

PORTFOLIO DIVERSIFICATION; BENEFITS OF INVESTING IN CARBON MARKETS

FROM A NEW ZEALAND INVESTOR PERSPECTIVE

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A dissertation submitted to Auckland University of Technology in partial
fulfilment of the requirements for the degree of

Master of Business (MBus)

January 2011

Business School – Finance Department

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Attestation of Authorship

“I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.”

Abstract

This study investigates the diversification opportunity for investing in carbon credits from a New Zealand investor's perspective. Investment in carbon credits, a relatively new commodity, is considered an alternative form of investment. The selected model, one of four, for evaluating the diversification opportunity is *Minimum Variance Portfolio Optimisation using the shrinkage method*. Comparing results for the period from January 2006 to January 2010 has shown more diversification in the portfolio with the carbon commodity, in comparison to the same portfolio without the carbon commodity (Carbon credit in Europe).

Introduction

It has been generally accepted amongst scientists and politicians that the human activities have caused the concentration of greenhouse gases (GHGs) in the atmosphere (Daskalakisa, Psychoyiosb, & Markellosa, 2009). The visible results of the GHGs are global warming and climate change, which have had disastrous consequences for the environment and the creatures on the earth (Stern, 2007). These environmental problems could spread to all aspects of life on earth including health, the global economy and resources (such as running out of fossil fuels, icebergs melting and forests being destroyed).

To prevent the devastating consequences of the GHGs, the United Nations (1992) established a treaty to bind major industrial countries to reduce their GHGs emissions (primarily CO₂). “The Kyoto Protocol is an international agreement and linked to the United Nations Framework Convention on Climate Change” (UNFCCC, 2010). The treaty came into force in 16 February 2005.

184 parties (countries and unions e.g. European Union and international organisations) have ratified the Kyoto protocol so far. One aspect of regional and international markets has been established to manage the trading of the emissions between seller and buyers. The emissions were only CO₂ at the beginning but other GHGs have been added to them. The protocol includes a mechanism for the trading of financial instruments in emission markets. The largest emissions trading market in the world is the European Union (EU), where more than 95% of the global emission/carbon transactions are being made. The market is based on The European Union Emission Trading Scheme (EU ETS). A Carbon credit represents a tradable permit that allows the owner to emit one tonne of carbon or carbon dioxide equivalent (tCO₂). Carbon

emitters are allowed to emit a certain amount of carbon; they can either use the carbon credits or reduce their emission level in different ways, such as investing in new technologies. This reduction in the emission level can be sold as a 'carbon allowance' (called the EU Allowance in European Emission Market). Emitters also can invest in Clean Development Mechanisms (CDM - investment in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries) to offset their emissions. There has been a considerable increase in carbon transactions during last few years. More than 2 billion tonnes of carbon has been traded in 2007 alone, with the value of more than US\$50 billion. This value has been incorporated in the price of all emission-related products, mainly energy (electricity, gas, oil) and all other consumer products which are related directly (petrochemical products) or indirectly (dairy products) and caused an increase in the cost of those products .

These days, the investors are looking for a new class of investment to diversify their portfolio of investment. As a new class of assets, emission trading markets have been introduced to financial markets in the last few years. These markets are growing fast and have attracted many investors.

New Zealand is one of the countries with many natural resources which could benefit from the Emission Trading Markets (according to the government at the time of joining the Kyoto Protocol). Also, the New Zealand public supports the idea of a green and protected environment. But, on the other hand, the actual trading of emission allowance and its market instruments is very primitive at this stage. Still, a lot of regulatory work has been done on this issue by the government and private companies

(such as New Zealand Carbon Exchange¹). There is an opportunity for New Zealand investors to invest in a mature carbon market to be able to diversify their portfolios (if such diversification opportunity exists).

This research investigates the benefits of investment in Emission Allowances / Carbon Emissions Market in Europe for New Zealand investors who seek diversification in their portfolios.

Next section is the introduction to the carbon market mechanisms, structure of the European Emission Market (the largest emission market in the world) and the emission trading methods. The literature review covers a review of how some assets (such as art, stamps, antique furniture and wine) have been used as alternative investments, the methodology used in the studies and their contributions to the topic. The review also includes papers that have investigated emissions modelling (such as emissions spot price behaviour and derivatives). In the methodology and data description section, the indices and data sources are introduced. In this section, the advantage and disadvantages of the selected models are discussed. Finally, the empirical results are presented in a separate section following with the conclusion section.

¹ www.nzcx.com

Introduction to Emission Markets²

With the ratification of the Kyoto Protocol, countries with reduction commitments must achieve their reduction target through national GHG reduction programmes. To assist the countries to meet their targets, the Kyoto Protocol introduced *Carbon Markets* that included three market-based mechanisms:

A. Emissions Trading

This mechanism was introduced under the 'Cap and Trade' trading scheme. As the name indicates, this system is based on putting a permanent cap on each country's emissions. Each government usually defines the specification of the cap (e.g. sources of pollution, the permitted amount of emission, the period of cap, and the cap unit measured) within their borders. The government then allocates/distributes the created allowances (equal to the size of the cap allocated by the Kyoto Protocol) to the regulated sources (e.g. industries, companies). The allocation is usually smaller than the historical emission by the regulated sources. Hence, the companies have four options to deal with their emission status:

² There are some common keywords in carbon and emission trading discussions. These keywords have been used in most of the next section's reviewed articles about emission related topics.

Cap and Trade: This method sets an aggregate cap on all pollution sources (industries, factories etc.), then allows trade among them to identify which source has more pollution than others. The compliance units traded in this system are called *Allowances* (Tietenberg & Johnstone, 2004).

Baseline and Credit programme: This system uses a baseline and there is no aggregate cap. Polluters can reduce their emissions under the baseline and sell the credits earned.

Certified Emission Reduction (CER): In the emission trading market, one unit of allowance or Certified Emission Reduction (CER) is equivalent to one metric tonne of CO₂. There is a spot market for Emission Allowances (usually in Euros per tonne of carbon dioxide or CO₂e). There are futures and options available for the allowances, too (IETA, n.d.).

- 1) Match their emission with the allocated amount,
- 2) If emissions are over the limit, cover their shortage by purchasing an emission allowance,
- 3) If emissions are less than the limit, sell the margin in the market,
- 4) If emissions are less than the limit, save them for future years (Farrell, 2004).

B. The Clean Development Mechanism (CDM)

Under this mechanism, industrial countries are allowed to undertake emission reduction projects in developing countries and earn a saleable Certified Emission Reduction credit which is equal to one tonne of CO₂. The achieved credits from CDM projects can offset the emission position of the country if it is over the limit, or be saved for future sales. Also, the emission trading market allows the credits to be sold to other parties. CERs are issued by the UNFCCC-operated CDM registry when the emission reduction units (ERUs) have been verified by independent organisations³. (Cox, Simpson, & Turner, 2010)

C. Joint Implementation (JI)

This mechanism “allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party)⁴ to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex

³ For the definition of such an organisation see:
<http://cdm.unfccc.int/Projects/pac/howto/CDMProjectActivity/VerifyCertify/index.html>

⁴ Under the UNFCCC, a group of countries (basically the OECD plus the ex-Soviet Union countries) are known as Annex 1 countries. A subset of the Annex 1 countries that ratified Kyoto (a group known as Annex B) agreed to reduce their GHG emissions relative to 1990 levels on aggregate by 5.2%. (Cox, et al., 2010)

B Party, each equivalent to one tonne of CO₂, which can be counted towards meeting its Kyoto target.”(UNFCCC, 2010)

Each country needs to have a registry to hold the Kyoto units and design a system for transferring their units locally and internationally. Assigned amount units (AAUs), removal units (RMUs), and ERUs are issued by the national registry of each country. If a country approves another country's issued units (AAUs, RMUs and ERUs) it is able to transfer them to each other's accounts locally and internationally. The first economy-wide emission trading scheme was introduced by the UK with the intention of making London the main location for emission trading (Cox, et al., 2010).

