Climate Change Capital
ThinkTank

Essays on information and climate change: why cap-and-trade systems don't lead to investment decisions

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As noted in the previous essay, tackling climate change is a capital mobilisation challenge. The extent of this capital intensity and its associated irreversibility merits significant further investigation. Here we will seek to explore how information, or the potential receipt of future information, can delay capital intensive investments and increase investment costs.

In particular we show how uncertain and information rich incentive regimes such as cap-and-trade systems may not affect investment decisions in the ways that policy-makers might hope and expect.

Delays to investment are created by the possibility of waiting, or put the other way around, by the opportunity cost of investing today being greater than the value of investing. In this essay we analyse this trade-off through the medium of option theory. We will show how the higher the information potential of a system, the higher the value of delay, and the higher the cost of investment.

We will also see that the actions of companies and individuals making investments provide us with observable action and information which is vital for improving climate policy design and mobilising the capital needed for the transition to a low carbon economy.

Derivatives

Let's be honest, much of the literature on derivatives is very hard to penetrate. There seems to be a desire on the part of authors to construct massive amounts of numerical and theoretical analysis when the beauty of derivatives is the clear insights that they give you into information flows, decision making and the relationship between economic agents[2].

When looking at derivatives it is important to differentiate the three main components of any such analysis. Behind the famous Black-Scholes-Merton[3] formula, for instance, and other derivatives models are three things. First, the general structure and properties of the derivative itself. Second, some assumptions about how the world works today. In the case of Black-Scholes-Merton these assumptions include the ability to trade the underlying security continuously in any quantum and without cost. Third, they make assumptions as to how the underlying securities behave in the future: in the case of Black-Scholes-Merton they assume that stock prices obey geometric Brownian motion, for instance.

Elegant formulas such as the Black-Scholes-Merton formula and less elegant numerical analyses created by vast numbers of computer simulations rely very heavily on certain, often unrealistic and arbitrary assumptions that fall in the second and third of these categories. Many texts on derivatives, therefore, spend inordinate amounts of time explaining things like stochastic calculus to the reader in order to lay the groundwork for the elegance of the final solution. It is this that makes thinking about derivatives inaccessible[4]. The Mathematical Appendix (to be published separately) for this essay has a lot of this, but in the main text we are going to stick to relatively simple mathematical formulations and we are also going to make it clear what assumptions are made and when. We are also going to use accessible numerical examples that people can relate to. I have roughly referenced my sources and the examples are realistic at the time of writing, but I have obviously manipulated the individual numerical examples in order to get the answer I am looking for. The formal and general proof of the answers can be found in the Mathematical Appendix.

References:

1. Ian Temperton is Head of Advisory at Climate Change Capital. From late 2009 to early 2011, he was a Visiting Business Fellow at the Smith School of Enterprise and the Environment at Oxford University. This is one of a collection of essays that are the result of his research during that time. I would like to thank everyone at the Smith School and Oxford (especially Cameron Hepburn) and those who have read early versions and provided comments. These include Rupert Edwards, Malcolm Keay, Rick Jefferys, Walt Patterson, Ben Caldecott and Robert Ritz. All errors and omissions remain entirely mine.
2. The two best texts for those learning and applying derivatives I would say are (Hull, 2003) and (Dixit & Pindyck, 1994) and these essays draw substantially on each.
3. See (Black & Scholes, 1973).
4. See (Dunbar, 2000) to observe how it can all go so wrong.

NewClear investment decisions

For the purposes of analysing an investment decision and illustrating the various effects of information on that decision to deploy capital, we are going to take a simple example: the replacement of existing traditional light bulbs with energy efficient ones. I am going to construct an artificial example in order for the analysis not to be clouded by too many facts.

Let us say that there is a new form of energy efficient light bulb, which in order to garner kudos with the early-adopter green-consumer segment of the marketplace has been branded the NewClear light bulb. As we noted in the previous essay, this will have a higher average to marginal cost ratio and because they are only of use as a light bulb there is a high degree of irreversibility associated with this investment.

