Emission allowances trading system and its impact on investment decision-making (real option approach)

Miroslav Čulík [1]

Abstract

This paper is focused on the investments, which lead to the polluting decrease. Companies polluting emissions have to reduce the quantity of emissions to meet the target level. There are two ways how to do it: first, to invest in a new technologies leading to the emission reduction or, to buy emission allowances from other firm. It is apparent that emission allowances and their prices affect importantly decision strategies. The result is that investment process is under emission trade system more complicated and new investment policy decision tools and techniques must be employed. In the first part, fundamentals of emission trade system and its impact on financial decision—making is described, in the second part, an illustrative example of a pollution decreasing investment using real option approach is stated.

Key words

Real option, option to defer, emission allowance, underlying asset, decision function.

1 Introduction

Greenhouse gas emission trading system is one of the mechanisms how to reduce the world air pollution. This system covers industries with the highest share on the world emission pollution (power generation, metal industry, oil refining, etc.) For each country involved in the trading system, certain target emission amount has been established. This quantity of emission is than distributed within a country according to certain schemes among industry areas. For example, in the Czech Republic, 99,2 millions of allowances were allocated among 12 industrial areas and within industries among companies. Each company can meet the emission target (expressed in the allowances amount, where one allowance represents one tone of emissions) either by reducing the emission released on the target level or by buying other allowances to cover the produced emission quantity. Due to the fact, that the total allowances amount is fixed and can not be increased; the purchase of allowances by a company has to be accompanied by emission reduction at the selling company.

It is apparent, that emission allowances will become in the nearest future an important tool, which affects investment policy of companies involved in trading system. The emissions can therefore represent a direct cost for the company or, in contrary can be an important part of revenues.

The aim of this paper is to analyze the impact of emission allowance trading system on timing an investment in a new technology leading to emission decrease by employing real option approach.

---

[1] Ing. Miroslav Čulík, Ph.D. VŠB-Technical University Ostrava, Faculty of Economics, Finance Department, Sokolská tř. 33, 701 21 Ostrava, email: miroslav.culik@vsb.cz.

This paper is supported by the Grant Agency of the Czech Republic (GAČR): 402/04/1357.

2 Emission allowance trading and investment decision

Companies involved in the emission trading are free to decide how they comply with the emission target level. If the current emission level is above the emission target level, the company can either buy emission allowances or to make autonomous reduction investment and sell the allowance surplus. In contrary, if the current emission level is below the emission target level, the allowance surplus can be sold on the market. This system ensures that each company can decide how to reach the target emission level (depends on cost reduction and emission allowances prices). Some companies may be able to reduce the emissions at a low cost and thus would prefer to invest in new technologies leading to the decrease in emissions released, whereas the other ones may prefer to buy emission allowances if the costs on emission decrease are rather high.

It is apparent, that the system allows the companies flexibility how to meet the target emission level and makes the investment process more complicated.

The most important variable is the price of an emission allowance. If the market price of allowance is relatively low, than the overall impact of emission trading on companies is at a low level and *vice versa*. According to Laurikka (2005), in the short term, the emission allowance price is market-driven variable and depends on energy demand, industrial products demand etc, whereas in the long term period it is a partly political and is driven by allocation of allowances from the government.

To sum up, the impact of emission trading on investment appraisal depends not only on expected emission allowance prices, but also on their volatility, correlation with fuel prices and electricity etc. and investment process becomes more complicated, where traditional appraisal methods fail and new techniques have to be employed and are described in the following chapter.

3 New investment appraisal methods

Standard techniques of investment appraisal at present are Net Present Value (NPV), Internal Rate of Return (IRR) and payback period, all of which can be accompanied by the sensitivity analysis. All these standard techniques rely on pre-defined scenario of cash inflows and outflows discounted by appropriate cost of capital reflecting time value of money and their risk.