Structure of the European Market

The European Union Greenhouse Gas Emission Trading System (EU ETS), started in 2005, is the largest emission trading scheme and currently covers around 12,000 installations in the energy and industrial sectors. It represents 40% of the total greenhouse gas emissions for the European continent (Cox, et al., 2010).

The participants in the EU ETS are the installations (12,000 large industrial companies covered under the EU ETS), CDM Project developers (who finance the projects and receive the CERs created from the projects), brokers (like any other asset trader, they facilitate CER market trading by sourcing CERs or operations of the secondary market), traders (trade emission units) and voluntary offsetters (sell/buy emission units to offset own emissions) (Cox, et al., 2010).

Emission trading methods and locations

The primary market of the emission allowances and credits are being carried out by the national governments. “Allowances and credits first become tradable through an

auction process.”(Cox, et al., 2010, p. 12) This method generates revenue for the government and sells the CER credits released by CDM projects. The UK debt management office uses its experience in auctioning government bonds to auction EUAs emission allowances. (Cox, et al., 2010)

The secondary trading markets, as with any asset, consist of a private contract (between the parties who successfully bought their emissions under the cap and those parties ready to pay cash for such emission credits), OTC and exchange markets. Emission units are traded in the form of spot, forwards, futures and options. The major exchange markets that trade EU ETS eligible units are BlueNext, Climex, the European Climate Exchange (ECX/ICE – ECX operates in partnership with the Intercontinental Exchange (ICE) Europe), the European Energy Exchange (EEX), the Green Exchange and Nord Pool.(Cox, et al., 2010)

Table 1 summarises the six major emission exchanges under EU ETS, their country of operation and their offers.

| Exchange | Country of Operation | Continuous Exchange Trading | | | | | | | | Auctions | OTC Clearing | |
|----------------|----------------------|-----------------------------|------|------|---------|------|----------|------|---------|----------|--------------|------|
| | | Spot | | | Futures | | Forwards | | Options | | | |
| | | EUAs | CERs | ERUs | EUAs | CERs | EUAs | CERs | EUAs | | | CERs |
| ECX/ICE | UK | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| Bluenext | France | ✓ | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ |
| EEX | Germany | ✓ | | | ✓ | ✓ | | | ✓ | | ✓ | ✓ |
| Nord Pool | Norway | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Green Exchange | USA | | | | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| Climex | The Netherlands | ✓ | ✓ | ✓ | | | | | | | ✓ | |

Table 1: Offerings of European emissions exchanges (Cox, et al., 2010, p. 15)

Literature Review

Investing in other classes of assets has been a method for investors to diversify their portfolios and seek more profit or reduce risks. Stamps, wine, violins and art (in general) are some examples of these investments. One of the similarities of the studies on the above classes of assets to emissions is the location of the market. For all of them, most of the transactions concentrate in one or two indices (or in a specific area, like Europe or United States). The studies have modelled price trends and the diversification opportunities in investing in the assets.

Art

Some authors have found that investment in art has less return than long-term government bonds (Baumol, 1986) and equity investments (Renneboog & Houtte, 2002). One of the reasons for lower return on art (especially in the 80s) could be the lack of communication technology such as auction websites. Renneboog and Van Houtte (2002) have used Sharpe and Treynor ratios, and Markowitz efficient frontiers to investigate investment in paintings and compared its risk-return trade off with stocks. The data has been gathered for the period 1970 to 1997 (10500 art auction prices from around the globe). In this research, most of the auction periods (which the prices have been extracted from) had been before the 90s and the internet boom.

The art market is not easily accessible on the internet or through agents for investors/traders. This can be one of the reasons that the art market was not so efficient at attracting investors, as it could have lead to underperformance of the art market compared to the equity market, according to the research. The internet has had a significant impact on financial markets and has brought most of the markets very

close to the investors and traders (a click away). Renneboog and Van Houtte (2002) also showed that “art yields limited diversification potential”(Renneboog & Houtte, 2002, p. 1). The authors have shown that sometimes there are big returns in investment in visual arts, but there are, however, drawbacks such as transaction costs (more than 25% of the auction price), taxes, annual insurance and even copyright costs. In Figure 1, the art market evolution has been compared with value-weighted world stocks. Figure 2 shows that adding art to the investment portfolio shifts the efficient frontier upwards. This gives investors a higher return with the same amount of risk in the equity portfolio.

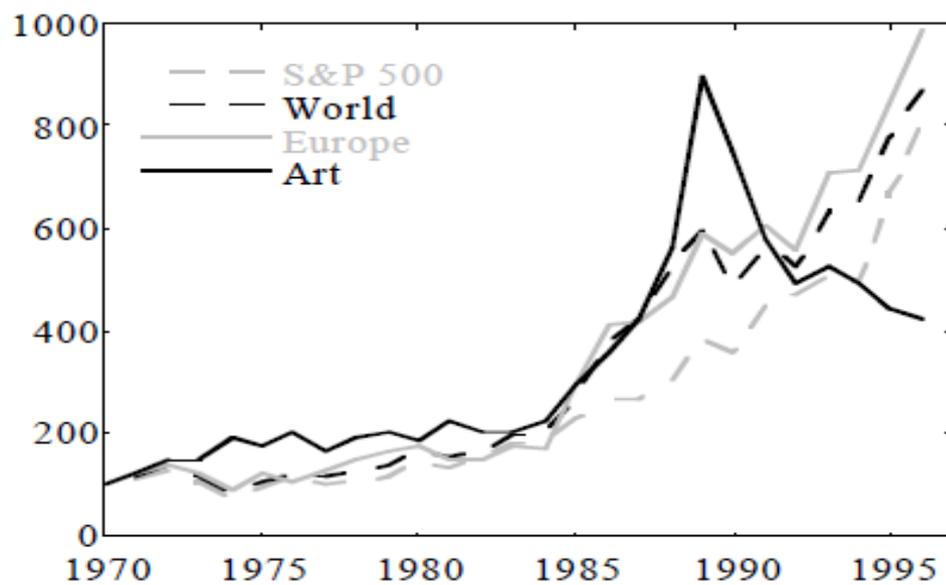


Figure 1. Art and Stock market indices 1970-97 (Renneboog & Houtte, 2002, p. 15)