Below are the parameters for the NewClear investment:

Parameter	Assumed value
Average UK domestic energy usage	4,196kWh/year
Lighting as a percentage of energy usage	19%
Claimed savings for energy efficient light bulbs over life of the bulb	£45 – 60
Number of bulbs in an average house	25
Price of power today	15p/kWh
Cost of a new conventional light bulb	£1
Cost of a new energy efficient light bulb	£20
Energy saving from using an energy efficient bulb	80%
Bulb lifetime	10 years

We are going to further assume that the appropriate cost of capital for an investment in NewClear is 10% and that the risk free rate in the relevant economy is 3%.

Using the above parameters we can deduce that the average traditional bulb in an average house uses about 31.9kWh/year[5] of energy and that the equivalent energy efficient bulb would use 20% of that or 6.4kWh/year[6]. This means that the energy saving from using a NewClear bulb instead of a traditional bulb is 25.5kWh/year (31.9 – 6.4).

Now let us assume that one of the traditional bulbs has failed and not having light in the future is not a viable option and so it needs replacing. In order to decide which bulb to invest in I can do a simple net present value (NPV) calculation of the two alternative ways of providing light. We will assume that the light has failed the moment following payment of the last electricity bill, which was issued and paid instantaneously at the end of the period to which it pertains[7]. We will also assume that the investment can be made instantaneously[8].

This table shows the total cost of light provision using a traditional bulb:

Element of lighting cost	Calculation	Cost
Cost of energy usage over lifetime	Present value at 10% of the energy usage of 31.9kWh/year at 15p/kWh over 10 years	£29.39
Cost of light bulb	Traditional light bulb	£1.00
Total cost of lighting	**Sum of above**	**£30.39**

References:

5. 4,196kWh/year of consumption times 19% divided by 25 bulbs.
6. 20% of 31.9 kWh/year.
7. This statement seems a little laboured but the timing of cash flows is really important in these kinds of analysis and all too often forgotten when such analyses are explained.
8. Not a bad assumption for a light bulb (takes me about an 30 minutes to get to B&Q and back, traffic permitting).

This table gives the same calculation for an investment in NewClear light bulb:

Element of lighting cost	Calculation	Cost
Cost of energy usage over lifetime	Present value at 10% of the energy usage of 6.4kWh/year at 15p/kWh over 10 years	£5.88
Cost of light bulb	NewClear light bulb investment cost	£20.00
Total cost of lighting	**Sum of above**	**£25.88**

We now have two sets of cash flows and their discounted values and we should choose the one that yields a positive net present value. In the case of the NewClear investment, this provides for a net present value of £4.51 (£30.39 – £25.88). The above two tables represent the present value or asset value of the stream of cash flows associated with initial investment and lifetime energy usage, and the difference between them is the asset in which I am really investing with this decision. The underlying asset of the light bulb investment is the difference between the energy cost of the traditional and NewClear light bulb.

Note the careful choice of words. You can only take a net present value of the difference between two sets of numbers, because a net present value is used to decide to do one thing or another as noted above. As we will see throughout this essay, a "no" decision is in itself a decision – it is a decision (usually) to delay.

You will also note in the above example that the ratio of energy usage over the life of the investment to the light bulbs themselves are very different for the traditional light bulb and the energy efficient NewClear investment (29x for the traditional light bulb versus 0.29x for the NewClear bulb[9]).

The above example implicitly assumes that I have as easy an access to £20 as I have to £1, or in other words that I am perfectly and costlessly integrated into a financial market which permits me limitless access to capital for rational decisions.

Now moving to a more complex example, let us assume that the traditional light bulb is working perfectly well, but that as a caring environmentally conscious consumer I have to decide whether to replace the traditional light bulb with a new one despite the old one working perfectly well. We must redo the calculations.

This table shows the total cost of continued light provision using a traditional bulb:

Element of lighting cost	Calculation	Cost
Cost of energy usage over lifetime	Present value at 10% of the energy usage of 31.9kWh/year at 15p/kWh over 10 years	£29.39
Cost of light bulb	Traditional light bulb (which is already owned)	£0.00
Total cost of lighting	**Sum of above**	**£29.39**

This table gives the same calculation for an investment in NewClear light bulb:

Element of lighting cost	Calculation	Cost
Cost of energy usage over lifetime	Present value at 10% of the energy usage of 6.4kWh/year at 15p/kWh over 10 years	£5.88
Cost of light bulb	NewClear light bulb investment cost	£20.00
Total cost of lighting	**Sum of above**	**£25.88**

References:

9. Based on the ratio of NPV of energy usage to NPV of initial capital investment.

As you can see, the net present value of the decision to replace the old light bulb with a NewClear one is still positive with a value of £3.51 (£29.39 – £25.88). For the quick-witted it was clearly always going to be £4.52 – £1.00, with £1.00 being the cost of the traditional light bulb[10].

