A Global Carbon Market

Analysing the Risk of Potential Changes to Australia's Carbon Pricing Policy on Schroders' Investment

Prepared by:

Manon O'Neill
Tricia Garcia
Erin Shen
Shen Goh
Sherry Fan
Chloe Bi

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EXECUTIVE SUMMARY

With the increasing adoption of emissions trading schemes (ETS) globally, the world is transitioning towards a unified carbon market. This report explores the effects of adopting a globally-linked ETS in Australia, focusing on the industries Schroder Investment Management Australia Limited (Schoders) is invested in.

Investigating this problem, a qualitative study was conducted on linked ETS systems, examining their effects using case studies. Correlation analysis and Carbon VaR predictions quantified carbon pricing effects on German industries. Through these analyses, we found a carbon price increase in Australia upon adopting a global ETS. This would expose Schroders to the risk of a stock price decrease, more prominent in emissions-intensive industries.

Guided by our findings, we suggested portfolio reconstruction and investment diversification towards less carbon-intensive sectors. This is evidenced by the carbon-intensive German utilities sector being less affected by the 2018 carbon price increase, partly due to its biggest utility companies, E.ON and RWE, diversifying towards renewables. We also recommended a stronger fostering of engagements. We believe that our recommendations would protect Schroders from the risks associated with a carbon price increase induced by Australia adopting a globally-linked ETS.

With our model focusing on Germany, subsequently drawing implications for Australia qualitatively, future work could be done to apply the model directly to Australia. To adopt our recommendations, it is also crucial for Schroders to create a long-term implementation plan for investment diversification.

INTRODUCTION

Climate change is beginning to cause irreversible impacts to our environment. The effects are on the precipice of causing wide scale financial damage to world economies (Ameile, 2017). The globe needs to move towards low carbon initiatives, however quick unplanned movements can be damaging to companies who currently depend on carbon intensive energy (Zapt, Pengg & Weindl, 2019).

As an asset manager, Schroders has a fiduciary responsibility towards their clients but they also need to reflect their clients interests. Increasingly Australians are demanding a move away from fossil fuels and Schroders' clients have named climate change as their top fifth concern when investing (Brett, 2019).

Recently there has been a worldwide trend to internalise the external risks of climate change into the market. This has been accomplished by charging polluters of CO2, enacting market mechanisms to avoid economic risks ("About carbon pricing", 2020). This has emerged in the form of carbon credits, carbon taxes and ETS's.

This problem needed an interdisciplinary approach that involved both knowledge and knower codes (Maton, 2017). Members of the group with knower codes needed to scope international and domestic policy, conduct qualitative analysis of various case studies and form the recommendations for the project. Other members with knowledge codes used quantitative analysis to conduct data and correlation analysis and build models.

Australia's Historical and Current Emissions Reduction Policies

Currently Australia has an emissions reduction fund (ERF) scheme in place, with its three key elements involving crediting, purchasing and safeguarding. The Safeguard Mechanism mandates a baseline limit for Australia's largest greenhouse gas emitters – facilities with annual direct scope 1 emissions of more than 100,000 tonnes of CO2-e (Department of Parliamentary Services, 2018). However, the scheme is insufficient in achieving Australia's target emissions. Australia has a projected 15% increase of emissions by 2030 which will lead to Australia's unfulfillment of its

UNFCCC and Paris Agreement obligations (Climate Analytics for the Australian Conservation Foundation, 2019). Due to these insufficiencies, we predict that changes to this policy will likely occur.

What is an Emissions Trading Scheme (ETS)?

An emissions trading scheme is a market of carbon allowances or credits that can be bought or sold depending on if companies exceed or are below their designated cap.

To date, these schemes have been the most successful in reducing emissions while minimising financial damage ("About carbon pricing", 2020). In the 2015 Paris Agreement, Article Six states countries need to introduce "the use of internationally transferred mitigation outcomes towards nationally determined contributions" (United Nations, 2015). Referring to a global ETS, it would be the most cost effective way to transition countries and companies to low carbon initiatives.

If Australia partook in a globally-linked ETS, Australia's carbon price would increase. This is due to Australia's price being low at AUD$16.50/t$CO_2$, which is below the European Union price at AUD$37 (Reputex, 2019).

A Globally-Linked Australian ETS?

Australia could soon be part of a globally-linked ETS, for three reasons:

1. Australia is signatory to the 2015 Paris Agreement, which stipulates that an international carbon market is the most cost-effective way to achieve reduction targets (United Nations, 2015). The agreed goal is to keep a global temperature rise below 1.5°C, requiring a highly effective method.

2. There is an increasing trend of linking ETS's, such as Quebec and California in 2014 and Switzerland with the EU in 2020.

3. With many Pacific and Asian countries adopting ETSs, a multinational ETS within the region could be established (Kaneti, 2020), potentially affecting economic relationships between countries for those left out.

Problem Statement and Aims

Having acknowledged the global trends towards cooperative action against climate change, and the possible economic impacts some of these actions may have on certain industries, our problem statement is:

"How would Schroders' Australian investment portfolio be impacted upon the introduction of an international emissions trading scheme within Australia?"

Project Aims

To mitigate risks to Schroders' Australian investments as a result of Australia implementing a globally-linked ETS.