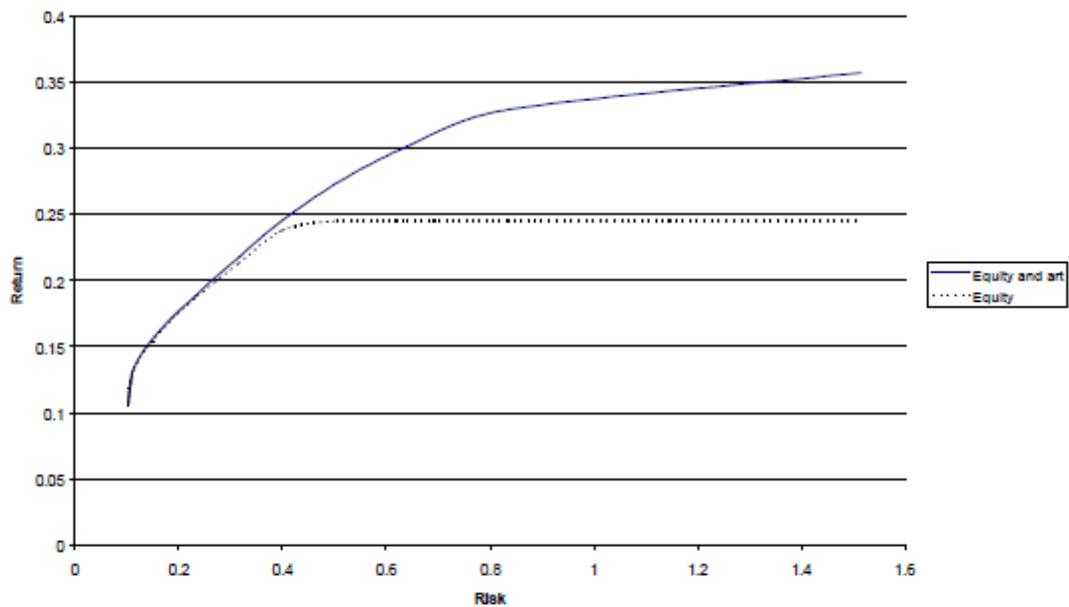


Figure 2. Efficient Frontier: Equity markets and auctioned art (Renneboog & Houtte, 2002, p. 17)

There are two ways an art piece can be sold: at auction or by a dealer. Two main factors make up the final price: mark-up by a dealer (the higher the price, the lower the mark-up; usually about 10% of the hammered-down price to the buyer and 10% of the proceeds to the seller) and the estimated holding period. Other factors that can change the price are the history of the owners or the size and quality of the paintings. Even bidding by a well-known collector can increase the price. (Veld & Veld-Merkoulova, 2007)

Similar to the last discussed research (Renneboog & Houtte, 2002), Anderson (1974) investigated the rate of return on paintings and concluded that the rate of return on recent (20th century) paintings is the same as the common stock but, in the long run, the paintings' rate of return is almost half of the common stock. He used regression of price on several attributes to find the dependency and significance impact of the attributes on the price. Anderson tested different attributes of the paintings and found the price is dependent on the year of sale, the size of the painting and the

reputation of the artist. He also found that the two factors 'the year sold' and 'whether the artist is alive or not' were insignificant.

There are some studies that show the importance of the relationship between the art market and the economy in general, but relatively little research has been done on it. Goetzmann (1993) and Mei and Moses (2002) have found opposite results. While Goetzmann has shown a high correlation between the art index and an index of London Stock Exchange shares over the very long term, Mei and Moses reported a correlation coefficient of 0.04 between the S&P 500 and annual real returns of the art index from 1950 to 1999. In more recent research, Pesando and Shum (2008) have found a correlation of 0.21 between S&P 500 and the index for modern prints (data for the period 1977-2004).

Goetzmann (1993) has used repeat-sales regression (RSR) to estimate the fluctuations in value of the art items by using the purchase and sale prices. This method has frequently been used to estimate an index of real-estate returns. Anderson (1974) and Goetzmann (1993) have applied the repeat-sales regression (RSR) to the art market.

Goetzmann has also shown the high correlation between the art and the stock and bond markets. This may be the reason that many investors do not invest in art items such as paintings, the subject of the research.

Mei and Moses (2002) have extended the work of Goetzmann (1993) and Pesando (1993) by focusing on the increase in the number of art sales. This has helped them to overcome two major obstacles in analysing the art market with heterogeneity of artworks and infrequency of trading. They have used a repeat-sales regression (RSR) method to analyse their new set of data (that has more repeated sales data than

previous studies. They have concluded that, although the investment in art underperforms stocks, it has been a better investment than some fixed-income securities. They mentioned that artworks can help diversification of a portfolio.

By reviewing the above studies, the difference in the reported mixed results could be caused by:

- Use of different intervals of observation estimation.
- A common method in creation of art index: drawback of the repeat sales regression.
- Ignoring the global art market trading and concentrating on the U.S. market. It has been shown in research by Renneboog and Spaenjers (2009) that the hedonic pricing approach reported a doubled (0.38) correlation between a global art index and a global stock index in comparison to the same art index and S&P 500 (0.19).

Goetzmann, Renneboog and Spaenjers (2009) have pointed out few reasons that show the market may not reflect the correct correlation. First, the return measurement period in art indices and financial market are different. Second, there is a lag between wealth creation in financial markets and investment in art objects. There is evidence that shows that, in the last century, art prices followed the stock market trends. (Goetzmann, 1993)

Stamps

Stamps are one of the collectible items that can be considered as an alternative investment. The methodologies used in studies on stamps can help us in our

methodology selection. Collectors can be described as “individuals who passionately and sometimes even obsessively, search and shop for unique but in essence useless items, such as obsolete postage stamps” (Belk, 1995, p. 3). Collecting stamps goes back to the 18th century when the first prepaid adhesive stamp was introduced to the market in the UK. (Johnson, 2009)

Different methodologies have been used to investigate the diversification and profitability of opportunities from investing in stamps. One of the oldest stamp auctioneers in the US is Siegel Auction Galleries. In 1983, William Taylor found that the α (mean of the annual rate of return of common stocks⁵) and β (systematic risk in the stamp returns) in a regression of excess return of a stamp portfolio on the excess return of a stock market index were not significantly different from zero (using Siegel Auction Galleries' data). But in this research we can see that the time of the research (1963-1977) is prior to the information revolution. A study which showed that the stamp can be a proper hedge for stock investments was carried out by Cardell, Kling and Petry (1995). They have used the natural logarithm (log) of auction prices instead of transaction prices (which had been used by previous authors) to regress on economic factors (the variables). They could show positive α (indication of diversification possibilities). They also showed that the return on investment in stamps is inversely related to systematic factors that have had an impact on returns on stocks and bonds. In 2007, Veld and Veld-Merkoulova have shown diversification evidence from investing in stamps for US and UK investors using the stamp index of Stanley Gibbons 100 (a US based index). They have run Capital Asset Pricing Model (CAPM)

⁵ New York Stock Exchange (NYSE) in William Taylor's study

regression of the monthly stamp index excess returns on the excess returns of the stock market indexes.

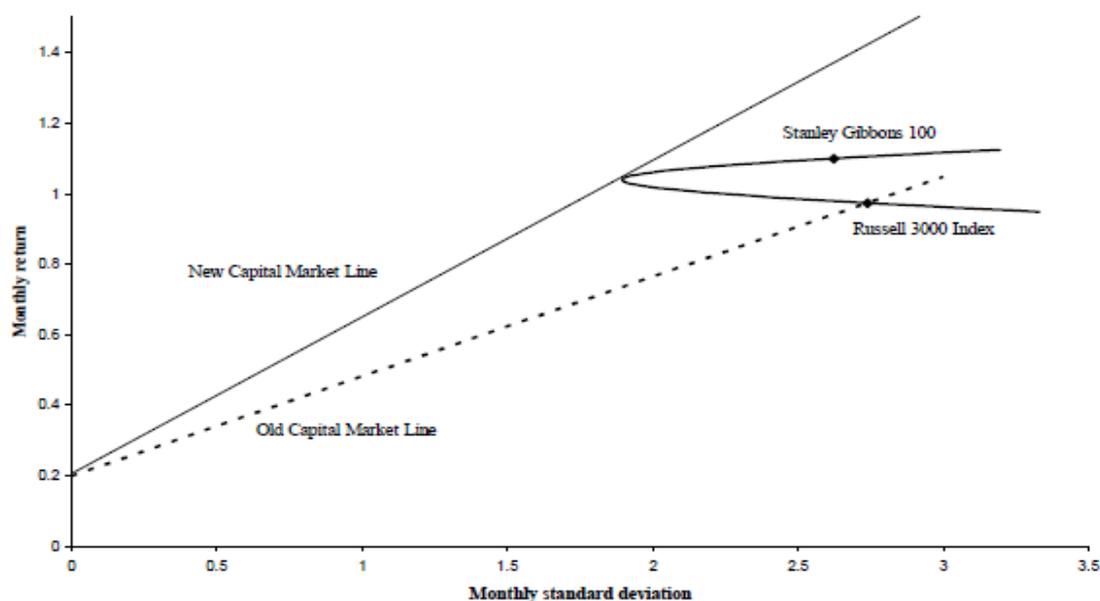


Figure 3. The Capital Market Line with and without stamp investments (Veld & Veld-Merkoulova, 2007, p. 11)

