6

Publication 6

Reprinted from *Global Environmental Change*, Vol. 13, Issue 3, Laurikka, H., Springer, U., Risk and return of project-based climate change mitigation: a portfolio approach, 207-217, Copyright (2003), with permission from Elsevier

PERGAMON

Global Environmental Change 13 (2003) 207–217

GLOBAL ENVIRONMENTAL CHANGE

www.elsevier.com/locate/gloenvcha

Risk and return of project-based climate change mitigation: a portfolio approach

Harri Laurikka[a], Urs Springer[b,*]

[a] *Laboratory for Energy Economics and Power Plant Engineering, Helsinki University of Technology, Finland*
[b] *ECOPLAN, Economic Research and Policy Consultancy, Thunstrasse 22, CH-3005 Bern, Switzerland*

Abstract

We present a framework for evaluating the risks of investments in climate change mitigation projects to generate emission credits. Risk factors that influence the quantity of emission credits are identified for six project types. Since not all project types are affected by the same factors, diversification is a viable risk reduction strategy. We propose a methodology for quantifying risk and return of such investments, discuss data requirements, and illustrate it using a sample of voluntary projects. In our sample, the returns of an optimally diversified low-risk portfolio are up to 10 times higher than those of single projects, holding risk exposure constant.

Keywords: Kyoto protocol; Portfolio diversification; Return; Risk; Tradable permits

1. Introduction

The Kyoto Protocol allows countries to acquire emission permits[1] from projects carried out abroad. Transfers of permits from industrialised countries and countries with economies in transition listed in Annex B of the Kyoto Protocol are called Joint Implementation (JI). Through the Clean Development Mechanism (CDM), permits generated in projects in developing countries may be acquired. In many countries, domestic firms are allowed to use permits acquired via JI and the CDM for compliance with legally binding emission limits.

The economic advantage of the Kyoto mechanisms is obvious: Since the marginal abatement costs of reducing emissions of greenhouse gases (GHG) are much lower in many developing countries and countries with economies in transition (host countries), a given reduction in emissions can be achieved at much *lower cost*. Yet, this reasoning implicitly assumes that the *risks* of such projects are at an equal level at home and in the host country. Only if this is the case, low-cost abatement projects in developing countries can be superior to domestic activities. If the risks are high compared to the benefits, private companies are likely to refrain from using project-based mechanisms and rather undertake domestic mitigation measures, even if they are more expensive at first sight (Janssen, 2001; Springer, 2003).

In this paper, we present a framework for evaluating investment risks of project-based climate change mitigation. We examine projects whose return is exclusively based on the net cash flow from the emission permits generated. Key investment risks of project-based climate change mitigation are identified for six main project types. Since not all project types are affected by the same factors, *diversification* of investments is a promising risk reduction strategy. We present a methodology for quantifying risk and return of climate change mitigation investments and illustrate it using a sample of projects from the US Voluntary Reporting of Greenhouse Gases (VRGHG) Program.

Springer (2003) examines the risk reduction potential of diversification using data from pilot projects carried out under the Activities Implemented Jointly (AIJ) program. We extend his risk analysis and provide another illustration using a different sample of projects. We use emission reduction data from the VRGHG

*Corresponding author. Tel.: +41-31-356-6161; fax: +41-31-356-6160.

E-mail address: springer@ecoplan.ch (U. Springer).

[1] We use the generic term "*emission permit*" for both emission credits and allowances. In an *allowance* trading scheme, regulated entities face an emissions cap, an aggregate emissions limit for a given period. *Credits*, on the other hand, are generated when a plant reduces emissions below an agreed emissions baseline, a hypothetical non-project scenario.

0959-3780/$ - see front matter
doi:10.1016/S0959-3780(03)00048-7

Program run by the US Energy Information Agency. Cost data for some of the projects in the public database have been gathered and enable us to calculate *returns* in terms of emissions reductions per dollar invested in each project. Substantial differences between the returns of different project types can be observed. Analogously to portfolio theory applied in financial markets, we measure project *risk* as the variance of project returns. The returns of the projects we examine vary strongly over time. We find that investing in a portfolio of projects reduces risk significantly compared to investments in single projects. An optimised portfolio performs up to 10 times better than single low-risk projects. This implies that *carbon funds* are a promising way to reduce the risks of project-based climate change mitigation.

The rest of the paper is organised as follows: Section 2 describes and compares the risks faced by investors in different types of climate change mitigation projects. In Section 3, we describe our approach and the data used. We illustrate the diversification effect for a portfolio of projects from the VRGHG program and discuss data requirements. Section 4 concludes.

2. Risk analysis

In investment analysis, risk refers to the possibility that the actual return of an investment *deviates* from its expected value. Risks are thus directly traceable to returns. Risks and returns can be defined in different ways depending on the perspective of the investor. In this article, we use the term ''climate change mitigation project'' as a general term referring to projects that either reduce GHG emissions or sequester carbon. In the following, we briefly discuss the risks of conventional real investments and examine in more detail the risks faced by an investor interested *exclusively* in GHG emission permits and the related costs.

2.1. Risks of conventional real investments

Climate change mitigation projects transform different kinds of investments into a variety of cash flows. Emission permits seem to be the minor source of revenue in most energy, industry and transport infrastructure investments (European Commission, 2001; PCF, 2000). In a *conventional real investment*, the investor provides debt and equity financing in exchange for property rights to the project and the net cash flows it produces, i.e. the *financial* return. Revenues vary: Power projects create income from electricity and heat; energy efficiency projects and methane recovery projects can reduce energy costs; afforestation and reforestation projects can increase timber or food supply (Ellis, 2001). Emission reductions within an emission trading scheme provide either emission credits or savings in allowances, which contribute to the cash flow of the ''conventional'' projects.