So far we have used no derivative analysis and instead we have simply used the kind of net present value analysis which appears to be prevalent in all investment decision making in business, and on which policy-makers often rely for their decisions on policy frameworks in climate change investment and finance. However, we have implicitly assumed, in the last example, that we have no capacity to delay the investment, which as I have a perfectly well functioning light bulb is clearly wrong. We have also assumed that we are not aware of the prospect of any future information which might affect my decision making today. This again is wrong, and hence is where derivatives start to come into play.

NewClear options

Now let us assume that we have just read an article in an environmental magazine which assures me that NewClear investments will halve in value in a year's time (to £10 rather than the £20 that they cost today). This is obviously great news for the planet and for our finances. Let us assume that we treat this claim as being absolutely certain. What will this do to our investment decision?

If we make an investment in NewClear today we make £3.51 in net present value compared to doing nothing as we saw above.

This table shows the value of investing in one year's time:

Cost / benefit	Calculation rationale	Value in one year
Energy saving	25.5kWh/year at 15p/kWh saved discounted at 10% for a 10 year investment life	£23.51
NewClear light bulb	Cost of investment in one year's time	(£10.00)
Payment of one year's electricity	25.5kWh/year times 15p/kWh as payment for difference in energy usage between NewClear and traditional bulb	(£3.83)
Present value of bulb replacement in one year's time	Sum of the above	£9.68
Present value discounted to today	**Note that this is done at the risk free rate not 10% as we said we were certain we knew the future**	**£9.40**

The present value today of an investment in a year's time is £9.40 and the present value of an investment today is £3.51, and so the net present value of the decision to delay the investment for a year is £5.89 (£9.40 – £3.51) and hence that is what we should rationally do.

This table shows the sources of value in waiting for a year compared to investing now.

Part of investment decision	Value for investment today	Value today for investment in a year	Difference	Source of difference
Investment cost	£20.00	£9.71	£10.29	Reduced cost of bulb and delayed outlay of investment cost
Energy savings	£23.51	£22.83	(£0.68)	Delay in achieving energy savings
Payment for inefficient energy	NA	£3.72	(£3.72)	Have to pay for inefficient energy while waiting to change the bulb (discounted)
Total	**£3.51**	**£9.40**	**£5.89**	

References:

10. Please forgive a penny of rounding.

Hence the information that this investment will become cheaper in the future, causes the investment decision to be delayed, even in the case where we have no uncertainty and where the investment today has a positive present value.

Being a pioneer does you no good.

Now cost reductions are often dependent upon volume sales and hence there is a possibility that the decision to delay will influence future cost reduction. This is a major issue in incentive design, especially when learning curves and learning-by-doing are important supposed benefits of that incentive scheme.

In the above example we have introduced the possibility of delay in the investment in new lighting, but we have not introduced any uncertainty into the calculations yet. We have simply said that we have certain information about the future and that we have the potential to delay the investment.

Now we can finally introduce some uncertainty into the analysis. Our household is debating whether replacing the light bulb is rational given what might happen to future electricity prices. One half of the household believes that come next year domestic energy prices could have risen to 25p/kWh. The other half of the household believes that domestic electricity prices will have fallen to 5p/kWh by next year.

The halves of the household, while disagreeing, have decided that they are equally likely to be right, but also that no outcome other than the two described above will come to pass. Hence they have agreed that each of these scenarios has a probability of 50%.