The study shows that adding stamps (Stanley Gibbons 100 – Stamp Index based on actual prices for 100 of the world’s most frequently traded stamps) to a broad portfolio of American stocks (presented by Russell 3000) can change the Capital Market Line (CML). Figure 3 shows the new CML forms above the old CML, which indicates that investment in stamps can reduce the risk and improve the return on the portfolio (Veld & Veld-Merkoulova, 2007).

Wine

Wine is another collectible that has been used for alternative investments. An early study has shown that the return on investment in wine between 1973 and 1979 was very close to zero (Krasker, 1979). But Burton and Jacobsen (2001) investigated a different period of time (1986 – 1996) and showed an 8% nominal return. On the

other hand, Sanning, Shaffer, & Sharratt (2006) found that return on investment in wine can be more profitable than previously reported. Using the Capital Asset Pricing Model, they found some diversification benefits because of its low exposure to market risk factor.

Emissions Allowance

A new class of asset that could have diversification benefits for investors, who are looking for investment internationally as well as nationally, is emission credits. In the last few years, after establishment of the carbon emission market, empirical studies have been performed on modelling and price behaviour of the carbon allowances and the derivatives in the European Union Emissions Trading Scheme (EU ETS), but not on diversification benefits from a New Zealand investor perspective.

In 2008, Chesney and Taschini constructed a constant model to explain the emission allowance spot price dynamics (Chesney & Taschini, 2008). They also extended the model in the presence of asymmetric information in the market. The model and its extension can optimise the cost of the company's emission permit/allowance portfolio allocation.

Seifert, Uhrig-Homburg, and Wagner (2006) have used a representative agent for emission allowances to develop a theoretical stochastic equilibrium model in order to incorporate stylized facts of the European market model. Their reason for using an agent is "in case of an efficient emissions trading market the marginal abatement costs for all emitters should converge and equal the certificate price" (Seifert, et al., 2006, p. 4). The model presented is in the form of stochastic optimal control, with the possibility of deriving a characteristic partial differential equation (PDE). They have

concluded that, from the empirical point of view, the emissions market is relatively efficient compared to other environmental or financial markets. They further found that the CO₂ prices do not follow any seasonal patterns.

On the other hand, another study on emissions market efficiency has been carried out by Daskalakis and Markellos (2008) and showed that the European emissions market does not show consistency with the weak-form of market efficiency. They employed technical analysis and naïve forecasts to test procedures and trading strategies econometrically. Daskalakis and Markellos showed some evidence of inconsistency of the extracted data with the weak form of market efficiency. Their data were extracted from the Powernext, Nord Pool and European Climate Exchange (ECX). Lack of adequate data (due to immaturity of the market) and restrictions imposed on short-selling could be the reason of such an inconsistency.

Price behaviour of Emission allowance has been investigated by Benz and Trück (2009). They discussed two types of models for their analysis: ARCH-GARCH models (which allows for heteroscedasticity) and regime-switching models (Markov regime-switching model). The model they chose to use was the Markov regime-switching model, as this enabled them to estimate the probabilities of any regime change occurrences. These regimes can be determined by unobservable, latent variables.⁶ The authors justified the reason for choosing Markov regime-switching model by pointing out the certain and uncertain variables (such as weather, macroeconomic variables and regulations, policies, sociological factors, respectively). By using in-sample and out-of-sample forecasting analysis, they show strong support for adequacy of their model, “capturing

⁶ There are two classes of regime-switching models. Class one: regime can be determined by an observable variable. Class two is what we discussed above.

characteristics like skewness, excess kurtosis and different phases of volatility behaviour in the returns” (Benz & Trück, 2009, p. 1).

Most recently, Daskalakis, Psychoyiosb and Markellosa (2009) showed how to price futures and options on futures contracts in EU ETS. They showed that for these contracts, a “two-factor equilibrium model, based on a jump-diffusion spot price process and a mean reverting stochastic convenience yield, offers the best approximation to actual prices amongst competing specifications”(Daskalakis, et al., 2009, p. 2). They also tested the proposed model against actual option prices and found it describes in-sample and out-of-sample data better than a simple alternative pricing model. This paper extended the study to three emission allowance markets within the EU to find more evidence of adequacy of their model. They found negative correlation between EU Allowance futures returns with equity market returns. This correlation may show significant diversification opportunities to equity investors.

The carbon market is mostly concentrated in the European Union. Finding the correlation between such a market and other equity indices (in Europe and New Zealand) can help us to find an opportunity for investors to diversify their portfolios and gain profit.

This study investigates the diversification opportunities which would exist for a New Zealand investor in emission allowances in EU.

In the next section, resources of the data and the methodology which have been used in this study are explained.

Methodology and Data Description

This research investigates whether any diversification opportunities exist in investment in carbon allowances and their derivatives in the European Union Emissions Trading Scheme carbon market for a New Zealand investor who can invest in Europe and the USA. The data are daily index values. The period which has been investigated is 15/01/2006 to 15/01/2010.

In this section, the index and model selection are described:

Index Selection

In this study, we use 'Morgan Stanley Capital International (MSCI) Constituent indices of Regional and World indices' in this study. Morgan Stanley constructs the regional indices at the country level and aggregates them into regional and other composites (MSCI, 2010). The indices used are:

All Country - Americas: Consists of Argentina, Brazil, Canada, Chile, Colombia, Mexico, Peru, United States and Venezuela.

All Country - Asia: This constituent index covers China, Hong Kong, India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Singapore, Taiwan and Thailand.

All Country - Europe: This index consists of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

New Zealand Stock: To present a portfolio from New Zealand equity market, the return of NZX All Gross is used as the market return in CAPM model.

New Zealand 10-year Government Bond in New Zealand Dollars (NZD): The bond yields have been used for risk free rate.

Germany 10-year Government Bond (in Euros): This bond has been used as one of the assets in the portfolios.

The emission and energy indices used in this study are:

Intercontinental Exchange: “Through its ECX⁷ product suite, ICE Futures Europe is the leading global marketplace for trading carbon dioxide (CO₂) emissions.”

Nord Pool: The Nord Pool market (the Nordic Power Exchange) is the first multinational exchange for trading electricity and the single power market for Norway, Denmark, Estonia, Sweden and Finland. It was the world's first multinational exchange for trading electric power. Nord Pool is the largest power derivatives exchange and the second largest exchange in European Union emission allowances (EUAs) and global certified emission reductions (CERs) trading.

Powernext: Powernext is an investment firm that operates several energy markets in Europe (based in Paris).

Except for Nord Pool & Powernext indices data (extracted from Bloomberg), the rest of the data has been extracted from Thomson Datastream. The reason for the inclusion of the Euro currency indices is that the major emissions/carbon markets are in the European Union and the Emission Allowances are traded in the Euro. The exchange rate risk needs to be considered and investigated in the research. I will include an exchange rate index to find the impacts of exchange rate risk on diversification of the portfolio (the portfolio created and discussed in this study).