In this article, we limit ourselves to private costs and benefits, i.e. the *financial* return. Climate change mitigation projects also create social and environmental benefits (OECD, 2000a) that can be of relevance in policy-making and project evaluation, thus being part of the *economic* return.

A comprehensive risk assessment for a project that reduces GHG emissions involves a large number of critical variables, such as the market prices of primary products (e.g. electricity), the fuel costs and other operating and maintenance costs. It is a data-intensive task that is required from equity investors or banks providing debt capital in project financing who aim at optimising their project portfolios based on the free cash flow and the related risks.

2.2. Risks of climate change mitigation investments

A different contractual arrangement from the conventional one discussed above is also possible: The owner of a plant (or forest) could give the right to the emission permits generated in a project to another party. This party, which we call ''GHG investor'', could be a carbon fund or a company interested in emission permits for compliance with domestic regulation.[2] The investor finances (a part of) the abatement costs by paying a share of the capital costs or part of the operating costs. This corresponds to the concept of *incremental costs* of GHG abatement, which would be paid by the GHG investor.

In contrast to investments in end-of-pipe technologies such as scrubbers or electrostatic separators, an emission abatement investment in the case of GHG is in many cases physically *inseparable* from the conventional investment. The investment in SO_2 emissions abatement through a scrubber is the sum of capital costs and installation costs. However, the climate change mitigation investment attributable to a new wind or hydroturbine cannot be determined so easily, as it is no physically separate component of the project. GHG abatement costs depend on the baseline emissions and the project scenario, which makes the determination of the climate change mitigation investment basically a matter of negotiation between the project sponsor and the GHG investor.

In the following, we take the perspective of a GHG investor and focus on the emission permit related cash

[2] This corresponds to the *bilateral model* of the CDM. Note that an ownership structure where the investor (from the host country) owns all permits produced and sells them on the market (usually referred to as the *unilateral model)* is also possible (Haites and Yamin, 2000).

flow. The cash flow in period t can be written as

$$p_t^{ghg}(e_t^b \cdot x_t^b - e_t^p \cdot x_t^p) - C_t^{ghg}, \quad (1)$$

where p_t^{ghg} is the price of the emission permits in period t; e_t^b the baseline emission intensity (in e.g. gCO_2e/kWh_e) in period t; e_t^p the project emission intensity (in e.g. gCO_2e/kWh_e) in period t; x_t^b the baseline activity level (in e.g. kWh_e) in period t; x_t^p the project activity level (in e.g. kWh_e) in period t; and C_t^{ghg} the production costs of emission permits in period t.

The project-based Kyoto-mechanisms, JI and the CDM, require an analysis of the development of emissions in the absence of the project. The amount of GHG emissions emitted in the hypothetical non-project (business-as-usual) scenario is referred to as a project *baseline*, i.e., CDM projects will qualify for certified emission reduction units and JI projects for emission reduction units if they reduce GHG emissions relative to the baseline (UNFCCC, 2001). The amount of emission permits generated is obtained by subtracting the project emissions from the baseline emissions.

Furthermore, the Kyoto Protocol states that reductions in emissions or enhancements of sinks have to be "additional to any that would otherwise occur". Formally, (environmental) additionality requires

$$e^p < e^b \vee x^p < x^b. \quad (2)$$

While reductions in the activity level ($x^p < x^b$) could result from an energy efficiency project, fuel switch and renewable energy projects typically reduce the emission intensity below its baseline level (see e.g. Laurikka, 2002).

Numerous risks of project-based climate change mitigation have been described in the literature and several different classifications have been proposed.[3] We distinguish *three types* of risks which are directly derived from Eq. (1) that describes the cash flow from emission credits in climate change mitigation projects:

- price risks,
- cost risks,
- quantity risks.

The *price risk* is caused by the price volatility of the international or national GHG permit market. Varilek and Marenzi (2001) identify three determinants of price volatility: First, banking restrictions tend to increase volatility by constraining the compliance flexibility of affected sources. Second, broad sectoral coverage helps to reduce permit price movements resulting from external shocks to any given sector. Third, regulatory uncertainty increases price volatility, as market participants reconsider their permit valuations as a result of each expected or announced change in trading rules. Currently, it is not possible to quantify the price volatility of GHG emission permits because of low market activity.

The *cost risk* comes from the fact that the production costs of emission permits may be uncertain ex-ante. The responsibility for the costs is a matter of negotiation and contracting between the GHG investor and the project sponsor. The costs agreement can specify anything from a fixed upfront payment to a share of operating costs or an index-based annual payment. Obviously, these arrangements have totally different implications for the cost risk.

The *quantity risk* is associated with the ex-ante uncertain amount of credits generated or allowances saved due to the project. The quantity risk consists of four factors: baseline activity level (x^b), baseline emission intensity (e^b), project activity level (x^p) and project emission intensity (e^p).

In addition to the categories above, there is one risk category that affects all project types: the reduction *crediting period*. The crediting period—which is not necessarily equal to the project lifetime—determines how many years a project can generate emission credits. This issue is likely to be solved by the rules of international climate policy. At present, most programs provide monetary incentives for emission reductions until 2012 with certainty. Furthermore, it was agreed at the seventh Conference of the Parties to the UNFCCC that the crediting period of a CDM project is either 10 years without baseline revisions or maximally 21 years including revisions (UNFCCC, 2001, p. 37).