Recently, modern investment theory has been proposed, which put aside some shortcomings and assumptions of traditional methods. The central argument of this theory is, that above mentioned methods (which assumes a single static decision) ignore management's flexibility to adapt and revise past decisions in response to the market developments. From this reason, these methods must be extended, to take into account the value of real options, which and assumes dynamic series of decisions and are in many projects involved. These options are valuable and create great part of total project value. In the energy and other energy intensive industries, the value of real options is driven by many sources of uncertainty and that is why they are called rainbow options.

There are at least three areas, where traditional DCF comes up short versus option theory:

- *Flexibility*. Flexibility is the ability (or option) to defer, abandon, expand, contract, etc. a project. Because the NPV rule is defined as passive (or static), values these options at zero, while the real option approach would correctly allocate some project value into these future options.
- *Contingency*. This is a situation, when future investments are contingent on the success of today's investment. Managers can make investments today – even those with negative

NVP – to access future possibilities. Traditional budgeting models inadequately value these option-creating investments.

- *Volatility*. Somewhat counter intuitively, investments with greater uncertainty have higher option value. In standard finance, higher volatility means higher risk, higher discount rate and lower present value. In option theory, higher volatility – because of asymmetric payoff schemes – leads to higher option value.

Real option is the right but not obligation to take some action concerning real asset. These actions are modelled as a put or call options, which can be under pre-specified conditions exercised. A call option on an asset gives the right (but no obligation) to acquire the underlying asset by paying a pre-specified price on or before a given maturity. Similarly, put option gives the right to sell the underlying asset and receive the exercise price. Among the basic are:

- *Option to defer* – if there is a positive probability, that the market will be more favourable than today, management may defer starting a project even with positive NPV, which might be more profitable to wait and see especially if the future is uncertain. Detailed description, see chapter 3.2.
- *Option to expand* - If the project has already been once undertaken, management have the possibility to make additional investment and expand the initial scale of the production (i.e. by building additional production capacity) if it turns out, that its product is better accepted by the market then originally anticipated. In the option pricing terminology, firm has a call option on additional cash flow from extended part of project with exercise price equals to investment cost, which has to be spent on building additional capacity.
- *Option to contract*- Analogous to the option to expand the project it is the option to contract a project. In this case, management has the option to contract the initial scale of the production and sale a part of the project in the case, if the conditions (for example if the product is not well received on the market) turned out to be less favourable than those expected at the beginning of the investment process. The option to contract thus can bee seen as a put option on the part of the initial project and cash flow generated by this part, which can be contracted with exercise price equals to the saved investment cost.
- *Option to abandon* - if the conditions turned out to be permanently unfavourable, management may have option to abandon the project in exchange for its salvage (or sale) price before its expected life. From the firm's point of view, management has a put option on the gross value of the project with exercise price equals to the salvage or resale.
- *Option to shut down and restart a production* - in the case the revenue in a given year is not sufficient to cover variable cost of the production (so called *spark spread* is negative), management may have the option to temporarily shut down the production (or simply not to operate). Thus, operation in a given year may be viewed as a call option on the production (i.e. revenue) by paying variable cost as the exercise price value.
- *Option to switch inputs* – many power generating technologies enables to switch between two or more inputs, i.e. select the cheapest fuel to produce electricity.

The basic advantage of real option methodology is that it takes advantages of analytical and numerical models of financial options valuing, i.e. there is no need to complicatedly calculate risk - adjusted cost of capital but only risk free rate is necessary to know and use. Other advantages and characteristics of option pricing models compared to DCF model when valued real assets can be found in Trigeorgis (2000) etc.

3.1 Real option model valuation description

There are a few models for options valuation and can be categorised according to different criterias. If there is an exact formula for option value calculation, then deals with analytical models, (Black and Scholes model), otherwise we deal with numerical models (finite difference method, simulation, discrete models).

Due to the fact that most of the real options are American type, an numerical model of replication strategy will be employed.