⁷ European Climate Exchange

The indices which have been chosen from Morgan Stanley Constituent indices are representative of the American (the whole continent), European and Asian stock markets. One of the reasons for choosing them along with Nord Pool, PowerNext and ICE indices is to investigate the impact of investing in different regions and including the energy indices and emission units to test the presence of diversification opportunities.

The descriptive data and correlation tables are available in the Appendix. High correlations are observed between MSCI Americas and MSCI Europe (66%) and MSCI Americas and US Treasury 10-year bond (55%). A high correlation between Nord Pool and PowerNext (41%) is expected because both of them are in the same region (European Union) and industry (Energy).

Using the data from the selected indices, I constructed a portfolio and added bonds, Energy indices (Nord Pool and Powernext) and finally emissions index (ICE) to test for diversification opportunity.

Model Selection

I have investigated four models to construct the portfolio and optimise its allocation. The models are: *Mean Variance Analysis (using Sharpe ratio)*, *Naïve diversification*, *Minimum Variance Portfolio Optimisation using shrinkage method* and *Minimum Variance Portfolio Optimisation using the constant correlation model*. In this section, I describe the models and discuss each model's advantages and disadvantages.

1) Mean Variance Analysis (using Sharpe ratio)

Sharpe ratio is an evaluation of risk-adjusted performance. This ratio calculates “the return on a portfolio, in excess of the risk-free rate, divided by its standard deviation” (Solnik, 2000, p. 398).

$$\text{Sharpe Ratio} = \frac{E(R) - \text{Risk free rate}}{\sigma}$$

In this research $E(R)$ is represented by average daily returns of each index. *Risk free rate* is the average of New Zealand 10-year Government Bond (daily) from 15/01/2005 to 15/01/2010.

In this model, matrices are used to formulate the means and weights.

$$\text{Efficient Portfolio} = \frac{S^{-1}[E(r) - R_f]}{\sum S^{-1}[E(r) - R_f]}$$

Where S is the variance-covariance matrix. (Benninga, 2008, p. 301)

The mean-variance method was largely being used for portfolio optimisation after Markowitz (1952) introduced it. However, in 1980, Jobson and Korkie documented the problems with sample covariance matrix of past stock returns under the Markowitz mean-variance optimisation model. They found the sample covariance matrix of expected returns (excess returns) was estimated with many errors (Jobson & Korkie, 1980). In another study, the estimation risk due to uncertain mean returns and their impacts on optimal portfolio selection was discussed (Jorion, 1985). Jorion described “instability of portfolio weights and the sharp deterioration of performance when out-of-sample data are used” as the most notable shortcoming of the Markowitz model (Jorion, 1985, p. 17).

However, the mean-variance model is still known as a method of computing efficient portfolios (Benninga, 2008, p. 301) but it should be considered that it may lead to observing unrealistic portfolio proportions in terms of the optimisation process (Benninga, 2008). After studying these problems, I decided to look for more accurate estimating models.

2) Naïve diversification

In this model, $1/N$ of the portfolio is simply allocated to each component of it. DeMinguel, Garlappi and Uppal (2009) have found that using the naïve diversification method is almost the same as using other more complicated methods. They have also shown that other methods have not continuously outperformed the naïve diversification method.

To evaluate these portfolios and to investigate whether the diversification opportunity exists using the naïve diversification, I use Capital Asset Pricing Model (CAPM):

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it}$$

Where R_{it} is return of portfolio i at time t , R_{ft} represents the return of the risk-free rate (daily return of New Zealand 10-year Government Bond) at time t and R_{mt} is the market return (NZX All Gross daily returns) at time t . Veld and Veld-Merkoulova (2007) have used CAPM for evaluation of the portfolio diversification in investing in stamps (reviewed in Literature Review section).

I specified CAPM regression of the daily portfolios excess returns on the daily market excess returns. In regression results, R-square can “measure the completeness of diversification relative to that of the overall market” (Hagin, 2004, p. 126). I compared

the R-square of the four portfolios and checked whether the portfolio 4 (the portfolio that includes carbon asset) had the highest R-square.

3) Minimum Variance Portfolio Optimisation using shrinkage method

If there are N assets and the variance-covariance matrix is S , this method constructs a Global Minimum Variance Portfolio (GMVP) with the least variance (σ_{GMVP}^2) of all portfolios of the N assets (Benninga, 2008):

$$\text{Minimum Variance Portfolio} = \frac{\mathbf{1} \times S^{-1}}{\mathbf{1} \times S^{-1} \times \mathbf{1}^T}$$

Where S is the variance-covariance matrix and $\mathbf{1}$ is a column vector of 1's (Benninga, 2008, p. 310). The constraint on this portfolio allocation is that the total weights (ω) of the assets should be equal to one.

This method still uses the sample variance-covariance matrix (S) and is subject to the estimation error which was discussed in the first method (Mean Variance Analysis).

Olivier Ledoit and Michael Wolf (2003) proposed an “estimate of the covariance matrix of stock returns by an optimally weighted average of two existing estimators: the sample covariance matrix and single-index covariance matrix” (Ledoit & Wolf, 2003, p. 603). They have developed the method in a series of articles (Ledoit & Wolf, 2003, 2004A, 2004B). The method is known as the shrinkage method and is used in Bayesian statistics. This method reduces the extreme covariances which are caused by error maximisation (Michaud, 1998).

In the shrinkage method, a shrinkage estimator is inserted into the equation to apply more structure into a variance-covariance matrix. Assuming the variance-covariance

matrix is a convex combination of the sample covariance matrix and some other matrix:

Shrinkage Variance – Covariance Matrix

$$= \lambda \times \text{Sample Variance – Covariance Matrix} + (1 - \lambda) \times \text{Other Matrix}$$

The *other* matrix is assumed to be a diagonal matrix of only variances with zeros elsewhere (Benninga, 2008, p. 308).

The selection of λ is another part of the discussion in the above-mentioned articles of Ledoit and Wolf. I have chosen to follow Benninga’s suggestion and select a “shrinkage operator so that GMVP is wholly positive”. (Benninga, 2008, p. 310)

I have specified the selected λ for each portfolio in the Empirical Results section.

4) Minimum Variance Portfolio Optimisation using the constant correlation model

This final model calculates the variance–covariance matrix by using a correlation coefficient which is the average correlation of the assets in the study. This coefficient has been introduced by Elton and Gruber (1973). They assumed that the variances of the asset returns are the sample returns and the correlation coefficient relates the covariances of the assets. The correlation coefficient computes as below where N is the number of assets in the portfolio:

$$\text{Correlation Coefficient} = (\text{Average Correlation Matrix} - 1/N) \times \frac{N^2}{(N - 1) \times N}$$

Empirical Results

Out of the four models that I have used to investigate and test my data, as discussed in the last section, I have chosen the *Minimum Variance Portfolio Optimisation using*

Shrinkage method because it suits my data set better than the other three. This model also assures⁸ that the variance (an indicator of the portfolio risk) of the resultant portfolio is lower than the other possible portfolios.

I have rejected the rest of the models for the following reasons:

Mean Variance model: As it was discussed in the methodology section, the estimation errors produced by the mean-variance model in the sample covariance matrix and unrealistic asset allocations are the reasons to reject this model.

Naïve diversification: Although Naïve diversification has been found not to be outperformed generally by other models, DeMiguel, Garlappi, & Uppal (2009), have noted in their research that, for international diversification, minimum variance strategy has either the same or better performance.