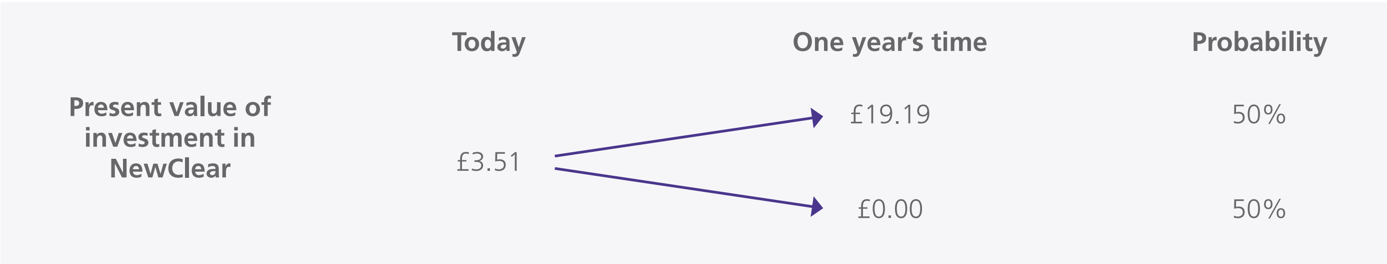
This progression of the power price is illustrated below:

	Today	One year's time	Probability
Power Price	15p/kWh	25p/kWh	50%
		5p/kWh	50%

Using the same calculations for energy saving as we have done previously we can illustrate the uncertainty in the value of the energy savings which come from replacing the light bulb in a similar way.

	Today	One year's time	Probability
Present value of energy savings	£23.51	£39.19	50%
		£7.84	50%

You will note in the above that in the case of a movement to low energy prices a NewClear investment clearly does not make sense anymore (£7.84 of present value of savings is less than £20 investment cost) and so in the case where we wait a year to see who in the household is right, then if the low energy price case is right no investment will be made. Hence we can illustrate the value of making a NewClear investment in each scenario in a similar format to the above (note we are back to assuming the cost of the NewClear bulb is £20 forever).



You will see that the above is simply the application of the formula (max[NPV Savings – Investment, 0]) or in other words: only make the NewClear investment if it makes sense at the time you make it.

From the above we can now calculate the value of waiting for a year to make the investment decision. In one year's time we will have an investment worth £19.19 with a probability of 50% or one worth zero with the same probability and hence this is worth £9.59 in a year (£19.19 x 50% plus zero x 50%) or £9.32 (discounted at the risk-free rate) today.

We will have to have paid for another year of inefficient energy which we know from the previous analysis has a present value of £3.72 and hence the net present value of waiting for a year to invest is £5.60 (£9.32 minus £3.72).

Given that the present value of an investment today is £3.51 then the net present value of the decision to wait a year is clearly positive and has a value of £2.09. The uncertainty of the future energy price causes us to delay the decision to invest in the light bulb, despite the fact that the present value of the investment is positive today.

The table below highlights the sources of the differences between the case of investing today and deciding to delay for one year.

Part of investment decision	Value for investment today	Value today for investment in a year	Difference	Source of difference
Investment cost	(£20.00)	(£19.42)	£0.58	Delayed outlay of investment cost
Energy savings	£23.51	£22.83	(£0.68)	Delay in achieving energy savings
Payment for inefficient energy	NA	(£3.72)	(£3.72)	Have to pay for inefficient energy while waiting to change the bulb (discounted)
Value of resolving uncertainty / value of information	NA	£5.90	£5.90	Ability to avoid investment in low price case
Total	**£3.51**	**£5.60**	**£2.09**	

What we can see from the above table is that the delay in investing means that future costs and future benefits are delayed (the first two lines above), that costs are incurred in the intervening period (the third line), but that uncertainty is resolved (the fourth line), and that the value of uncertainty exceeds the loss in value of benefit foregone and interim costs incurred.

In other words, future uncertainty has caused us to delay an investment decision despite the fact that the investment has a positive net present value today (£3.51 in this case) and the fact that not investing causes us to lose the time value of that benefit (in this case £0.10[11]). This is because delaying the decision in order to achieve resolution of the uncertainty has a benefit of £5.90.

Uncertainty is basically the knowledge that the investment parameters might change in the future. At present, in the above example, there is a wide range of known future parameters, and information arrives in the future which reduces that uncertainty. In our example, the value of that future information, in fact the value of that information exceeds the other costs of delaying the investment.

References:

11. £0.68 - £0.58 in the above table for those who didn't spot it.