2.3. Determinants of quantity risk

Since cost risks depend on the specific contractual arrangement and price risks cannot be assessed for lack of data, only the *quantity risk* can be the subject of a quantitative analysis. In the following, we discuss the components of quantity risk and explore the environmental, economic, and social factors that affect the activity level and thus the quantity risk of six main project types.

Variations of the *baseline activity level* (x^b) depend on the baseline type.[4] The baseline activity level in a *relative* baseline, i.e. given for example in tCO_2e/kWh, is equal to the project activity level x^p (Laurikka, 2002). However, in the case of an *absolute* baseline, i.e. given in tCO_2e, additional variations may occur depending on the selection method of x^b, e.g. depending on whether the baseline is fixed or revisable.

[3] In one of the first analyses of this topic, Janssen (1998) distinguishes three broad categories: (i) technological risks, (ii) economic risks, and (iii) political risks. A similar classification can be found in Larson and Parks (1999). They distinguish (i) private performance risk, (ii) price risk, and (iii) sovereign or policy risks. Zhang and Maruyama (2001) describe a number of risks of climate change mitigation and CDM projects, but do not classify them.

[4] On baseline terminology, see e.g. Kartha et al. (2002) or OECD (2000b).

Table 1
Risk factors

Project type	Technological and environmental factors	Economic factors	Social factors
Wind/solar/hydropower plants without a reservoir	Local weather Technical availability	None	Local stakeholders NGOs
On-grid power plants with combustible fuels	Technical availability	Fuel prices Electricity and heat prices	Local stakeholders NGOs
Off-grid heat and power plants with combustible fuels	Technical availability	Client demand	Local stakeholders NGOs
Carbon sequestration	Natural hazards	Wood prices	Site management Local stakeholders
Methane projects	Volume of gas recovery Methane content of the gas	None	Negligible
Energy efficiency projects	Technical availability	Fuel price Energy price Energy use (DSM)	Energy users' behaviour

Whether the *baseline emission intensity* (e^b) changes over time also depends on the baseline type. In a revisable baseline, the calculation basis e^b may change during the project lifetime. In a dynamic baseline, the calculation basis can be agreed to depend on external factors such as the average emission intensity of the grid.

The *project emission intensity* (e^p) is largely dependent on technological (e.g. fuels used and efficiency of the plant) or biological parameters (in carbon sequestration). Some project types do not have significant project emission intensity risk (for example, renewables). For some project types, like thermal power plants with multiple fuels, economic factors also have an impact on the project emission intensity via fuel selection. Furthermore, the actual efficiency of the plant or fuel mix used may deviate from the expected efficiency.

The variation of the *project activity level* (x^p) is a combined effect of technological, environmental, economic, and social factors that have different weight in different project types (see Table 1). We discuss the relevance of these factors for each project type below in more detail. In addition to these four factors, *political* decisions regarding the design and implementation of international and national climate policies can also influence the amount of credits generated.

The risk related to the social factors can—and often *must*—be reduced already ex-ante by licensing and an Environmental Impact Assessment. Involving local stakeholders in an early phase into the project planning can avoid problems for the project sponsor later.

The project activity level of *non-combustible renewable power without a reservoir*, such as wind, solar power and hydropower plants without a storage, depends less on economic factors than on weather conditions and the technical availability of the plants. The reasons are the low variable costs of these plants and proportionately high initial investment that is sunk when the project gets operational. Wind and hydropower plants have local environmental impacts that may contain a certain social risk factor even after an Environmental Impact Assessment has been made.

The load factors (i.e. the ratio of average energy production to maximum production during a specific period) of *on-grid power plants with combustible fuels* are not directly dependent on the variation in local weather conditions. On the other hand, they tend to have a positive correlation with electricity prices in an *annual* analysis, when electricity production is operating on cost basis (see Table 2 for two examples in free electricity markets). As suggested in Table 1, this is clearly different from the behaviour of wind and hydropower plants.

Combined heat and power (CHP) generation can also show different behaviour with respect to the activity level. In back pressure units, the proportion of heat and power generated is fairly constant, which implies that the activity level is mainly determined by the local heat demand. In extraction units, the relation of power and heat production can be adjusted to some extent. Therefore, electricity prices have a higher impact on power production.

The generation of *off-grid heat and power plants with combustible fuels* is less elastic to fuel or electricity prices in the short-term, as the producer often has a local

Table 2
Correlation of electricity prices and load factors: two examples

Type of generation	Country	
	UK[a] (1996–2000)	Finland[b] (1994–2000)
Hydropower	−0.97[c]	−0.60
Nuclear power	0.34	−0.36
Wind power (on-shore)	−0.75	−0.34
Biofuels	−0.01	n.a.
Combined cycle gas turbines (CCGT)	−0.47	n.a.
Conventional power (incl. CHP)	0.54	0.93
Combined heat and power (CHP)	−0.90	n.a
Industry	n.a	−0.80
District heating	n.a	0.80
Condensing power	n.a	0.92

Sources: Based on DTI (2001), Statistics Finland (2001), Nordpool.
[a] Electricity: average price for the industry (DTI, 2001), Load factors: hydro, wind, bio-fuels, CHP (DTI, 2001), conventional power, load factors for CCGT, nuclear calculated for all power producers based on capacity and production data (DTI, 2001).
[b] Electricity: Nordpool average spot prices, load factors for all sources calculated based on capacity and production data (Statistics Finland, 2001).
[c] Excluding pumped storage stations.

mono/oligopoly in energy production. The level of production, however, depends on the client's energy demand that can vary considerably.

