlier result in Albers et al., 1996). Other studies have sought to throw light on the empirical significance of QOV (or related concepts) by looking how this influences people's willingness to pay (WTP) for environmental improvements both in theory and by testing this in practice. For example, Zhao and Kling (2009) examine the conceptual consequences of acknowledging that real world policy settings are often dynamic in the sense that there is potential to delay a decision (e.g. a policy to deliver an environmental improvement) and learn about the future. The point is that this opportunity for learning is a tangible characteristic of the decision of how much a person would be willing to pay. Specifically, enjoying the improvement now provides people with a benefit sooner rather than later but it also entails what Zhao and Kling denote as a "commitment cost": i.e. a parallel concept to QOV in this WTP application of the theory. Put another way, people sacrifice the ability to learn about whether the policy change is worthwhile to them or not. The practical consequence of this is a prediction about WTP. For example, in a stated preference survey, asking people for their WTP to receive this environmental improvement sooner rather than later – and where there is uncertainty and the potential for learning – the amount elicited implicitly will reflect a "discount" reflecting the respondent's valuation of the "commitment cost". Put another way, total WTP for this policy change will be lower than in the case where there is no scope for learning; the reason being that in the context of learning there is a lost opportunity that the respondent, in effect, is being asked to give up.

Teasing out this component of WTP is a useful means of assessing the extent to which QOV is important to people in different policy settings. Corrigan et al. (2008) use contingent valuation (or CV, see Chapter 4) to do just this for the case of local water quality improvements in Clear Lake, Iowa in the USA. What this application did is examine the (implied) compensation that respondents require in order to consume the environmental good now, rather than delay this decision for a further year in order to learn more about the consumption value of specified improvements at Clear Lake. In other words, this was a test of whether people were willing to pay less to enact water quality improvements now given that it involves sacrificing this learning opportunity. Notwithstanding a rather small sample (N=158), the results of this study indicate that the "commitment cost" is more than 75% of total (average) WTP for options to improve water quality at Clear Lake.

Strazzera et al. (2010), in a similar vein, use a discrete choice experiment (DCE, see Chapter 5) to assess the value that respondents, drawn from residents of an urban area on the island of Sardinia in Italy, place on improvements to a nearby coastal wetland. Where respondents were told that there exist opportunities for further learning about the "scientific" and "cultural" value of the wetland, they appear to place a significant premium on such options in the choice sets with which they were confronted. That is, WTP is higher for those wetland improvement options which take a cautious approach and seek to avoid irreversible consequences of acting "now" without further information about the consequences of this.

made rationally. Despite this, QOV often does appear in the literature as if it is a component of TEV. This is not correct. Freeman et al. (2013) sums it up well:

> Quasi-option value is not a component of the values individuals attach to resource changes. Even if individuals' utility functions were known, quasi-option value could not

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> be estimated separately and added into a benefit-cost equation. Quasi-option value is a benefit of adopting better decision-making procedures. Its magnitude can only be revealed by comparing two strategies where one of the strategies involves optimal sequential decision making to take advantage of information obtained by delaying irreversible resource commitments. The decision maker who knows how to use an optimal sequential decision making strategy has no reason to calculate quasi-option value. The calculation would be redundant because the best decision is already known. (pp. 250-1).

10.4. Conclusions

The notion of quasi option value was introduced in the environmental economics literature some three decades ago. In parallel, financial economists developed the notion of "option value". Somewhat confusingly, environmental economists also developed a concept of option value that was unlinked to either QOV or the OV of the financial literature. In the end, QOV was recognised as being the same as the financial literature's OV.

QOV is not a separate category of economic value. Rather it is the difference between the net benefits of making an optimal decision and one that is not optimal because it ignores the gains that may be made by delaying a decision and learning during the period of delay. Usually, QOV arises in the context of irreversibility. But it can only emerge if there is uncertainty which can be resolved by learning. If the potential to learn is not there, QOV cannot arise.

Can QOV make a significant difference to decision-making? Potentially, yes. It is there to remind us that decisions should be made on the basis of maximum feasible information about the costs and benefits involved, and that includes "knowing that we do not know". If this ignorance cannot be resolved then nothing is to be gained by delay. But if information can resolve it, then delay can improve the quality of the decision. How large the gain is from this process is essentially an empirical question since QOV is the difference in the net benefits of an optimal decision and a less than optimal one. The financial literature suggests that this difference can be large relative to the scale of resources being committed to a decision. Further study is needed in the environmental context to see if similar results hold. Examples to date are limited.

Notes

1. Which is the more important of these features is open to debate. Some have argued that it is uncertainty and the opportunity for learning that matter most and that irreversibility is a limited consequence. Nonetheless, the literature has generally proceeded on the basis of there being irreversibility in either the commitment of resources or some of the benefits forgone.
2. Specifically, Traeger (2014) notes that QOV represents the value of learning if a project is postponed and that "real" OV is the net value from postponing a project when there is learning, with slightly different implications for going about changing the standard net present value rule in CBA.
3. This section has been adapted from material kindly supplied by Dr. Joseph Swierzbinski of the Department of Economics, University College London and largely comprises a simplification of the original article by Arrow and Fisher (1974).
4. Decision trees are one of the basic constructs of *decision analysis* (e.g. see Merkhofer, 1987).
5. Dixit and Pindyck (1994, pp. 395-6) advocated the use of their "real options" approach to global warming policy evaluation. For an application, see Ulph and Ulph (1997).
6. There are also analogies with financial call options in the financial literature – see Dixit and Pindyck (1994).

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ANNEX 10.A1

Deriving the expected value of waiting

Equation [10.5] in the text was written as

$$EW = V_0 + EV_1 + E\max(D_1 - V_1, 0) = EP + E\max[D_1 - V_1, 0] \qquad [10.A1.1]$$

This is derived from the first expression for EW (equation [10.4] in the text) as follows:

$$EW = V_0 + pV_{high} + (1-p)D_1 \qquad [10.A1.2]$$

Add $(1-p)V_{low}$ and then subtract it from [10.A1.2] to give

$$EW = V_0 + pV_{high} + (1-p)V_{low} + (1-p)(D_1 - V_{low}) \qquad [10.A1.3]$$

or

$$EW = EP + (1-p)(D_1 - V_{low}) \qquad [10.A1.4]$$

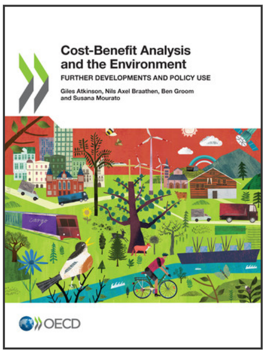
High preservation benefits occur in period 1 with a probability of p, so the maximum of $D_1 - V_1$ and 0 is 0 since the development value in period 1 is below the high preservation value. Low preservation benefits in period 1 occur with a probability (1-p) and the maximum of $D_1 - V_1$ and 0 is then $D_1 - V_{low}$ since the development value exceeds the low preservation value. Hence:

$$E\max(D_1 - V_1, 0) = (1-p)(D_1 - V_{low}) + p.0 = (1-p)(D_1 - V_{low}, 0) \qquad [10.A1.5]$$

Hence [A10.4] can be written:

$$EW = EP + E\max(D_1 - V_1, 0) \qquad [10.A1.6]$$

which is equation [10.5] in the main text.



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