Replication strategy results from the fact, that a replication portfolio V can be created and is made of a certain quantity, h, of underlying asset S and risk free borrowing , which precisely mimics the derivative value f., i.e.,

$$V_{t_0} = h \cdot S_{t_0} + B_{t_0}, \tag{1}$$

and in the absence of arbitrage profit opportunities must hold,

$$f_{t_0} \equiv \left(h \cdot S_{t_0} + B_{t_0}\right). \tag{2}$$

At time t_1 if the value of underlying asset moves up is the portfolio value,

$$h \cdot S^u_{t_1} + B \cdot (1+r) = V^u_{t_1} \equiv f^u_{t_1}, \tag{3}$$

and if it moves down, then

$$h \cdot S^d_{t_1} + B \cdot (1+r) = V^d_{t_1} \equiv f^d_{t_1}., \tag{4}$$

where r is risk free rate and u (d) are coefficients of upward and downward movement.

If the portfolio is correctly created, i.e. exactly mimics derivatives payoff function, then the following equality must hold,

$$f_{t_0} \cdot (1+r) \equiv \left(h \cdot S_{t_0} + B_{t_0}\right) \cdot (1+r) = \begin{Bmatrix} h \cdot S^u_{t_1} + B \cdot (1+r) = V^u_{t_1} \approx f^u_{t_1} \\ h \cdot S^d_{t_1} + B \cdot (1+r) = V^d_{t_1} \approx f^d_{t_1} \end{Bmatrix}. \tag{5}$$

By solving (2), (3) and (4) for unknown h, B and C, we get the valuation formula for derivative,

$$f_{t_0} \cdot (1+r) = f^u_{t_1}\left(\frac{(1+r) \cdot S_{t_0} - S^d_{t_1}}{S^u_{t_1} - S^d_{t_1}}\right) + f^d_{t_1}\left(\frac{S^u_{t_1} - (1+r) \cdot S_{t_0}}{S^u_{t_1} - S^d_{t_1}}\right), \tag{6}$$

where expressions in parenthesis are risk-neutral probabilities. Valuation formula (6) can be rewritten as follows,

$$f_{t_0} = \frac{1}{(1+r)} \cdot \left[f^u_{t_1} \cdot p + f^d_{t_1} \cdot (1-p)\right]. \tag{7}$$

Equation (6) can be modified as

$$f_{t_0} \cdot (1+r) = f^u_{t_1} \cdot \left(\frac{1+r-d}{u-d}\right) + f^d_{t_1} \cdot \left(\frac{u-(1+r)}{u-d}\right), \tag{8}$$

if holds, that $S^u_{t+dt} = S_t \cdot u$ and $S^d_{t+dt} = S_t \cdot d$.

3.2 Option to defer a project

This type of option is formally an American call option. It enables managers temporarily to defer starting a project and profit from future information, which are over time resolved and were unknown at the outset of decision. Managers defer a project with investment cost *I*, if project's NPV is higher (if deferred) compared with immediate starting. In other words, the option to defer (or wait) can bee seen as a call option on the gross project value *V* with the exercise price equals to required investment outlay *I*.

Function of intrinsic value option can be formally written as follows,

$$VH = max\left[V_0 - I_0, \frac{1}{(1+r)^t}(V_t - I_t)\right], \tag{1}$$

where V_t is gross value of project, i.e. present value of subsequent cash flow discounted back to the time moment *t*.

Decision function can then be written this way,

$$F = \begin{cases} 1 & for\ (V_0 - I_0) < \frac{1}{(1+r)^t} \cdot (V_t - I_t) \\ 0 & for\ (V_0 - I_0) > \frac{1}{(1+r)^t} \cdot (V_t - I_t) \end{cases}. \tag{2}$$

where 1 means to defer a project, 0 means start a project immediately.