Environmental factors affecting project emission intensity in *carbon sequestration* can be divided into naturally occurring risks, fires and human-induced risks (Ellis, 2001). In contrast to other project types, these physical risks do not only affect the removal rate of the present year, but can also affect the removal of *earlier* years: a fire, for example, can destroy the entire carbon stock. In other words, in carbon sequestration projects there is a risk of "negative reductions" that is not present in other project types.

Procedures to account for the increase in carbon stocks will obviously have a direct impact on the number of emission permits. The actual increase follows an S-shaped curve, but multiple crediting procedures have been discussed for practical application (Ellis, 2001). The total amount of carbon stored by a forest will vary according to species, climatic conditions (e.g. temperature and rainfall), site conditions (wind, pests, slope etc.) and site management (Ellis, 2001). In addition to environmental parameters, the rate of carbon sequestration could be affected by the behaviour of the local population, for which the forest or land may be an important source of income. Important environmental impacts that may affect the social acceptability and success of carbon sequestration projects are its effects on biodiversity, water resources, and ecosystem productivity (IPCC, 2001). Co-operation with the local population is thus necessary in order to reduce social risks (for example, illegal deforestation).

In *methane projects*, the project activity level (x^p) can vary considerably depending on the project type and the method selected. For example, in methane recovery from solid waste disposal, at least three different accounting methods are available (IPCC, 1996). Both gas recovery volume and the methane content of the gas can vary over time. Methane projects are unlikely to conflict with the interests of stakeholders as they improve local environmental conditions.

In *energy efficiency projects*, the definition of the activity level x^p is not trivial. Energy consumption depends not only on the efficiency, but also on several other parameters like economic growth, technological change, product movements, policy or regulatory shifts, social and population pressure and market barriers (Vine and Sathaye, 2000), which can either be included or excluded. Social factors are present via the potential *rebound* effect: A decrease in the unit price of energy services can (partly) be compensated by an increase in consumption.

3. Risk diversification

One way to reduce the substantial risks involved in project-based climate change mitigation activities is portfolio diversification (Janssen, 2001; Springer, 2003). The basic idea behind it is simple: The more projects or assets an investor owns, the less he is affected by the failure of a single project. The correlation of the returns of the assets is an important parameter. The lower it is, the greater are the gains from diversification. Portfolio diversification is widely applied in theory and practice of financial markets. There are also a few applications in the field of energy economics. Humphreys and McClain (1998), for example, analyse the United States' exposure to energy price volatility and compare its current portfolio of energy supply to an optimised portfolio.

Portfolio optimisation can also be applied in the context of GHG reduction investments.[5] The average *return* (in dollars or emission permits) of a portfolio of projects that generate emission permits is a weighted average of the returns of each project. Consider, for example, a portfolio with two projects of equal size and costs, whose annual returns are 5 per cent (or 5 t of CO_2 per dollar invested) and 10 per cent (or tons of CO_2), respectively. Then, the expected return of a portfolio which is fully invested in those two projects is simply the average return, 7.5 per cent (or tons of CO_2). The *risk* of a project or a portfolio of projects can be measured as the variance of returns. Most investors not only have a

[5] For a more formal description, see Springer (2003).

preference for high returns, but also for *stable* returns. Projects whose returns vary little over time—thus exhibiting a low variance of returns—are preferred to very volatile projects with comparable returns. The crucial point in risk diversification is the fact that the *variance* of a portfolio of projects is *not* the average variance of the returns of all projects. Rather, the variance of a portfolio is a weighted average of the variance of all projects and their *covariance*. The lower the covariance (or correlation) of the returns of two projects, the lower is the variance of the returns and thus the risk of a portfolio.

3.1. Returns of climate change mitigation investments

The return of a project is a measure of its profitability. We can define returns as the change in wealth from one period to the next. This general definition holds for investments that generate either financial or real returns. For financial investments like stocks, for example, the return is usually stated more specifically as

$$r_t = \frac{S_t - S_{t-1} + d_t}{S_{t-1}}, \quad (3)$$

where S_t is the market value of the stock(s) in period t; d_t the dividend in period t.

Comparing the change in wealth to the initial level of wealth makes projects or assets of different size comparable. The information needed to calculate the return on investment is easily accessible for stocks which are traded daily on the stock exchange.

How could the return on investment in a climate change mitigation investment be determined? As with all *real* investments, the return is the difference between the market value of the output and total costs. Again, this return should be expressed in relative terms to make projects comparable. Hence, we can write the return of a climate change mitigation project in period t as

$$r_t = \frac{p_t^{ghg}(e_t^b \cdot x_t^b - e_t^p \cdot x_t^p) - C_t^{ghg}}{1/T \sum_{t=1}^{T} C_t^{ghg}}. \quad (4)$$

In practice, this characterisation is of limited use because consistent GHG price data does not exist.[6] This problem is also present in other contexts: Most small-cap stocks and real estate properties are traded seldom and in small quantities. Hence, there is no (public) price information. Nevertheless, the returns on real estate property can be estimated by analysing the *fundamental data* of an asset or property (see e.g. Brown and Matysiak, 2000). For real estate, for example, the main determinants of the returns are the rents. They differ for commercial and housing property as well as among cities. Rents also change substantially over time, reflecting general economic and specific market conditions. Hence, instead of looking at the evolution of the *market value* of different real estate properties, one can analyse the dynamics of the rents as a reasonable *proxy* for the returns on real estate investments.