Constant correlation model: The constant correlation model can include correlation between assets into the optimal allocation, but, if the correlation between estimation error on the sample covariance matrix and the shrinkage estimator (correlation between assets in the portfolio) is positively or negatively correlated, then the combination makes the benefit of containing information smaller or larger (Ledoit & Wolf, 2003). This would result in unrealistic allocations.

⁸ In this method, the calculations are based on finding all possible portfolios and selecting the one with the least variance.

Table 2: Descriptive summary

| Descriptive Summary | | NZX ALL GROSS | MSCI AC AMERICAS | MSCI AC EUROPE | MSCI AC ASIA | US Treasury Bond 10-Yr | NZ Government Bond 10-Yr | Germany Government Bond10-Yr | Powernext | Nord Pool | ICE-ECX European Emissions - Emissions Index |
|----------------------------|--------------------|---------------|------------------|----------------|--------------|------------------------|--------------------------|------------------------------|-----------|-----------|--|
| NZD | Mean | -0.0844% | -0.0139% | -0.0091% | -0.0094% | -0.0260% | 0.0055% | 0.0090% | -0.0421% | 0.0252% | -0.0371% |
| | Median | -0.0342% | -0.0142% | 0.0439% | -0.0166% | -0.0793% | 0.0000% | 0.0391% | -2.0446% | -0.5874% | 0.0120% |
| | Standard Deviation | 1.4381% | 1.9867% | 1.8937% | 1.5337% | 2.3305% | 1.0253% | 1.5689% | 22.9866% | 9.8569% | 3.7138% |
| Local Currency | Mean | -0.0844% | -0.0054% | -0.0006% | -0.0009% | -0.0176% | 0.0055% | -0.0025% | -0.0536% | 0.0137% | -0.0486% |
| | Median | -0.0342% | 0.0703% | 0.0877% | 0.0676% | 0.0000% | 0.0000% | 0.0000% | -2.1694% | -0.5731% | -0.0442% |
| | Standard Deviation | 1.4381% | 1.6014% | 1.8365% | 1.5739% | 2.0065% | 1.0253% | 1.3029% | 22.9703% | 9.7763% | 3.6199% |

Table 3: Correlation (Underlined numbers= in local currencies, normal font numbers =in NZD)

| Correlation | NZX ALL GROSS | MSCI AC AMERICAS | MSCI AC EUROPE | MSCI AC ASIA | US Treasury Bond 10-Yr | NZ Government Bond 10-Yr | Germany Government Bond10 Yr | Powernext | Nord Pool | ICE-ECX European Emissions - Emissions Index |
|--|---------------|------------------|----------------|--------------|------------------------|--------------------------|------------------------------|------------|------------|--|
| NZX ALL GROSS | - | <u>2%</u> | <u>1%</u> | <u>9%</u> | <u>-2%</u> | <u>4%</u> | <u>-2%</u> | <u>2%</u> | <u>3%</u> | <u>-3%</u> |
| MSCI AC AMERICAS | -1% | - | <u>57%</u> | <u>11%</u> | <u>36%</u> | <u>0%</u> | <u>-3%</u> | <u>-4%</u> | <u>-3%</u> | <u>8%</u> |
| MSCI AC EUROPE | -2% | 66% | - | <u>44%</u> | <u>30%</u> | <u>5%</u> | <u>-3%</u> | <u>1%</u> | <u>-2%</u> | <u>15%</u> |
| MSCI AC ASIA | 6% | 30% | 45% | - | <u>2%</u> | <u>16%</u> | <u>0%</u> | <u>-2%</u> | <u>-3%</u> | <u>12%</u> |
| US Treas Bond 10-Yr | -4% | 55% | 43% | 20% | - | <u>-1%</u> | <u>1%</u> | <u>1%</u> | <u>-1%</u> | <u>8%</u> |
| NZ Government Bond 10-Yr | 4% | -12% | -7% | 2% | -11% | - | <u>0%</u> | <u>1%</u> | <u>-2%</u> | <u>0%</u> |
| Germany Government Bond10 Yr | -4% | 22% | 8% | 11% | 18% | -13% | - | <u>0%</u> | <u>1%</u> | <u>0%</u> |
| Powernext | 1% | 0% | 3% | 1% | 4% | 0% | 2% | - | <u>41%</u> | <u>-3%</u> |
| Nord Pool | 2% | 4% | 2% | 2% | 5% | -4% | 8% | 41% | - | <u>-3%</u> |
| ICE-ECX European Emissions - Emissions Index | -4% | 16% | 18% | 15% | 13% | -5% | 13% | -2% | 0% | - |

The descriptive summary and correlation of the returns is shown in Tables 2 and 3. As can be seen from Table 2, the highest return is gained from Nord Pool energy index in both currency situations.

The second highest return is for German 10-year Government Bond (in NZD) and New Zealand Government 10-year Bond (local currency). The lowest volatility of the returns is for New Zealand ten-year Government Bonds in both currency situations. The MSCI Asian index also shows a low volatility in the returns. Interestingly, the second lowest volatility in returns is for NZX All and German ten-year Government Bond (in local currency). As can also be seen in the Table 2, Powernext and Nord Pool has the highest standard deviation. This is due to the introduction of the carbon regulations to the energy/financial markets and the volatility in fossil fuels (oil and gas) during the period of study.

In the correlation table (Table 3), the high correlations were as expected between indices (especially between Europe and America). The returns also show low correlation (if not negative) between NZX index and other indices and assets in the study. This is an indicator of the possibility of diversification opportunities in investing in carbon assets (the correlation between ICE index and NZX All and NZ Government Bond are -3% and -5%, respectively).

There are two points that need to be mentioned about the calculations:

- 1) To check the foreign exchange impact on the portfolios, the optimisation has been done once in local indices currencies (Appendix 1) and once converted to New Zealand Dollars (using daily exchange rates from Datastream). In both of the currency situations, the returns are continuously compounded (logarithm).

2) Structured emission markets are relatively new, so we expect to have some volatility at the beginning of the markets' establishment. Because of this, in addition to testing the whole data, the data is divided into two parts relating to the first and second halves of the investigation period. The first half (from 30/12/2005 to 30/01/2008) has more volatility due to new establishment of the emission markets and the second half (1/02/2008 to 15/01/2010) shows less volatility in price indices.

In Figure 4, it can be observed that the variance of the portfolios have been reduced with the addition of the energy and carbon indices. This is comparable with the risk reduction of adding a stamp index to the portfolio.

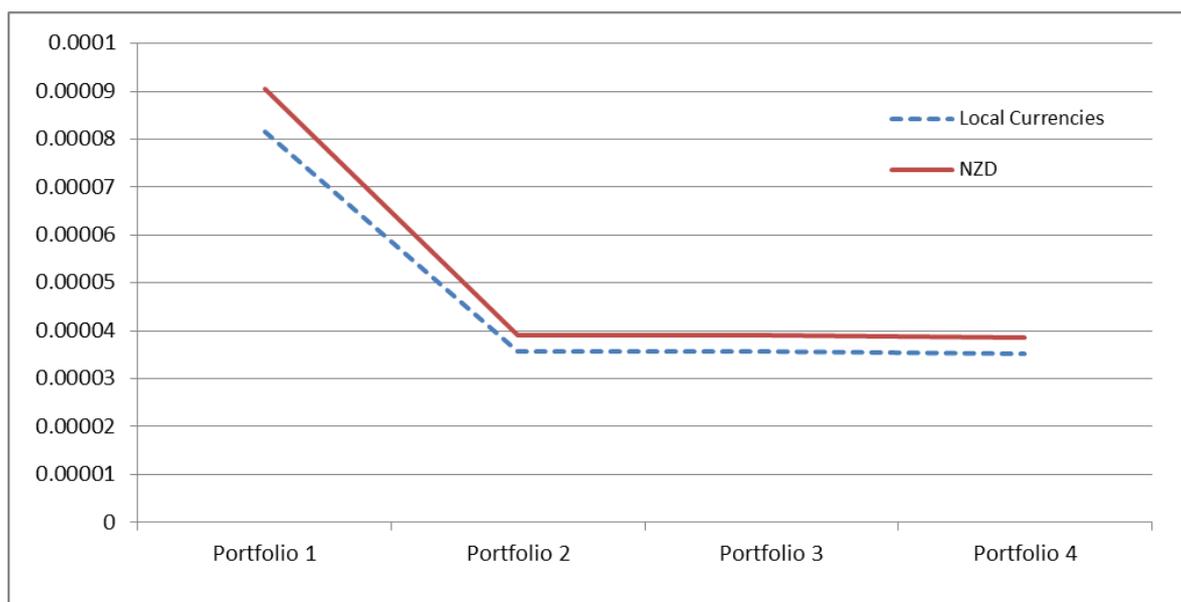


Figure 4. Variances of the portfolios for period of 2006 to 2010.