4 An illustrative example

In the illustrative example, the attention will be focused on a company, which is in the emission trading system from 2005 involved. From the year of 2004, the company solves the problem of investment opportunity to a new technology, which will reduce its emissions by 7500 tonnes per year. At present, the total investment costs of the new technology are 700 000 EUR, but the investment may be postponed until 2010. If deferred, the total costs will go up with risk free rate, r_f, which is equal to 5 % p.a. It is also supposed that if the decision to invest is made in a given year, the first emission reduction is achieved in the same year. The expected life of the investment is 20 years.

Emission allowance prices are supposed to be the prime uncertain variable. For its future development, the binomial tree is used. In this tree it is assumed the price can go up or down with certain probability. For the initial node the expected price of one emission allowance is 15 EUR/tonne. In the subsequent period it can increase by upward coefficient of *u* = 1,16 or decrease by downward coefficient *d* = 0,86. which correspond to the price volatility of 15 % per year[2].

The revenues of the investment are determinate by two variables, i.e. the reduced quantity of emissions (which are supposed to be constant every year) and emission allowance prices, which can vary every year. It implies that if the emission target is met by the company, the emission allowances surplus can be sold at the market at a market price.

Present value of expected revenues from year *t* to year *t+20* when invested in year *t* for a given emission allowance price can be calculated as a difference of the two perpetuities, i.e.

---

[2] Upward and downward coefficients calculation are described in Zmeškal (2004), Hull (2002) etc.

$$ {}_{t}PV_{t+20}(Rev) = Q_t^E \cdot P_t^E \cdot \left[\frac{1}{WACC} - \frac{1}{(1+WACC)^{20} \cdot WACC} \right], \tag{3} $$

where ${}_{t}PV_{t+20}(REV)$ is present value of expected revenues *REV* from year *t* to year *t+20* when invested in year *t*, Q_t^E is reduced quantity of emission per year (which is constant at the level of 7500 tonnes per year), P_t^E is emission price allowance in year *t*, *WACC* is weighted average cost of capital. The expected present value of total revenues calculated according to the above mentioned algorithm and over the investment opportunity period is in Figure 1.

Figure 1: Gross project value for the period 2004 – 2010.

2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
						1731990,51
					1490738,04	
				1283090		1283090
			1104365,91		1104366	
		950537		950537		950537
	818134		818134		818134	
704175		704175		704175		704175
	606089		606089		606089	
		521666		521666		521666
			449002		449002	
				386459		386459
					332629	
						286296

Now, the Net Present Value *NPV* of the investment for each node can be calculated according to,

$$ NPV_t = max\left[{}_{t}PV_{t+20}(Rev) - INV_t ; 0\right], \tag{4} $$

where *INV* is investment costs in a given year *t*. If positive, than project should be accepted, otherwise reject it. (see Figure 2).

Figure 2: NPV of project (without deferral option)

2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
						793924
					597341	
				432236		345023
			294028		210969	
		178787		99682		12470
	83134		7797		0	
4175		0		0		0
	0		0		0	
		0		0		0
			0		0	
				0		0
					0	
						0

As it was described in the Chapter 3, instead of investing in the project whenever its NPV is positive, the company may defer the investment and capture "wait and see" strategy and profit from resolving the uncertainty of emission prices allowances. In the subsequent period, the present value of revenues can be higher or lower, the same is true about the NPVs. The difference is logical, because the higher the allowance price, the higher the revenues (not only in the firs year, but in the coming 20 years). The NPV value of this investment opportunity is calculated as,

$$NPV_t^{defer} = \left[\frac{p \cdot max\left({}_{t+1}PV_{t+21}^{u}(Rev) - INV_{t+1};\, 0 \right) + (1-p) \cdot max\left({}_{t+1}PV_{t+21}^{d}(Rev) - INV_{t+1};\, 0 \right)}{1 + r_f} \right]$$

where p respective ($1-p$) are risk-neutral probabilities of upward and downward movement. It can be shown (see Zmeškal, 2004) that the probability is equal to 62,9 % for upward movement (i.e. 37,1 % for downward movement). The results are depicted in the following Figure 3.