Similarly, in the absence of GHG permit price data, the *project performance*, i.e. the amount of permits generated in climate change mitigation investments, can serve as a proxy for the unobservable returns (Janssen, 2001). The number of permits accruing from a project every year is likely to vary significantly over time. Permit related costs (C_t^{ghg}), on the other hand, do not vary significantly over time, unless the GHG investor contractually shares the operating costs with the project sponsor. In the following, we assume a case where the investor only pays (part of the) constant upfront costs. For our subsequent empirical analysis, we define returns as

$$r_t = \frac{(e_t^b \cdot x_t^b - e_t^p \cdot x_t^p}{AC^{ghg}}. \quad (5)$$

Dividing annual emission reductions by average annual costs (AC^{ghg}) yields an annual return denominated in tons of CO_2 reduced per dollar invested, which is independent of the size of a project.[7] Furthermore, the term $1/r_t$ can be interpreted as (annual) average *abatement costs*, a more meaningful number in this context.

3.2. Data

We analyse a sample of projects from the VRGHG Program administered by the Energy Information Administration of the United States. This program has been initiated under Section 1605(b) of the Energy Policy Act of 1992. It states that public and private entities may report *reductions in greenhouse gas emissions* achieved as a result of voluntary reductions, plant or facility closings, and State or Federal requirements. The guidelines for reporting date from 1994 (EIA, 1994). In the year 2000, 1882 projects totalling emission reductions of 269 million tons CO_2 have been reported (EIA, 2002). However, most projects started very recently and thus could not be used for the purpose of our analysis, because the variance of returns can only be interpreted as a measure of risk if data for several consecutive years exist.

The VRGHG Program requires companies to establish "a reference case", i.e. the *baseline* for all projects

[6] Greenhouse gas emission permits traded until today are very heterogeneous, ranging from emission offsets to government-issued allowances (Varilek and Marenzi, 2001). Hence, their prices are not comparable. A further practical problem is that in most cases prices are not made public neither by buyers and sellers nor by brokers.

[7] By using average annual costs to calculate returns, we may *underestimate* the returns in some cases: Projects with high initial investments compared to operation and maintenance costs exhibit higher average abatement costs in the beginning, if the project lifetime is long (say, 20 years) and the rest of the project lifetime is not considered in the analysis.

reported in the program. Two possibilities to determine the reference case are proposed: the basic and the modified reference cases. The *basic* reference case refers to a baseline using historic emissions. The *modified* reference case refers to a baseline where the historic emissions are adjusted, e.g. due to growth or decline in demand or, in the case of new capacity, to non-existing earlier emissions. Eleven out of 21 projects which we analyse use modified reference cases, which are mostly fixed, relative (rate-based) baselines. The other 10 projects have an absolute baseline (i.e. in tCO_2e) which corresponds to total emissions in the year before the project start in all but one cases. Note that the emission reductions were not required to be *additional* in the sense of the Kyoto Protocol.

The second input needed for our portfolio approach is *cost data*, which is *not* provided in most project reports. For two projects, cost data was provided in the publicly available reports. One of them is the Rangely Weber Sand Unit, a CO_2 injection project in the state of Colorado. In that project, CO_2 from a gas plant is injected into an oil reservoir (instead of being vented to the atmosphere) to increase oil recovery and extend the life of the field. The injected gas, up to 52,000 t of CO_2 annually, is argued to be permanently sequestered in the oil field because of its geological properties and the fact that all wells are plugged at the end of their lifetime. We took the value of the methane and helium that could not be sold as a result of the CO_2-injection as the cost figure of that project.

The second project is a wind power retrofit (SeaWest Windpower, Inc.) located in California. The facility was installed in 1985 and produced approximately 71,000 MWh of electricity in 1990. In 1991 and 1992, production declined because of deterioration over time and other problems. The CO_2 emission reductions claimed for this project are the result of major retrofits and repairs undertaken until 1995. According to the project report, these activities cost 2.1 million USD and displaced electricity from fossil fuels equivalent to a total of 36,230 t of CO_2.[8]

Upon written request, we received cost data from 19 projects which started in or before 1993. There are two main reasons for this small number: Many companies responded that they had not kept track of the costs of those projects (separately), others regarded cost information as confidential. Costs comprise total investment costs, operation expenses for conservation, the costs for planting trees or maintenance costs.[9] Project revenues or energy cost savings are not included.

[8] To achieve comparability of the annual emission reductions, we adjusted the numbers for 1999 and 2000 (upwards) to take account of capacity changes in those years.

[9] Maintenance costs were used in the case of an old hydro-power plant built in the 1920s.

Table 3
Returns and abatement costs (1993–2000)

Project no.	Project type	Mean return	Abatement costs ($/$tCO_2e$)	IRR at permit price of 2$/t (%)
1	SEQ	0.0676	14.8	11
2	HYD	0.2117	4.7	34
3	EE	0.0081	123.3	1
4	EE	0.0003	3474.9	0
6	EE	0.0056	178.7	1
7	EE	0.0312	32.1	5
5	DSM	0.1180	8.5	19
8	WIN	0.0290	34.4	6
9	WIN	0.0080	125.5	2
10	FOR	3.1959	0.3	511
11	FOR	0.3083	3.2	49
12	FOR	0.2460	4.1	39
13	FOR	0.1550	6.4	25
14	FOR	0.8350	1.2	134
15	FOR	0.4543	2.2	73
16	FOR	0.3131	3.2	50
17	FOR	0.2767	3.6	44
18	FOR	0.1429	7.0	23
19	FOR	0.0877	11.4	14
20	FOR	0.1752	5.7	28
21	FOR	0.0108	92.4	2

SEQ: sequestration, HYD: hydropower, EE: energy efficiency (supply side), DSM: demand side management, WIN: wind power, FOR: Forestry.