Objectives

Our aim will be achieved through the following objectives:

1. Understand the qualitative effects of linked ETS's on regional industries using case studies from several countries,
2. Focus our analysis on the effects within Germany, due to similarities between the German and Australian economies and due to Germany being a part of the most comprehensive ETS,

3. Conduct a quantitative analysis on German industry stock prices when carbon pricing is introduced and then increased, including the use of a carbon VaR. We will then relate our findings back to Schroders' investments within Australia, and

4. Provide recommendations to Schroders on how to prepare their Australian investments for effects caused by Australia joining an internationally-linked ETS.

APPROACH AND GROUP PROFILE

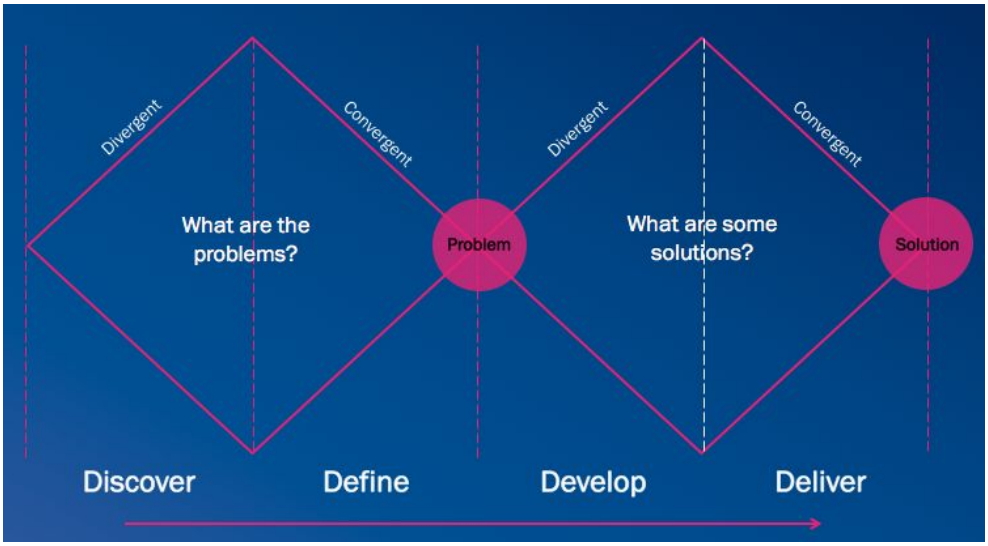


Fig.1. Double Diamond Approach (Heffernan,2017)

We approached this report using a Double Diamond structure (Fig.1), which encompasses a series of divergent and convergent thinking (Heffernan, 2017). We believe that this approach would guide our research and focus as we expand our knowledge to gain a greater understanding of the problem/solution, and then consolidate what we have learnt into a concise format which clearly articulates our point. Altogether, there were four stages of our approach:

Stage 1: Discover

Being unfamiliar with topics around finance and ESG investing, we began our process by searching for key terms on Google and Scopus, gathering information from news articles, websites and journal articles to gain a understanding of our topic. Once we had a sense of the research field, we developed potential problems by starbursting, a process of selecting topics and asking questions which narrow in scope over time, helping us think of problems which we might not have otherwise considered (Rudy, 2016). After our subsequent questioning, we eventually landed on focusing on climate policy changes, particularly regarding Australia.

Stage 2: Define

Knowing the direction in which we wanted to take our research, we began to form a concise problem. This meant identifying a gap in Schroders' knowledge which we could potentially fill, and involved a rigorous process of drawing links between investment funds management and climate policy, with both political ambition and action being acknowledged by Schroders as being vital to climate change ("Climate Progress Dashboard", 2019). We continuously consulted with University of Sydney ICPU supervisors, Bruce Chapman and Jennifer Fletcher, and CEO of Schroders Australia, Chris Durack, on our project's feasibility before eventually settling on our current problem statement.

However, the process of formulating a problem was not linear, with us having to redefine our problem several times due to group members focusing on a problem with either a primarily quantitative or qualitative approach. Subsequently, our current problem relies on a balance between both approaches.

Stage 3: Develop

To formulate a potential solution, we asked ourselves a series of "How might we" questions (""How Might We" Questions", n.d.), allowing us to focus our solution by asking how we might improve complications surrounding ETS's, carbon pricing and particularly how to mitigate negative impacts on Schroders' Australian investments.

With a concise problem statement in mind, our scope was divided into parts between team members who focused their research on particular aspects, such as the history of carbon pricing in Europe. During this time, members with a quantitative mindset assisted those with a qualitative approach by searching the Bloomberg Terminal for data, visualising trends and patterns stated in the literature. Similarly, those with a qualitative mindset assisted the quantitative analysts by identifying reasons for outliers in data, such as events being caused by policy changes, etc.

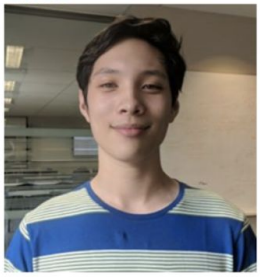
Stage 4: Deliver

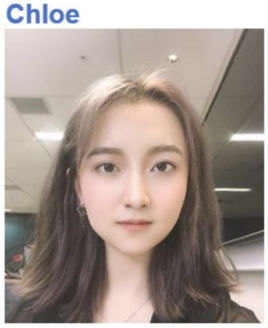
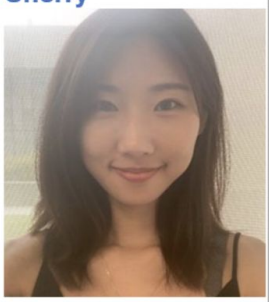
Once the information had been gathered, we consolidated everything into a presentation to be presented to Schroders. This completed report is a culmination of our research process and our findings, and whilst this is not identical in scope to our plan, it is based on the foundations of our early brainstorming questioning leading up to this point.