This follows Benninga's suggestion that selection of shrinkage operator ($\lambda = 0.6$) should have a positive GMVP.

Tables 4 and 5 show how adding the new assets would change the asset allocation in portfolios. After adding bonds to portfolio 1, 60% of the allocation moves to the bonds.

The tables also indicate that in both situations (in local currencies and NZD) the asset allocation to the carbon assets is more than the energy assets. The largest reduction in variance has occurred when the bonds have been added to the portfolio. In Table 5, the model basically shows that Powernext does not diversify the portfolio. This may be due the high volatility of the asset.

Table 4: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in local currencies (2006 to 2010) | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|---|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 37.60% | 16.34% | 16.20% | 16.07% |
| MSCI AC AMERICAS (USD) | 25.64% | 10.18% | 10.18% | 9.96% |
| MSCI AC EUROPE (USD) | 10.54% | 3.81% | 3.80% | 3.51% |
| MSCI AC ASIA (USD) | 26.22% | 9.66% | 9.66% | 9.29% |
| US TREASURY BOND 10-YEAR (USD) | | 6.60% | 6.56% | 6.36% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 31.85% | 31.72% | 31.32% |
| GERMANY GOVERNMENT BOND 10-YEAR (Euro) | | 21.56% | 21.44% | 21.13% |
| Powernext (Euro) | | | 0.03% | 0.03% |
| Nord Pool (Euro) | | | 0.40% | 0.41% |
| ICE-ECX European Emissions (Euro) | | | | 1.91% |
| Variance | 0.008159% | 0.003576% | 0.003559% | 0.003511% |
| λ | 0.6 | 0.6 | 0.6 | 0.6 |

Table 5: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in NZD(2006 to 2010) | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|---|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 43.08% | 18.54% | 18.48% | 18.39% |
| MSCI AC AMERICAS (NZD) | 14.08% | 4.49% | 4.47% | 4.30% |
| MSCI AC EUROPE (NZD) | 13.38% | 5.77% | 5.76% | 5.50% |
| MSCI AC ASIA (NZD) | 29.46% | 11.07% | 11.04% | 10.69% |
| US TREASURY BOND 10-YEAR (NZD) | | 4.14% | 4.11% | 3.98% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 40.01% | 39.99% | 39.70% |
| GERMANY GOVERNMENT BOND 10-YEAR (NZD) | | 15.99% | 15.90% | 15.50% |
| Powernext (NZD) | | | 0.00% | 0.00% |
| Nord Pool (NZD) | | | 0.25% | 0.24% |
| ICE-ECX European Emissions (NZD) | | | | 1.69% |
| Variance | 0.009059% | 0.003913% | 0.003908% | 0.003869% |
| λ | 0.6 | 0.6 | 0.6 | 0.6 |

In Tables 6 and 7, Powernext's allocation has been doubled due to the reduction in volatility of the asset in the second half of the period; however it is still a very small percentage in comparison with the carbon and the other energy asset (Nord Pool). The results presented in the tables indicate that the volatility of the energy assets has had an impact on the allocation to the bonds too. In comparison with Table 7, bonds have more allocation in Table 6 (in total about 58% and 63% respectively).

Table 6: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in local currencies- First Half | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|---|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 28.19% | 11.31% | 11.17% | 11.07% |
| MSCI AC AMERICAS (USD) | 39.20% | 13.94% | 13.99% | 13.74% |
| MSCI AC EUROPE (USD) | 14.26% | 5.05% | 5.04% | 5.00% |
| MSCI AC ASIA (USD) | 18.36% | 6.66% | 6.71% | 6.58% |
| US TREASURY BOND 10-YEAR (USD) | | 9.13% | 9.18% | 9.11% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 31.49% | 31.29% | 31.04% |
| GERMANY GOVERNMENT BOND 10-YEAR (Euro) | | 22.42% | 22.23% | 22.02% |
| Powernext (Euro) | | | 0.02% | 0.02% |
| Nord Pool (Euro) | | | 0.37% | 0.37% |
| ICE-ECX European Emissions (Euro) | | | | 1.04% |
| Variance | 0.00355% | 0.00144% | 0.00143% | 0.00141% |
| λ | 0.60 | 0.60 | 0.60 | 0.60 |

Table 7: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in local currencies- Second Half | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|--|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 39.96% | 18.15% | 18.02% | 17.79% |
| MSCI AC AMERICAS (USD) | 22.45% | 9.41% | 9.39% | 9.06% |
| MSCI AC EUROPE (USD) | 8.89% | 3.31% | 3.29% | 2.60% |
| MSCI AC ASIA (USD) | 28.70% | 10.89% | 10.86% | 9.98% |
| US TREASURY BOND 10-YEAR (USD) | | 6.12% | 6.06% | 5.65% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 31.11% | 30.99% | 30.22% |
| GERMANY GOVERNMENT BOND 10-YEAR (Euro) | | 21.01% | 20.92% | 20.32% |
| Powernext (Euro) | | | 0.04% | 0.05% |
| Nord Pool (Euro) | | | 0.43% | 0.43% |
| ICE-ECX European Emissions (Euro) | | | | 3.89% |
| Variance | 0.01256% | 0.00575% | 0.00573% | 0.00560% |
| λ | 0.60 | 0.60 | 0.60 | 0.60 |

Another important point to note is the asset allocation of carbon in Table 6 and 7. In Table 7 (the second half of the dataset) the allocation to the carbon asset is more than three times bigger than in Table 6 (the first half of the dataset). In both Tables 6 and 7, the asset that makes the portfolios 3 and 4 diversified is the carbon asset, because the allocation to energy assets did not change considerably (only 0.01% for Powernext in Table 7).