Going back to the more established language of derivatives: the option to invest in the future has a value in excess of the investment today; or the opportunity cost of investment exceeds the value of investment today. We can express the value of an option generally in the following way:

Option Value = Intrinsic Value + Time Value of Delay + Information Value[12] + Real Cost of Delay[13]

Hence it is possible to re-present the above table in a way which is more relevant to option theory and which shows the true value of the option to invest.

Option Value Component	Previous Presentation	Calculation	Value
Intrinsic Value	Value of investment if made today	Value of savings today minus investment cost £23.51-£20.00	£3.51
Time Value of Delay	Delay in savings and delay in investment	Delay in achieving savings minus delay in having to invest money	(£0.10)
Real Value of Delay	Payment for inefficient energy	Discounted value of payment for inefficient energy	(£3.72)
Information Value	Value of resolving uncertainty	Avoided downside investments	£5.90
Option Value			**£5.60**

Note that the option to invest is worth £5.60. The intrinsic value is £3.51 and hence the net present value of the decision to wait is the difference between these, which is £2.09. Note also that in the case of an option with a positive intrinsic value, whether one invests today or delays, is a trade off between the Time Value, the Dividend Value and the Information Value. In our case the Information Value exceeds the Time Value and Dividend Value losses by £2.09.

We have used NewClear investments as a case study in the properties of an investment decision and the impacts which various parameters have on it. We have observed the following through this example:

- Where the investment must be made and there is no possibility of delay, then a simple net present value comparison of the two options is appropriate;
- Waiting can create a positive net present value in the case where everything is certain, and we have certain information that the investment costs will fall in the future;
- Uncertainty (the prospect of information which resolves uncertainty in the future) as to outcomes creates option value, which can again cause there to be a net present value associated with waiting;
- The decision to invest today or wait is a trade off between the time value of delay, the real value of delay and the value of future information.

The Mathematical Appendix to this essay deals with much of the formal mathematical development of option theory, both to prove the above characteristics in generality and to develop some more concepts and solutions, that for the purposes of the rest of the body of the essay will simply be asserted.

References:

12. Options experts will probably more commonly see this referred to as uncertainty value or even option value.
13. Options experts will understand this better as the dividend yield on the underlying asset which in this case is the cost of inefficient energy use during the delay.

Further option insights

We have seen from the above examples that the decision as to whether to invest today or in the future is a trade off between the costs and benefits of delay. The most substantial benefit of delay being the value of future information and hence the reduction in uncertainty under which the investment is made.

In the above examples we have implicitly assumed that the only times at which we can make the investment are today or in a year's time. In reality of course, for a light bulb replacement, an investment in a wind farm, solar farm, wall insulation or many other things in the energy system, we have a running indefinite option to make the investment decision or not. Hence in reality what I should have done in the above example is assess again in a year's time what the uncertainties as to investment might be and again evaluate the trade-off between investment in a year's time and investment at a future date. In fact I should have done that for every point in time in the future, in order to determine exactly when in the future the benefits of investment exceeded the benefits of delay. This is where the maths gets a little complex and hence here we shall simply assert the point that it is entirely possible to have an investment with a positive net present value which is never made because uncertainties about the future create value in waiting which exceed the value of investment at any point in time.

There are two other ways to look at the option value (the positive value in delay).

Firstly, one can see it as the amount by which the value of the investment today must exceed the calculated present value in order to incentivise investment today over delay. That is to say, that in order to incentivise investment in the presence of uncertainty, then the net present value of the investment decision must exceed that which would be calculated based on a simple discounted present value analysis. Another way of saying this (very much less rigorously from a finance theory perspective), is that the returns on investments must exceed their true cost of capital by a certain amount in order to provide an incentive to invest rather than delay in the presence of uncertainty.

Secondly, one can look upon this value as the cost of information on whether agents will make investments in certain technologies under the prevailing uncertainty. We cannot observe a net present value of an investment in the market; instead we can only observe companies and individuals making investments. Hence if we observe an economic agent making an investment, that tells us something about the parameters under which they will invest rather than delay. In order to make the investment, the value of that investment must have exceeded the value of delay, and hence we can see the premium of the net present value of the investment today as being a cost of the information or the cost of observing the investment decision[14] .

We can see, therefore, that in the presence of uncertainty about the future (a lack of information or the knowledge that information will arrive in the future), then the cost of incentivising and observing investments today goes up.