Group Profile

We aimed to take on a risk consultancy role towards Schroders. The academic backgrounds of group members allowed us to split between quantitative-focused and qualitative-focused researchers to concentrate on our strengths, consolidating throughout our process to compare information and fill any gaps in the other's findings.

Table.1. Individual Group Member Profiles

MEMBER	SKILLS & BACKGROUND	ROLES & RESPONSIBILITIES
Shen 	Bachelor of Medical Science, majoring in genetics. Expertise in forming scientific literature reviews.	Helped articulate and refine the problem statement. Gathered and organised qualitative information on researched countries. Identified international trends being discussed on the effects of carbon pricing on select industries. Detected crucial gaps in available data.
Manon	Bachelor of Arts, majoring in politics and a Bachelor of Advanced Studies (International and Global Studies). Has experience in policy analysis, public speaking, group projects and critical thinking from both within her degree and through her activism.	Conducted a policy analysis of the 2015 Paris Agreement. Compared functions of hypothetical international global emissions trading schemes. Identified the carbon pricing responses of specific companies within the Germany case study. Further developed the recommendations for Schroders using the case study companies as a reference.

MEMBER	SKILLS & BACKGROUND	ROLES & RESPONSIBILITIES
Tricia	Chemical Engineering student, majoring in process intensification. Has experience in utilising project management tools and strategies. Experience in conducting literature research.	Oversaw project progress using project management techniques. Decomposed research topic into subproject deliverables, delegating tasks to team members. Conducted a literature review on the mechanisms and effects of Australia's emissions reduction policies.
Chloe 	Science student, majoring in Statistics and Data Science, with experience in investment banking as Quant and Strategy research assistant.	Applied appropriate technical methods for quantitative analysis. Collected and pre-processed data, applied correlation analysis on carbon price and stock index by sector.
Sherry 	Physics and data science student, with expertise in mathematical modelling and data analysis.	Collaborated with Chloe in forming the quantitative analysis. Built models to decompose and predict carbon price; and to predict sectors' performance. Provided an integrated and automatic model to do Carbon VaR for assets managers.
Erin	Majoring in Finance and Business Analytics. Experience in understanding corporate reports and portfolio management.	Synthesised qualitative and quantitative analyses to analyse the implications of a global emissions trading scheme for Schroders. Articulated recommendations for Schroders.

Project Scope

This report is primarily intended for the Australian Equities division at Schroders, due to the nature of our research centred around the consequences an internationally-linked ETS's may have on particular industries which Schroders is invested in. Our findings can provide a source of previously unconsidered impacts a shift in Australian carbon pricing may have, with our recommendations expressing how Schroders may choose to act on its Australian equity investments to prepare for such a policy change in the future. Importantly, this report does not aim to model the exact impacts an Australian ETS will have on the performance of Australian sectors, but rather uses several international case studies to infer potential risks.

RESULTS

Insight into Emissions Trading Schemes

We conducted qualitative analyses on the impacts of international ETSs based on their distinct characteristics to provide a better understanding on what the impacts a linked Australian ETS may look like.

Québec

Overview

- Québec ETS (QC ETS) established 2013
- Covers 85% of province's GHG emissions - most comprehensive ETS globally ("Quebec Carbon Market", n.d.)
- Linked with California ETS 2014 (Purdon,Houle & Lachapelle,2014)
- Regulated facilities choose to reduce emissions below quota or purchase emission permits if exceeded (Ministère de l'Environnement, 2018)

Effect on Industry

A literature analysis on the effects of the QC ETS points towards Québecois industrial firms being slightly disadvantaged to their national non-regulated counterparts. Using ex-post data on facility performances, Hanoteau and Talbot (2019) devised a difference-in-differences regression model to estimate the effects of the ETS on certain facilities. They found that regulated industrial firms in Québec had scaled down their production levels to meet their emission allowances, leading to firms reducing employment 6.8% faster than non-regulated Canadian counterparts.

The advent of the QC ETS was also accompanied by a strong decline in mining investment in Québec, with investments dropping from CAD$5.13billion to CAD$2.49billion between 2012-2015 (Institut de la statistique du Québec, 2018). Although coal imports have remained fairly stable, exported coal has declined from CAD$8.4b in 2011 to CAD$4.7b in 2016 (Natural Resources Canada, 2018). While it is difficult to draw direct causation of these trends from the ETS, changing attitudes which bring about such policy changes are resultant on shifts in attitudes towards climate change, indirectly affecting certain carbon-emitting industries.