Table 8: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in NZD- First Half | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|--|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 41.04% | 14.57% | 14.50% | 14.44% |
| MSCI AC AMERICAS (NZD) | 21.52% | 4.99% | 4.99% | 4.82% |
| MSCI AC NZDPE (NZD) | 13.87% | 3.92% | 3.92% | 3.85% |
| MSCI AC ASIA (NZD) | 23.57% | 7.65% | 7.68% | 7.54% |
| US TREASURY BOND 10-YEAR (NZD) | | 5.46% | 5.47% | 5.40% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 48.33% | 48.28% | 48.22% |
| GERMANY GOVERNMENT BOND 10-YEAR (NZD) | | 15.07% | 14.91% | 14.69% |
| Powernext (NZD) | | | 0.01% | 0.01% |
| Nord Pool (NZD) | | | 0.24% | 0.24% |
| ICE-ECX European Emissions (NZD) | | | | 0.79% |
| Variance | 0.00498% | 0.00180% | 0.00179% | 0.00178% |
| λ | 0.60 | 0.60 | 0.60 | 0.60 |

Table 9: Minimum Variance - Shrinkage - Diagonal Matrix

| Portfolio components in NZD- Second Half | Portfolio 1 | Portfolio 2 | Portfolio 3 | Portfolio 4 |
|---|-------------|-------------|-------------|-------------|
| NZX ALL GROSS(NZD) | 43.32% | 19.85% | 19.81% | 19.63% |
| MSCI AC AMERICAS (NZD) | 12.06% | 4.18% | 4.15% | 3.91% |
| MSCI AC NZDPE (NZD) | 12.81% | 6.32% | 6.31% | 5.67% |
| MSCI AC ASIA (NZD) | 31.81% | 12.64% | 12.59% | 11.80% |
| US TREASURY BOND 10-YEAR (NZD) | | 3.67% | 3.64% | 3.37% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | | 37.00% | 36.99% | 36.29% |
| GERMANY GOVERNMENT BOND 10-YEAR (NZD) | | 16.33% | 16.26% | 15.45% |
| Powernext (NZD) | | | 0.00% | 0.01% |
| Nord Pool (NZD) | | | 0.24% | 0.23% |
| ICE-ECX European Emissions (NZD) | | | | 3.66% |
| Variance | 0.01322% | 0.00604% | 0.00604% | 0.00592% |
| λ | 0.60 | 0.60 | 0.60 | 0.60 |

In Tables 8 and 9, the portfolios are in New Zealand dollars. The main differences between the two series of tables (Tables 6-7 and Tables 8-9) are the same allocation to the energy assets and a lesser allocation to the carbon asset in the first half of the data set (0.79%). However, in general, the same pattern has occurred including approximately a 60% reduction in allocation to stock indices after adding bonds to

portfolio 1, and indication of diversification after adding the carbon asset to the portfolio 3.

Table 10 summarises the allocations to the carbon asset in tables 4 to 9.

Table 10: Allocation to the carbon asset in Portfolio 4

| Allocation to the Carbon Asset | Local | |
|--------------------------------|------------|-------|
| | Currencies | NZD |
| All Data | 1.91% | 1.69% |
| First Half of dataset | 1.04% | 3.89% |
| Second half of dataset | 0.79% | 3.66% |

Tables 11 and 12 compare the asset allocation of portfolio 4 in table 4 to table 9 in local currencies and NZD respectively.

Table 11: asset allocation for portfolio 4 in local currencies

| Portfolio components in local currencies | 2006-2010 | First Half | Second Half |
|--|-------------|-------------|-------------|
| | Portfolio 4 | Portfolio 4 | Portfolio 4 |
| NZX ALL GROSS(NZD) | 16.07% | 11.07% | 17.79% |
| MSCI AC AMERICAS (USD) | 9.96% | 13.74% | 9.06% |
| MSCI AC EUROPE (USD) | 3.51% | 5.00% | 2.60% |
| MSCI AC ASIA (USD) | 9.29% | 6.58% | 9.98% |
| US TREASURY BOND 10-YEAR (USD) | 6.36% | 9.11% | 5.65% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | 31.32% | 31.04% | 30.22% |
| GERMANY GOVERNMENT BOND 10-YEAR (Euro) | 21.13% | 22.02% | 20.32% |
| Powernext (Euro) | 0.03% | 0.02% | 0.05% |
| Nord Pool (Euro) | 0.41% | 0.37% | 0.43% |
| ICE-ECX European Emissions (Euro) | 1.91% | 1.04% | 3.89% |

Table 12: asset allocation for portfolio 4 in NZD

| Portfolio components in NZD | 2006-2010 | First Half | Second Half |
|---------------------------------------|-------------|-------------|-------------|
| | Portfolio 4 | Portfolio 4 | Portfolio 4 |
| NZX ALL GROSS(NZD) | 18.39% | 14.44% | 19.63% |
| MSCI AC AMERICAS (NZD) | 4.30% | 4.82% | 3.91% |
| MSCI AC NZDPE (NZD) | 5.50% | 3.85% | 5.67% |
| MSCI AC ASIA (NZD) | 10.69% | 7.54% | 11.80% |
| US TREASURY BOND 10-YEAR (NZD) | 3.98% | 5.40% | 3.37% |
| NZ GOVERNMENT BOND 10-YEAR (NZD) | 39.70% | 48.22% | 36.29% |
| GERMANY GOVERNMENT BOND 10-YEAR (NZD) | 15.50% | 14.69% | 15.45% |
| Powernext (NZD) | 0.00% | 0.01% | 0.01% |
| Nord Pool (NZD) | 0.24% | 0.24% | 0.23% |
| ICE-ECX European Emissions (NZD) | 1.69% | 0.79% | 3.66% |

The first and second highest allocated assets in this research have been New Zealand Government ten-year and German Government ten-year Bonds. As can also be seen in Tables 11 and 12, in the asset allocation, the model diversified the portfolio by allocating to the carbon asset.

It was previously pointed out that the first half of the dataset has more volatility due to the recently established emission market. The comparison in table 11 and 12 shows the first half has been allocated less carbon asset than the second half.

There is also less asset has been allocated to ICE-ECX European Emissions in NZD than in the local currencies (table 11) due to the currency conversion.

Conclusion

This study has investigated the diversification opportunities in investment in the emission market (specifically in carbon credits) from a New Zealand investor point of view. Based on the historical carbon spot prices (Jan 2006 to Jan 2010) from ICE Index and analysis by the selected method, the investigation identifies some signs of diversification opportunity. As a result of using the minimum variance portfolio optimisation with shrinkage method in asset allocation, the errors caused by daily expected returns has been minimised.

In comparison with the art market which was discussed in the literature review section of this study, the transaction costs are not as high as the art transaction costs. This is due to the availability of the emission markets (the emission indices and derivatives, the same as other financial markets and tools, are available through virtual and actual brokers) on the internet. Carbon assets have also shown less correlation (16%) with US

equity index (MSCI Americas in this study) in comparison with the art index and S&P 500 (21%).

In regard to the correlation of the carbon asset and the equity/bond market, I have found the same result as Daskalakisa, et al. (2009), who found the negative correlation between EU allowances and equity market. This study shows that there is a negative correlation between carbon spot prices and the New Zealand bond and equity market (-5% and -4% respectively). This is one of the indicators of diversification opportunity for a New Zealand investor.

Although I have not considered the transaction costs in this study, the investor should count it as a cost item (it can be included in the future studies).

One implication of the study is that those New Zealand investors who want to invest in carbon credits should monitor exchange rates for the volatility. As it was shown in the empirical results, the investment in local currencies gives more diversification to the portfolio by a higher percentage of carbon assets.

For future studies, inclusion of emission derivatives (futures and forwards) might show a clearer picture of diversification opportunities. Also, future studies could look at the emission spot prices in the future using previous studies such as Chesney and Taschini (2008) and Benz and Truck (2009) and investigate the diversification opportunities in the future.

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Appendix

| <i>Index</i> | <i>Local Currency</i> |
|---------------------------------|------------------------------|
| NZX ALL GROSS | NZD |
| MSCI AC AMERICAS | USD |
| MSCI AC EUROPE | USD |
| MSCI AC ASIA | USD |
| US TREASURY BOND 10-YEAR | USD |
| NZ GOVERNMENT BOND 10-YEAR | NZD |
| GERMANY GOVERNMENT BOND 10-YEAR | Euro |
| Powernext | Euro |
| Nord Pool | Euro |
| ICE-ECX European Emissions | Euro |