Figure 3: Project NPV with option to defer

2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
						793924
					597341	
				432236		345023
			294028		210969	
		178787		126303		12470
	107036		59678		7465	
49771		4668		0		0
	0		0		0	
		0		0		0
			0		0	
				0		0
					0	
						0

In the next step, the project NPV (if undertaken immediately) is compared with its NPV calculated as a deferral opportunity to invest. The optimal decision can be described by the following function,

$$If \begin{cases} NPV_t \geq NPV_t^{defer} \rightarrow invest \\ NPV_t < NPV_t^{defer} \rightarrow defer \\ NPV_t = NPV_t^{defer} = 0 \rightarrow cancel \end{cases} \tag{5}$$

According to (5) we make the optimal decision in every decision node, which maximises the project NPV, i.e. invest, defer or cancel, see Figure 3.

Figure 3: Optimal decisions tree

2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
						invest
					invest	
				invest		**invest**
			invest		**invest**	
		invest		**defer**		**invest**
	defer		**defer**		**defer**	
defer		**defer**		cancel		cancel
	cancel		cancel		cancel	
		cancel		cancel		cancel
			cancel		cancel	
				cancel		cancel
					cancel	
						cancel

In the following Figure 4 and Figure 5, sensitivity analysis has been undertaken, because all the assumptions on which the calculations are based need not be correct and are uncertain, at least. From that reason, the project NPV dependence on the emission allowance price was made (which is supposed to be the most important factor affecting the project value and its NPV). In the end the project dependence on the investment costs was analyzed.

Figure 4: Project NPV and its dependence on emission allowance price

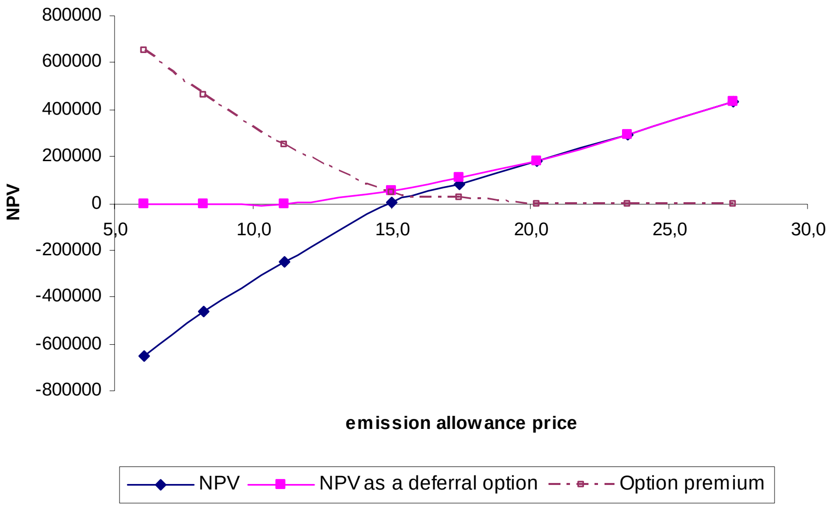
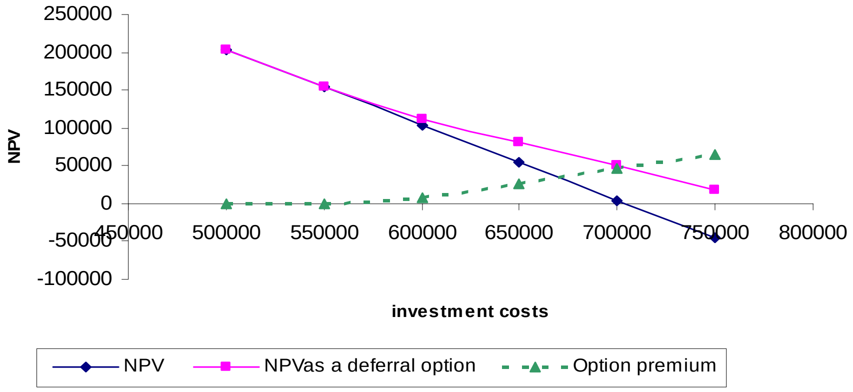