China

Overview

- Began 2013
- Composed of 8 individual pilot schemes in economically and geographically distinct regions of China (Zhang, Xu, Li, Zhou & Xiong, 2019)
- Provides a model for how separately regulated ETSs might interact under a linked ETS system (Hua & Dong, 2019)

Effect on Industry

Each region's ETS covers different sectors and GHGs, so their effects on industries vary. For example, carbon prices in only Guangdong, Hubei and Shenzhen had a negative impact on the stock value of thermal energy enterprises listed on the CSI 300 Index, such as Shaoneng Group and Baolihua New Energy (Zhang, Fang & Wang, 2018). However, this effect on value was short-term, with no observable effect on stock value after the first three years of the ETSs. An analysis by Tian et al. (2017) demonstrated that differences in carbon prices between regions vary in effect on industry. For instance, higher carbon prices in Shanghai than the rest of China leads to growth in the Shanghainese electronics and agriculture sectors, but deficits in the manufacturing, industrial and power-generation sectors.

Simulations by Zhao et al. (2017) found that regions under an ETS result in sectors reducing their fossil energy consumption, and instead opting for renewables, overall reducing the output of China's power sector by an average of 34.25%. This affects production costs of industrial facilities, reducing their output, unless carbon mitigation policies are implemented to reduce their CO2 intensity.

Germany

Overview

- Operated under European Union ETS (EU ETS) since 2005
- EU ETS currently in third phase (2013-2020), lowering cap for carbon emissions and increasing sector coverage

- Germany implementing plans for German ETS, covering sectors not covered under EU ETS

Effects on Industry

A literature review showed that, before 2019, the introduction of an ETS had little to no effect on German companies. Initial fears surrounding the effects of the EU ETS on Germany focused on deficits to competitiveness of German industries, due to a carbon price increase leading to loss of competitiveness of manufactured products to non-regulated companies outside of the EU (Loschel, Lutz & Managi, 2016). However Loschel found there was no significant effect, for example on the German manufacturing sector when the EU ETS was introduced (Loschel, Lutz & Managi, 2019).

Although, producing these results, we have theorised that the absence of effect was both due to an over allocation of emission allowances and firms' ability to pass costs to consumers (Joltreau & Sommerfield, 2018). A study found that 80% of sectors investigated were benefiting from the over allocation of allowances, including 165 million of allowances in excess of demand between 2008-2014 (Schep & deBruyn, 2016). Free allowances within Germany have benefited companies such as electricity firms. However in phase 3 of the EU ETS free allocation will be retracted (European Commission, 2020). Appunn and Sherman(2018) predicted that an increase in carbon price could put industries such as steel and chemical in strife. In January 2018 the EU ETS carbon price rose from 7 euros to 25.5 euros in December and is still on the rise. This has caused a significant rise in renewables and a set away from fossil fuels. German coal power fell at a 'record rate', hard coal by 41% and lignite by 38% (Bloomberg, 2019). This can be correlated with the sharp carbon price increase within Europe, recently reaching 30 euros (Bloomberg, 2019). In 2021 the EU is set to lower allowances by 2.2% per year.

To predict the impact an internationally linked ETS could have on Australia, we focused our quantitative analysis on Germany. The quantitative data within this report details information both pre- and post- rise of carbon prices in 2018, giving a current projection of carbon pricing effects unaddressed by our qualitative review.

Quantitative Study on Germany

Accurately forecasting carbon prices can provide guidance for production operations and investment decisions, helping to avoid risks and maximise assets (Bangzhu, 2017). To assess the climate policy transition risks in related industries and financial management, we chose carbon pricing as our quantitative indicator.

We used Germany due to its similarities to Australia in terms of economic output and coal consumption, of which it is the largest consumer in the EU. It also depicts the effects of a linked carbon market, being part of the EU ETS, the oldest and most comprehensive multinational ETS globally. Finally the data that was available was the most accessible, allowing us to be as accurate as possible.

We first conducted a correlation analysis of carbon prices against German industry performances to determine which sectors are most affected by policy transition risks, followed by long- and short-term carbon price predictions based on historical data. In this section, most of the quantitative calculations, analyses and results were processed using the programming language, "R".

Variable selection and pre-processing methods (detailed in Appendix B and C) were done to prepare the correlation analysis and carbon pricing prediction. Carbon pricing is represented by the European Emissions Allowances (EUA), sourced from Bloomberg. This is done as EUA is the materialization of the EU ETS quotas, and is the most liquid trading in the existing carbon market (ICE, 2020). Sector performance is represented by their daily closing prices in the German stock index (DAX), sourced from investing databases (investing.com, 2020). Taking Schroders' Australian portfolio composition and data accessibility into account, we finally looked at the following sectors:

- Banks
- Basic Resources
- Chemicals
- Financial Services
- Industrial
- Retail
- Technology
- Telecoms
- Utilities

Correlation analysis between carbon pricing and sector performance using B-P mutation test

Before conducting a correlation analysis, two structural breakdates were detected using the Bai & Perron (B-P) mutation test. The Eviews 10 statistical software was used to implement B-P mutation tests to EUA time-series data. These dates represent different correlations between carbon pricing and sector performance, the contexts of which are analysed qualitatively.

The two structural break dates were on 10th May 2018 and 13th December 2018, corresponding to changes in the trend of EUA prices.

The correlation analysis results for these time periods vary. In the first period (2013-2018 April), correlation between EUA price and sectors' performance are all positive. However, in the second period, correlation coefficient of Basic Resources, Chemicals, Industrial, Retail and Technology significantly decreased, indicating that increase of carbon prices negatively impacted these industries. In the third period, even though most of these sectors' results reverted back to positive correlations, a few industries are still under downtrends, namely Basic Resources.