There are three more insights into option theory which we will now discuss which again affect the costs and designs of incentive arrangements.

The first is the problem of future cost reductions which we observed in one of the earlier NewClear light-bulb examples. Simply knowing with certainty that prices of investments will fall leads to a disincentive to make the investment today. Often in the climate change arena policy-makers are convinced to support new technologies with very high initial costs on the basis that there are large potentials for costs to fall as the industry achieves certain volumes of production. This has been the case in wind and solar power, as well as in some forms of conventional power generation such as natural gas turbines, and so is an approach not without foundation. However, our option insights show us clearly that this promise can be self-defeating unless those who make the investment today are in some way insulated from the future price falls, or more correctly, that the benefits of future price falls are not reflected in lower remuneration in the future. There is also clearly an inherent problem with convincing people to go first with investments on the basis that this will create "learning-by-doing", as is often claimed. While the market and policy-makers may wish to see the "learning" it is not entirely clear what is in it for those doing the "doing".

References:

14. See (Dixit A., Entry and Exit Decisions Under Uncertainty, 1989), (Dixit A., Analytical Approximations in Models of Hysteresis, 1991) and (Lin & Huang, 2010) for more formal treatment of exit and entry issues and some examples.

Secondly, if we extend our analysis to industries, then we can gain some insight into the costs of incentivising new players to enter a market. If a company is already in a market and has, for instance, an operating plant or a division which does a certain thing, then it can be considered to hold a running option to abandon this particular business activity. Similarly any company not in a certain sector might be considered to have an option to enter the market under certain conditions.

In the latter case it is clear that the value of entering the business will need to exceed the net present value in the presence of uncertainty. Similarly, however, the company already in the business with the option to abandon will have to yield the option to be active or idle in the market if it decides to exit completely. This actually means that the value of being in the business, in the presence of future uncertainty, might have to fall substantially below the net present value in order for it to make the decision to exit[15].

This basically means that in the presence of uncertainty things have to get much worse than a simple net present value calculation might suggest for a company to exit a market, and that similarly things have to be a lot better than a simple net present value calculation might suggest in order to new companies to enter new markets.

Applied to energy companies, considering that power generation companies set off in coal-fired power, the additional costs which need to be put on coal-fired power (or conversely the extra incentives which are put on say wind or solar or nuclear power) need to exceed those simply required to equalise the costs of the dirty and clean technologies. Also, the greater the uncertainty in those instruments used to close the gap in the costs between these technologies, then the wider the gap that must be closed in order to incentivise such companies to abandon polluting technologies and begin a business focussed on clean technologies.

The third insight into option theory requires us to look again at the trade-offs which make an economic agent decide whether to make an investment or not. Investments in new projects are call options, that is they bestow the right, but not the obligation to invest on the agent involved, and as such they are left with making the decision as to whether they invest today or in the future. If we look at the components of option value again below we have the following:

Option Value = Intrinsic Value + Time Value of Delay + Information Value + Real Cost of Delay

Observe that the Intrinsic Value (the value of the investment today) is the first term in the calculation and hence simply increasing the value of the investment today does not cause the decision to invest today to prevail over waiting. In the case of a call option without dividends (real cost of delay), there is always a value in waiting unless exercise of the option is forced on the agent holding the option.

Hence the investment decision will only be made when the Real Cost of Delay and Time Value of Delay exceed the Information Value of the option. In other words, the benefits forgone from not making the investment and hence owning the asset in question, must exceed the Information or Uncertainty Value of the option in order for the decision to invest to be made.

The mathematics of this are quite complex, but the importance of the short-term returns to the underlying assets (the inefficient use of energy during the investment delay in our light bulb example) is worth emphasising due to the very long build times of many low-carbon assets. If one is building a nuclear power station, for instance, the first cash flows foregone by a delay in investment might be five or six years after the decision to invest and yet they are crucially important in making the decision to invest rather than delay.

This analysis all seems very complex and it is certainly true that I have no experience of a company making investment decisions in the clean energy sector using complex option theory, so is this analysis valid for the real world?

References:

15. There are, of course, also transaction costs which further increase costs of entry and exit, but I have ignored these simply to ensure that the reader gets the point that simply the presence of uncertainty creates the issue.