Figure 5: Project NPV and its dependence on investment costs



5 Conclusion

Emission allowance trading system is a complex approach applied as a economic tool to pollutants decrease. The main advantage of this system is, that it gives companies the flexibility in decision making how to meet the target emission level and ensures economical efficiency, how this goal has to be achieved, whereas other tools such as taxes and fees gives no flexibility.

It was showed in this paper the impact of the emission trading system on investment timing in a new technology. It is apparent from the results that it can be better for a firm to wait with an investment even if its Net Present Value is positive now. It is sometimes better to "wait and see", especially if there are more underlying stochastic variables with important impact on the investment as a whole.

Reference

[1] AMRAM, M., KULATILAKA, N.: *Real Options: managing strategic investments in an uncertain world*. Harvard Business School Press, Boston, 1999.

[2] BRENNAN, M.J., TRIGEORGIS, L.: *Project Flexibility, Agency and Competition: new developments in the theory and application of Real Options*. Oxford University Press, London, 2000.

[3] COPELAND, T.E., ANTIKAROV, V.: *Real Options: practitioner's guide*. Texere, New York, 2000.

[4] DLUHOŠOVÁ, D. et al.: *New approaches and financial instruments in financial decision-making.* EkF VŠB-TU Ostrava, 2004.

[5] DIXIT, A.K., PINDYCK, R.S.: *Investment under Uncertainty*. University Press, 1994.

[6] HOWEL, S. et al.: *Real options. Evaluating Corporate Investment Opportunities in a Dynamic World*. Prentice Hall, London, 2001.

[7] HULL, J.C. *Option, futures and other derivatives.* 5th edition. Prentice Hall, USA, 2002.

[8] MUN, J.: *Real Option Analysis. Tool and Techniques for Valuing Strategic Investments and Decisions.* John Wiley and Sons, Inc., New Jersey, USA, 2002.

[9] TRIGEORGIS, L.: *Real Options in Capital Investments: models, strategies and applications*. Praeger, Westport, 2000.

[10] TRIGEORGIS, L.: *Real Options: managerial flexibility and strategy in resource allocation*. The MIT Press, Cambridge, 1998.

[11] TRIGEORGIS, L., SCHWARTZ, E.S.: *Real Options and Investments under Uncertainty*. The MIT Press, Cambridge, 2001.

[12] VOLLERT, A.: *A Stochastic Control Framework for Real Options in Strategic valuation*. McKinsey Comp., Boston, 2003.

[13] ZMEŠKAL, Z., ČULÍK, M., TICHÝ, T.: *Finanční rozhodování za rizika. Sbírka řešených příkladů*. EkF VŠB-TU Ostrava, 2005.

[14] ZMEŠKAL, Z. et al.: *Financial models*. EkF VŠB-TU Ostrava, 2004.

Summary

Systém obchodování s emisními povolenkami a jejich dopad na investiční rozhodování (přístup na bázi reálných opcí)

Příspěvek se zabývá problematikou obchodování s emisními povolenkami a jejich dopadem na investiční proces firmy. V úvodu je zjednodušeně popsán princip emisních povolenek a jejich dopad na investiční politiku. Dále je zmíněn jeden z nových přístupů pro oceňování investic, kdy jsou zohledňovány možnosti aktivních změn v průběhu životnosti projektů (reálné opce). V závěru je uveden ilustrační příklad, kdy je posuzována investice do

technologie včetně doporučení optimální investiční strategie, která umožňuje snížení emisí, jejichž objem může být následně prodán formou emisních povolenek. Taktéž je provedena komparace tradiční NPV s opčním přístupem a jejich citlivost na vybrané ukazatele.