Table.2. Correlation Matrix of three periods

Strong Negative Correlation — Strong Positive Correlation

	2013-April 2018	May 2018-Dec 2018	Jan 2019-Present
	EUA		
Banks	0	-0.3	-0.3
Basic Resources	0.4	-0.6	-0.4
Chemicals	0.6	-0.6	0.4
Financial Services	0.5	0.4	0.1
Industrial	0.4	-0.4	0.3
Retail	0.5	-0.5	0.3
Technology	0.5	-0.6	-0.1
Telecom	0.5	0.3	0.4
Utilities	0	-0.1	0.2

To better understand the logic behind the change, we looked at the line charts of these factors in the whole period, and obtained four key findings:

1. At the start of 2018 (near the first structural break point), EUA price showed a clear increasing trend. After a 1-2 month delay, sectors responded to this movement and started to decrease, among which Industrial decreases fastest.

2. After 2018, EUA came into a fluctuating period similar to pre-2018. However, this time the amplitude of price changes was larger than the former one, appearing more volatile.

3. When EUA stopped its clear increasing trend at the start of 2019, sectors experienced increased performance and did not show a clear downward trend again.

4. Industrial sector data showed an increasing trend throughout the whole period. Basic Resources, demonstrated a stable trend pre-2016. After, it first demonstrated a rising trend in performance till 2018, whereupon it has experienced a still-ongoing decrease.

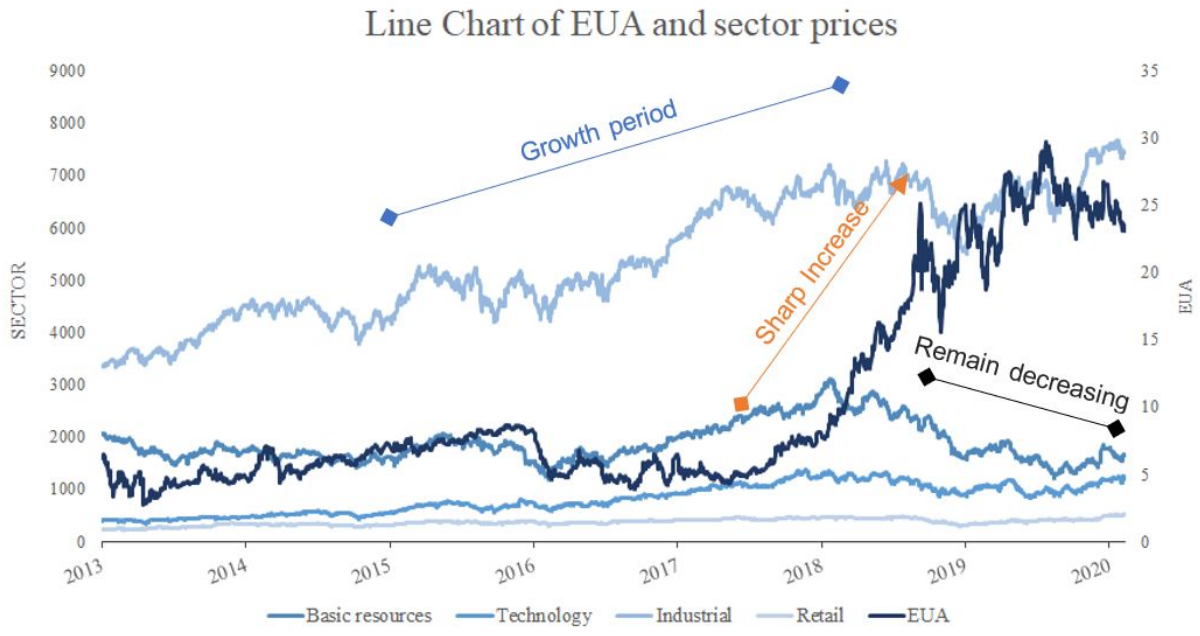


Fig.3. Line Charts of EUA price and Sector prices

In summary, a sharp increase in carbon pricing will bring negative impacts to market sentiment to certain sectors. If a sector is within a growth period (as the Industrial sector has been experiencing since 2018), the stock index will recover in a short period. If not, the index will be greatly affected by the carbon price movement.

Carbon Price Prediction

Decomposition of historical daily price of EUA

The historical daily price of EUA is a nonstationary and nonlinear dataset (Fig.4). The reasons behind carbon price trends can be complicated, with many factors contributing to EUA prices. To study the behaviour and get a reasonable prediction of carbon prices, we decomposed the historical price.

Fig.4. Historical daily price of EUA (December 2012 – February 2020)

Empirical Mode Decomposition (EMD) gives a way to study such kind of chaotic time-series data, decomposing the EUA price into different intrinsic mode functions (IMFs) and a residual (Rilling, Frandlin & Goncalves, 2003). The residual is the trend of the dataset. IMFs indicate different independent factors which make the price fluctuate. The method to find IMFs is in Appendix D. In our project, we used emd function (R language) to automatically sift out IMFs and the residue.

We obtained 7 IMFs and a residue from EMD. To make the IMFs more meaningful and related to the carbon price, we grouped the 7 IMFs into two layers, high frequency layer and low frequency layer using Fine-to-coarse Reconstruction (Appendix E). The actual price is the sum of high frequency, low frequency and trend layers (Fig.5).