Insights from real life[16]

It is true, I suspect, that there has never been a Board of Directors which has sat in front of an option calculation and decided to make an investment because the Real and Time cost of delay exceed the Information benefit of delay.

The investment decision however can be expressed in very simple terms. People invest when greed exceeds fear. In other words, our equations above can be easily re-expressed as the greed associated with the prospect of lost value of the investment today (time and real cost of delay) and the fear of making the wrong decision (the value of future information). Hence any decision maker in business will actually observe option valuation playing a key role in the way in which every investment decision is made in business. It is always the task of those sponsoring the investment to make the perceived risk (uncertainty / future information) of the investment as low as possible, and the immediate benefits of investment as high as possible. Indeed companies quite deliberately invest in the process of design and assessment of investment decisions[17] in order to reduce the uncertainty (future information) associated with them. This is what decision-makers probably see as the risk of the investment at the point at which they make the investment decision.

When decision makers in business refer to the risk and return of an investment, people often think they are referring to the cost of capital of the investment versus its return, and of course they are, but they shouldn't be, because nothing about the cost of capital of the underlying investment is going to change in the event of delay, and actually relatively little of the effort of exploring an investment decision in the corporate environment involves a rigorous analysis of what the appropriate cost of capital actually is. In fact when a decision maker says that they are balancing risk and reward they are really referring to is the information value of delay versus the rewards of immediate action.

One slightly awkward potential corollary of the option analysis presented above is that investment decisions are only made when the value of the underlying exceeds the NPV value and therefore it appears that all investment decisions should be inherently value creating. There are examples in the corporate world where investment decisions are not value creating and so does this not disprove the above? No. Firstly even in competitive markets, this analysis holds[18]. Secondly, and most importantly, it is not the outcome that matters, it is the basis on which the decision is actually made. Hence the case presented in all investment decisions, at the time of decision, will always show greed exceeding fear, even if that turns out not to be the case ex-post.

In daily life we can observe myriad examples of attempts to frame in our minds the idea that a decision must be made today. "Offer must end", "last day of sale" and so on are examples in the normal retail world where we are constantly bombarded with messages that our investment decision must be made today or we will lose out. Calls to arms in the climate arena, and in fact in all politics, are similarly framed to attempt to make people feel a need to act (we shall look at this in more detail in a later essay). I have a good friend and former colleague for whom the next three months have been critical in climate policy for the close to a decade that I have known her.

Such messages are trying to frame in the mind of the decision maker the idea that an option to invest may expire or that the time and real cost of delay far exceed the uncertainty as to whether, for instance, you really need another pair of shoes or not.

If you take a little time to observe those all around you who try to make you make decisions, you will observe them doing three things: making you feel like the investment option will soon expire; making you feel very certain about future events; and making you feel like the short term pay-off (the time and real cost of delay in other words) to owning the asset is as high as possible.

References:

16. For a range of applications of option theory to investment decisions in the climate and energy arena see (Albers & Goldbach, 2000), (Blyth, Yang, & Bradley, Climate Policy Uncertainty and Investment Risk, 2007), (Camacho & Menzes, 2009), (Xepapadeas, 1999) and (Yang, Blyth, Bradley, Bunn, Clarke, & Wilson, 2008).
17. They might, for instance, perform an engineering study to ascertain the investment cost with the greatest certainty possible.
18. See (Pindyck, A Note on Competitive Investment under Uncertainty, 1991) for a more formal treatment.

Why cap-and-trade schemes don't lead to investment decisions

The higher the level of uncertainty, the greater the value of delay in investment today. This can be proved rigorously, but should also be broadly intuitive and consistent with the above examples. Hence the greater the uncertainty today, and the greater the amount of information resolution which is possible in the future, then the greater the cost of incentivising (and hence observing) agents investing today rather than waiting.

This is why cap-and-trade schemes don't incentivise investment to the degree that policy-makers have historically hoped that they would. In terms of investment decisions, it is the very richness and breadth of the potential future information which a cap-and-trade scheme can provide which causes the uncertainty and delay today.

Should we then forget these high uncertainty / high information systems in favour of more certain regimes?

The next essay explores the reasons why this would be a disastrous course of action.

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