Table 3 shows mean annual returns calculated according to Eq. (5), average abatement costs and the internal rate of return (IRR)[10] for a hypothetical permit price of USD 2 per ton of CO_2 equivalent for 20 projects. Such a price is in the middle range of prices currently paid for verified emission reductions, whose government recognition is possible, but not guaranteed (Varilek and Marenzi, 2001). Note that the returns of many of these projects would be significantly lower if the costs for baseline determination, verification, and legal services were added. Transaction costs for JI and CDM projects are estimated to be 57,000 to 90,000 USD for supply side energy efficiency projects and 3000 to 15,000 USD annually for monitoring and verification (Harmelink and Soffe, 2001). The PCF (2003) reports much higher transaction costs: 265,000 USD for JI and CDM projects (without verification). There is a consensus that the share of transaction costs is particularly high for small-scale projects (see also Fichtner et al., 2003).

Average abatement costs differ strongly among the selected projects, ranging from less than one dollar to

[10] The internal rate of return (of the investment in emission reduction only) has been calculated for illustrative purposes, using total investment costs and emission reductions achieved during the project lifetime (i.e. 8 years).

Table 4
Risk, return, and minimum variance portfolio weights

Project no.	Project type	Mean return (tCO2/$)	Standard deviation	Coefficient of variation	MVP weights
1	SEQ	0.0676	0.025	0.37	0.08
2	HYD	0.2117	0.030	0.14	0.04
3	EE	0.0081	0.004	0.44	0.35
4	EE	0.0056	0.004	0.68	0.29
5	EE	0.0312	0.006	0.19	0
6	WIN	0.0290	0.008	0.28	0.22
7	WIN	0.0080	0.003	0.43	0.02
	MVP	0.0238	0.001	0.02	

MVP: minimum variance portfolio, SEQ: sequestration, HYD: hydropower, EE: energy efficiency, WIN: wind power, FOR: forestry.

more than 3000 dollars per ton of carbon dioxide.[11] Fifteen projects have average abatement costs between 3 and 150 USD, three projects are below and two are above this range. The wide range of costs is not surprising, since our sample includes projects which were not solely undertaken to reduce emissions of GHG. Forestry projects are most inexpensive (except for no. 21). The hydropower, demand side management and sequestration projects are also low cost projects, while the wind and energy efficiency projects exhibit significantly higher costs (lower returns).

For two reasons, two-thirds of the projects listed in Table 3 could not be used for illustrating the effect of portfolio diversification. First, in the EIA reports, there is often a rising *trend* in emissions reductions in projects, which does not result from an improved performance or normal activity variation, but from the gradual increase in emission abatement measures (for example, more trees were planted every year, which led to an increase in carbon storage). If possible, we eliminated this effect.[12] Projects where adjustments could not be made were excluded from our sample. Second, in most forestry projects and in the demand side management project, emission reductions reported were based on *estimates* of annual carbon uptake or energy saved. Based on the estimates, which were usually made once for each project, emission reductions were reported in the following years. The problem with estimated emission reductions is that they do not represent the actual variation in carbon uptake or emission reductions. They are either constant or increase at a constant rate, so that the variance is no meaningful measure of risk.

[11] Note that project no. 10—the only project with average abatement costs below one dollar—is a special case, as it includes carbon sequestered as a result of forest *conservation*, which naturally is a very inexpensive, but also highly controversial project category. The other extreme case, project no. 4, is an energy efficiency project with very high capital costs.

[12] In project no. 6 and 7, emissions reductions for the years 1999 and 2000 were adjusted according to the change in capacity.

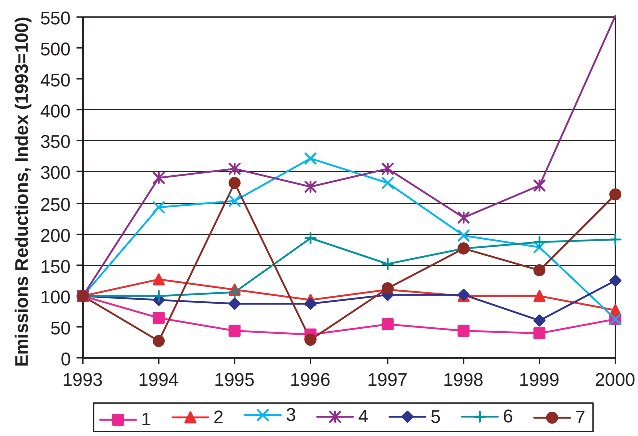

Fig. 1. Variation of returns (1993–2000).

3.3. Illustrating the effect of portfolio diversification

Table 4 shows the mean returns, the standard deviation of annual returns, and the coefficient of variation for seven emission reduction projects. Several points are noteworthy: First of all, the *volatility* of returns is remarkably *high*. This is illustrated in Fig. 1, which also shows *little co-movement* in project returns.