Fig.5. High frequency, low frequency and trend layers, with actual price

The high frequency layer indicates the carbon market fluctuation affected by daily disequilibrium of carbon allowance demand and supply. This layer usually could be ignored, as short-term arbitrage is less likely considered in superfund portfolio. The low frequency layer indicates that short-term extreme events drive the price to deviate from the trend. The trend layer shows carbon price decreased in 2015, due to a large surplus in carbon allowance supply in the market. We can also observe a sharp increase in the trend since 2017. At that time, the European Commission began implementing policies to reduce the carbon allowance supply (Marcu et al. 2020).

Carbon Price Prediction

Each layer has its own properties. In order to get reasonable predictions, we applied different methods to predict different layers.

For the high frequency and the low frequency layer, as they both drive carbon price fluctuations around the trend, we assumed the average of each layer will reach zero. Autoregressive Integrated Moving Average (ARIMA) gives a method to predict and smooth such fluctuations (DukePeople,2020).

For the trend layer, as the European commission announced they will increase the pace of carbon emission cuts from 2020 (European Commission 2020), we expect a rapid increasing trend in the future. We chose second-degree polynomial regression to predict trends.

By adding up the prediction result of the 3 layers, we could get the carbon price prediction. We tested our prediction model by comparing our predicted value against the actual EUA price from September 2019 to February 2020, finding that our model gives close and smooth prediction for this time period (Fig.6).

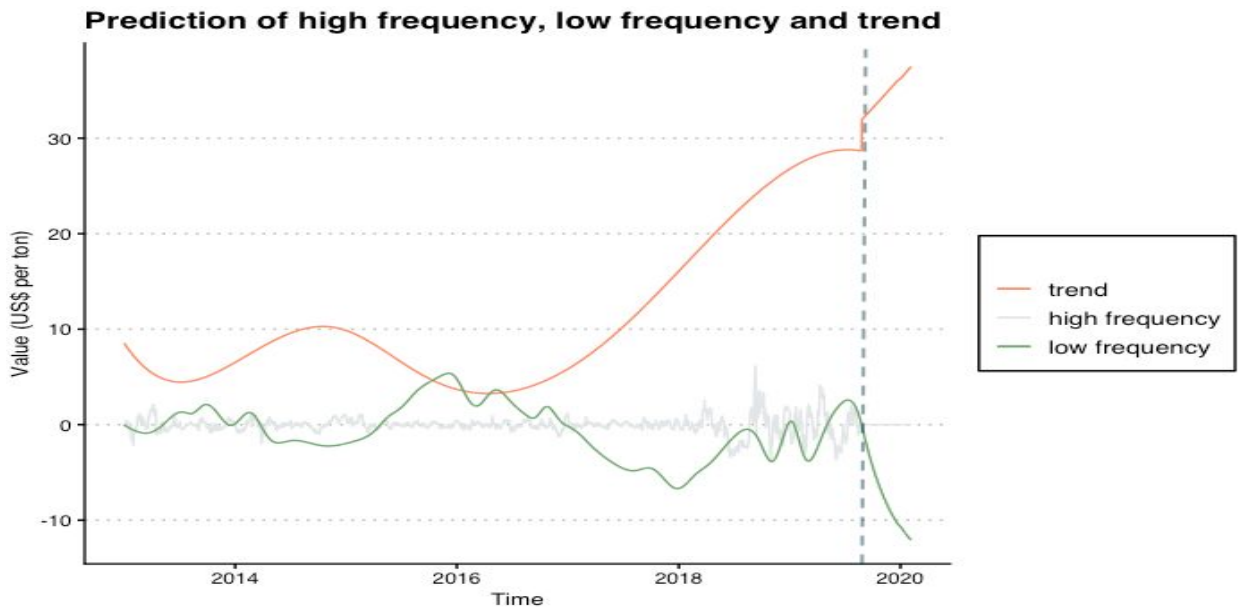


Fig.6. Testing prediction model: predicted price and actual price

We used our model to get carbon price predictions for the future (Fig.7). In 3 months, carbon price will drop to US$26.88, and then increase to US$74.09 in 3 years.

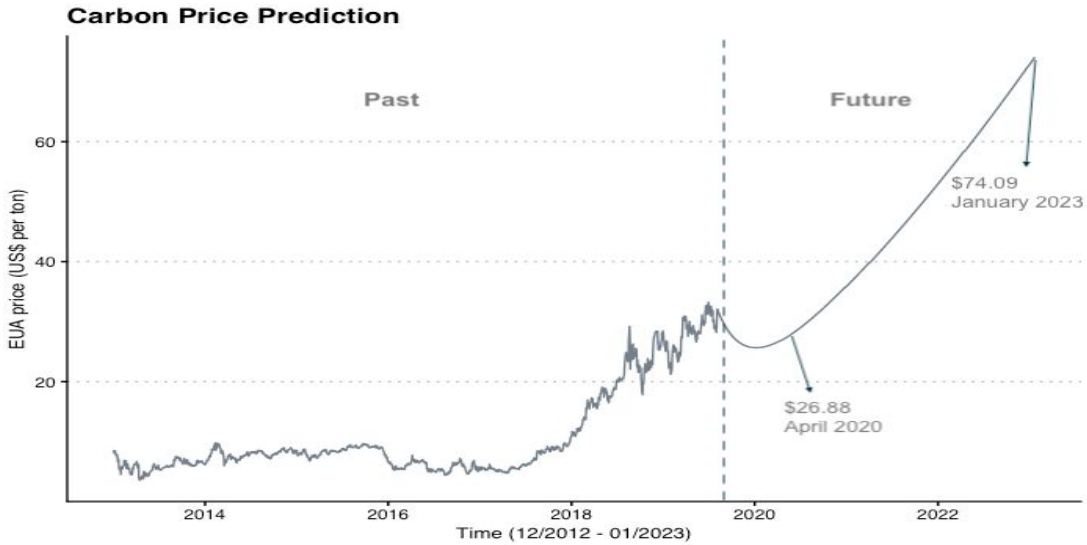


Fig.7. Carbon price prediction

Carbon VaR

Based on the carbon price prediction, we can obtain the value of investments at the risk of increasing carbon cost (Carbon VaR). In this part, after using a traditional cost-and-profit method to do Carbon VaR, we utilised a new method of correlation analysis.

Traditional Method: Cost-and-Profit Analysis

Assuming company's revenue, carbon emission and other costs are consistent over the time, higher carbon price results in lower net income attributable to shareholders. We used this method to predict the performance of Germany's largest utilities company, E.ON, based on the carbon price prediction (Table.3). In 3 months, E.ON's net income to shareholders will increase by 3% compared to 2018, and then decrease by 85% in 3 years.

Table.3. E.ON's net income to shareholders prediction, using the traditional Carbon VaR method

E.ON Carbon VaR	2018	April 2020	January 2023
carbon emission (ton CO2 eq)	69,060,000	69,060,000	69,060,000
carbon price (USD)	28.39	26.88	74.09
carbon cost (USD)	1,960,613,400	1,856,332,800	5,116,655,400
net income to shareholders before carbon cost (USD)	5,661,262,000	5,661,262,000	5,661,262,000
net income to shareholders (USD)	3,700,648,600	3,804,929,200	544,606,600
net income to shareholders compared to 2018(%)		3%	-85%

New Method: Correlation Analysis

Considering the disadvantage of strict assumptions in cost-and-profit analysis, we found correlation analysis as a new way to conduct carbon VaR for sectors. Sectors' indices are a good indication of sectors' performance in the stock market. Asset managers could reconstruct the sectors' proportion in their portfolio based on the performance prediction.

We calculated the correlation, *r*, between standardised EUA price and standardised sectors' indices. We then used *r* as the sectors' percentage change due to the change of EUA prices (Appendix F). As we assume the rapid increasing trend will continue, we looked into the correlation during the period from May 2018 to December 2018, where there was a sharp

increase in carbon price. We again focused on the 4 sectors: Basic Resources, Industrial, Retail, Technology. Additionally, we also chose to focus on Utilities, due to its importance in the German economy. Table.4 shows the standardised correlation between industries and EUA prices. For example, the correlation between standardised EUA and standardised basic resources' index is -0.51. This means, when the standardised EUA price increases by 1 unit, the standardised basic resources' indices will decrease by -0.51 units.

Table.4. Correlation between standardised EUA price and standardised sectors' indices

	Correlation with EUA (standardised)
Basic Resources	-0.51
Industrial	-0.33
Retail	-0.43
Technology	-0.55
Utilities	-0.15

By converting the result to unstandardised values, we can get the index change in the future (Table.5). All sectors will perform worse compared to 2018, as all of the sectors have negative correlation to EUA price. We predict a large decrease in 3 years with a high carbon price of US$74.09. If the correlation does not change in the future, industrial's index will decrease by 48% and utilities' index will decrease by 13% in 3 years.

Table.5. Sectors' indices prediction and percentage change

	Dec 2018	Apr 2020	Apr 2020 (% change to 2018)	Jan 2023	Jan 2023 (% change to 2018)
EUA	25.35	26.88	6.03%	74.09	192.27%
Basic Resources	1932.40	1829.21	-5.34%	-1360.72	-170.42%
Industrial	6693.67	6592.29	-1.51%	3458.12	-48.34%
Retail	364.13	350.28	-3.80%	-77.84	-121.38%
Technology	1069.05	1020.43	-4.55%	-482.33	-145.12%
Utilities	802.54	799.28	-0.41%	698.26	-12.99%

DISCUSSION

In analysing Germany, we noticed that qualitative trends described in the literature differed to our quantitative modelling. This is reasoned by the literature utilising market data prior to the carbon price increase in the EU ETS resulting from implemented policies. Our quantitative analysis is based on recent stock market and EUA data, providing a more current description of trends occurring in Germany under the EU ETS.

Our qualitative analyses of selected regions' ETSs demonstrates no clear trend of ETS impacts between countries, making it difficult to generalise a trend used to forecast impacts on Australia. However, after further analysis of the largest coal company within Germany, RWE, we can see a diversification of their resources. For example, RWE has recently invested $3.3billion in offshore wind projects to prepare for rising carbon prices, which have been increasing since 2018 (Thicknesse, 2019). This type of diversification can be modelled by Schroders to reduce their own investment risks.