Second, the hydropower and the sequestration project exhibit the highest absolute standard deviation of returns. Yet in relative terms, their variation is small, as they also have the highest returns. Annual returns varied most in project no. 3, one of the energy efficiency projects. Third, the variation of annual returns differs strongly *within* the same project type. Among the energy efficiency projects, for example, the second lowest and the highest coefficient of variation can be found. Hence, the risks appear to reflect individual events rather than systematic differences between project types. For the reasons given in Section 2, we would expect to find systematic differences. The fact that we do not see them here should not be taken as evidence against our hypothesis, since the number of projects is not large enough to perform any solid test. Moreover, our project categories are quite broad. Energy efficiency projects,

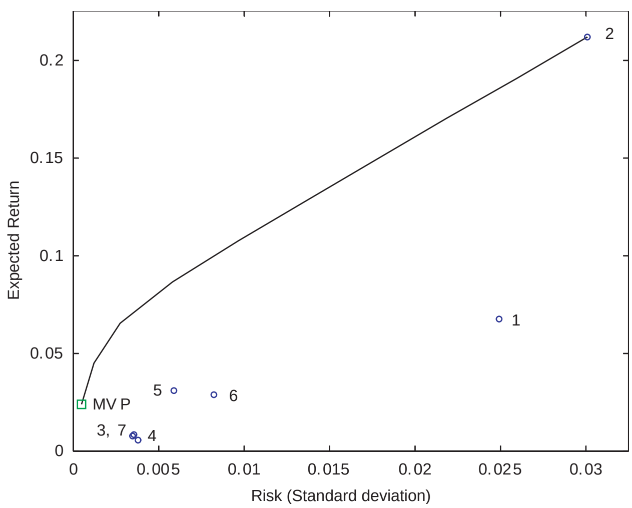

Fig. 2. Efficient portfolio.

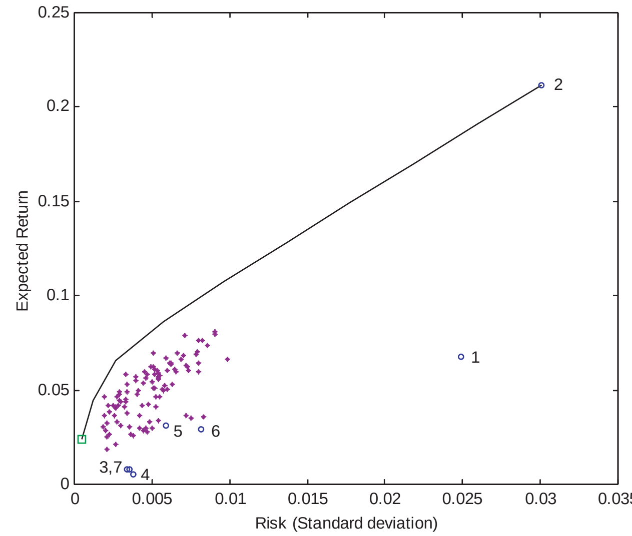

Fig. 3. Naive diversification (100 random portfolio).

for example, comprise very different projects, ranging from demand side management to technical measures on the supply side. Perhaps, differences between project types would be more visible if the categories were defined more narrowly.

From the expected return vector and a variance–covariance matrix estimated from our sample, we determine the *efficient frontier* using quadratic programming. The efficient frontier describes combinations of projects which minimise risk for each level of return. Since GHG emissions reporting at project level did not start before 1990, our time series are not sufficiently long to allow the precise estimation of variances and covariances. Hence, the results can only roughly illustrate the potential for portfolio diversification.

Fig. 2 shows the efficient frontier. The minimum variance portfolio (MVP) is located well above and to the left of the three least risky projects (no. 3, 4 and 7). Its standard deviation is 0.001, compared to 0.003 for project no. 7 (see also Table 4). Hence, in this case, portfolio diversification significantly reduces investment risk.

The efficient frontier also lies well above of the projects no. 5 and 6 in the risk-return space. This implies that an investor could have achieved, for example, a return more than twice as high as the return of project no. 5 without increasing his risk exposure by investing in the corresponding portfolio on the efficient frontier. The returns of investing in an optimised portfolio at low risk levels would have been 3–10 times higher than the returns of the individual projects.

In reality, neither risks nor returns of climate change mitigation projects are known ex-ante. Yet, this information as well as the covariance between project returns is needed to construct an optimised portfolio. If this information is not available, diversification may still yield a risk reduction, though only a smaller one than in the case of perfect information. Fig. 3 shows 100 portfolio with randomly chosen portfolio weights as well as the seven original projects and the efficient frontier. The random portfolio are superior to most single projects in terms of risk and return. However, none of the random portfolio happens to lie exactly on the efficient frontier.

Thus, even naive diversification yields better results than most single project investment strategies. On the other hand, diversification without exact information about the risk-return profile and the covariance structure naturally does not achieve the same results as the (ex-post) optimised efficient portfolio.

4. Conclusions

Climate change mitigation investments are exposed to price, cost, and quantity risks. In this paper, we focus on *quantity risk* because the other risks are more difficult to assess quantitatively. We describe environmental, technological, economic, and social factors which affect project activity levels and thus quantity risk. These factors do not influence the project activity level of all project types equally, which implies that *diversification* of investments is a promising risk reduction strategy in this context as well.

We present a methodology to quantify risk and return of climate change mitigation projects and illustrate it using a small sample of projects from the US Voluntary Reporting of Greenhouse Gases Program. Calculating meaningful values for risks and returns of those projects presented a number of challenges. First of all, sufficiently long time series of emission reductions do not exist. Second, many firms have not collected cost data or consider them confidential. Third, emission reductions were often estimated, but not measured (monitored). If constant estimated reductions per year are reported, the variance of emission reductions is zero. However, interpreting this as a low investment risk would be misleading.

We find that returns differ significantly across project types. Project risks (measured as the variation of annual returns) are high, but show no clear pattern across project types. Since we do not take market (price) risks and political risks into account, our analysis is likely to understate the risks involved in project-based climate change mitigation. Political risks such as the ratification of the Kyoto Protocol affect all projects equally. Hence, they cannot be diversified by investing in different emission reduction projects.

A portfolio allocation strategy based on a quantitative analysis would require a much larger sample covering a longer time period than the one we used. Nevertheless, the methodology presented in this paper could help to accomplish such a task. Our illustrative results indicate that portfolio diversification is a viable risk reduction strategy in the context of project-based climate change mitigation. Hence, *carbon funds* not only serve as vehicles for channelling investments, but can also help to reduce investment risks.

Acknowledgements

This is a revised version of our IWOe Discussion Paper No. 99. We thank Sven Bode, Karl-Heinz Flatnitzer, Josef Janssen, Michael Rumberg, Matt Varilek, and two anonymous referees for helpful comments and discussions. The paper was written as part of the European Research and Development Project "Implementing the Kyoto Mechanisms—Contributions by Financial Institutions (IMKYM-COFIN)". We wish to thank the companies that provided cost data for their co-operation. Financial support from the European Community under the specific programme for research, technological development and demonstration on "Energy, Environment and Sustainable Development" and from the Swiss Federal Office for Education and Science is gratefully acknowledged (contract no. EVK2-CT-2000-00076). The views expressed in this article are those of the authors, and do not necessarily reflect the opinions of the European Community. The Community is not responsible for any use that might be made of data appearing in this paper.

References

Brown, G.R., Matysiak, G.A., 2000. Real Estate Investment. A Capital Market Approach. Pearson Education, Essex, UK.

DTI (Department of Trade and Industry), 2001. Digest of United Kingdom Energy Statistics 2001. London.

Ellis, J., 2001. Forestry projects, permanence, credit accounting and lifetime. OECD and IEA Information Paper, Paris.

Energy Information Agency (EIA), 1994. General guidelines and supporting documents establishing the voluntary reporting of Greenhouse Gases Program, Washington, DC.

Energy Information Agency (EIA), 2002. Voluntary reporting of greenhouse gases 2000. Office of Integrated Analysis and Forecasting, US Department of Energy, Washington, DC.

European Commission, 2001. Joint implementation for international emissions reductions through electricity companies in the EU and CEE Countries (JOINT). Final Technical Report.

Fichtner, W., Graehl, S., Rentz, O., 2003. The impact of private investor's transaction costs on the cost effectiveness of project-based Kyoto mechanisms. Climate Policy, forthcoming.

Haites, E., Yamin, F., 2000. The clean development mechanism: proposals for its operation and governance. Global Environmental Change 10, 27–45.

Harmelink, M., Soffe, P., 2001. Financing and Financing Mechanisms for Joint Implementation (JI) Projects in the Electricity Sector. Ecosecurities, Ecofys, Utrecht.

Humphreys, H.B., McClain, K.T., 1998. Reducing the impacts of energy price volatility through dynamic portfolio selection. Energy Journal 19, 107–131.

IPCC (Intergovernmental Panel on Climate Change), 1996. Greenhouse Gas Inventory Reporting Instructions, Vol. III. Bracnell, UK.

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change 2001—Mitigation. Cambridge University Press, Cambridge.

Janssen, J., 1998. Strategies for risk management of joint implementation investments. In: Riemer, P., Smith, A., Thambimuthu, K. (Eds.), Greenhouse Gas Mitigation: Technologies for Activities Implemented Jointly. Elsevier, Amsterdam, pp. 357–365.

Janssen, J., 2001. Risk management of investments in joint implementation and clean development mechanism projects. Ph.D. Thesis. University of St. Gallen, Switzerland.

Kartha, S., Lazarus, M., Bosi, M., 2002. Practical baseline recommendations for greenhouse gas mitigation projects in the electric power sector. OECD and IEA Information Paper, Paris.

Larson, D.F., Parks, P., 1999. Risks, lessons learned, and secondary markets for greenhouse gas reductions policy. Research Working Paper 2090. The World Bank, Washington, DC.

Laurikka, H., 2002. Absolute or relative baselines for JI/CDM projects in the energy sector? Climate Policy 2, 19–33.

OECD, 2000a. Ancillary benefits and costs of greenhouse gas mitigation. Proceedings of an IPCC Co-sponsored Workshop, 27–29 March 2000, Washington, DC.

OECD, 2000b. Emission baselines—estimating the unknown, Paris.

PCF (Prototype Carbon Fund), 2000. Lessons learned from the implementation of the prototype carbon fund. Occasional Papers Series, No. 1.

PCF (Prototype Carbon Fund), 2003. PCF Annual Report 2002.

Springer, U., 2003. Can the risks of the Kyoto mechanisms be reduced through Portfolio diversification? Evidence from the Swedish AIJ Program, Environmental and Resource Economics, 25 (4), 395–445.

Statistics Finland, 2001. Energy Statistics 2000, Helsinki.

UNFCCC (United Nations Framework Convention on Climate Change), 2001. Report of the Conference of the Parties on its seventh session, held at Marrakesh from 29 October to 10 November 2001, Addendum, Part two: Action taken by the Conference of the Parties, Vol. II (FCCC/CP/2001/13/Add.2).

Varilek, M., Marenzi, N., 2001. Greenhouse gas price scenarios for 2000–2012: impact of different policy regimes. IWOE Discussion Paper No. 96, Institute for Economy and the Environment (IWOe), University of St. Gallen (HSG), Switzerland.

Vine, E.L., Sathaye, J.A., 2000. The monitoring, evaluation, reporting, verification and certification of energy-efficiency projects. Mitigation and Adaptation Strategies for Global Change 5, 182–189.

Zhang, Z., Maruyama, A., 2001. Towards a private–public synergy in financing climate change mitigation projects. Energy Policy 29, 1363–1378.