Looking into the two structural breakpoints detected by B-P mutation test, we deduced that the first point was caused by policy change, and the second due to market mechanisms (Fig.8). Specifically, these were due to EU ETS reforms and the introduction of the Market Stability Reserve (MSR) (European Commission 2020), surplus carbon credits were removed, adjusting their supply in the light of current demand, ultimately accelerating the increase of carbon pricing. This sharply increasing trend ceased as the supply for carbon credits again balanced with the demand.

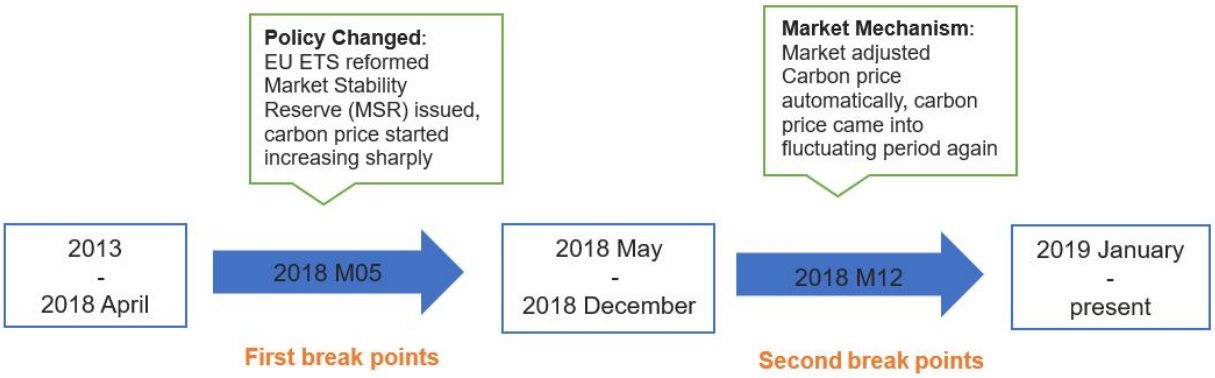


Fig.8. Bai & Perron mutation test result

Our correlation analysis found that there are some industries that are significantly affected by carbon price movements, for example, basic resources. This is understandable, as basic resources is a carbon-related industry, so market changes in EUAs dramatically impacts on its stock performance.

For the carbon price prediction, in 3 months, the carbon price will drop to US$26.88. The reason for the drop could be the carbon price following the short-term decline due to potential economic recession (Marcu, et al. 2020). The carbon price will then increase to US$74.09 in 3 years. This is a reasonable prediction, which follows the rapid increasing trend since 2018 and aligns with the European commission emission cuts policy (European Commission 2020). Our prediction could be improved by adding more data in the future, as more up-to-date data could train our model to be more accurate.

With traditional carbon VaR, E.ON's net income to shareholders is predicted to decrease by 85% in three years. However, E.ON is currently on the track of diversifying its energy consumption, resulting in lower carbon emission in the future. Additionally, the company's performance could be affected by many factors. It is unreasonable to assume consistent net income and consistent costs.

In our correlation analysis for carbon VaR, it is risky to assume consistent correlation for future predictions. As we can see from Table 5, the prediction of basic resources', retail's and technology's indices will drop to negative in 3 years, which is impossible. This is shown due to using a consistent negative correlation for our long-term future prediction. With increasing carbon prices, it will eventually result in a negative index. To fix this problem, we could extend the time period we used in our model. By adding more data in the future, this model could provide a dynamic correlation as well as accurate predictions.

Correlation does not mean causation. A possible limitation of this model is using correlation to predict the future. If the dynamic correlation could be stable in the future, then we can use this model to get safer and more accurate predictions of sectors' indices in the future. Overall, compared to the traditional cost-and-profit method, our new method has more advantages, as it relaxes the assumption of fixed emission amount, revenue and other costs. Our model compacts all the information into time-series data, it is dynamic and has room for improvement.

In summary, our entire model starts from carbon price decomposition and prediction, ends with a carbon VaR of Germany's sectors. As all of these are processed and modelled using computer

programming, by adding future EUA price and sectors' indices, our model could provide dynamic predictions for sectors' performance. Our model focused on the German market, but has the potential to model the Australian market and other global markets with other markets' input data. As the output of our model is simply sectors' indices predictions and sectors' change in the future, it gives direct recommendations to Schroders' asset managers about what is the risk exposure of their Australian portfolio, and how they should reconstruct the composition of each sectors' stocks in their portfolio.

Although qualitatively, impacts of the EU ETS on Germany are limited, recent policy changes under the EU ETS, as well as the implementation of new German ETS regulations, could produce unforeseen impacts on German industries. Future research should analyse recent and future trends on Germany's industries' performance in relation to current carbon pricing regulations for a more accurate perspective on how increasing carbon prices affects industries.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In this report, the team collaborated and contributed our interdisciplinary knowledge to qualitatively and quantitatively assess the risks of implementing an ETS against Australian industries using a case study approach. The trends of linked ETS's on regional industries from Quebec, China and Germany are not obvious, however, further qualitative analysis from Germany indicated the importance of diversification while facing carbon emission policy. Adapting a global ETS is predicted to not change the carbon price much in Australia in the next 3 months, instead increasing in 3 years based on our model. Investment risks of increasing carbon price is predicted to decrease in 3 years using traditional carbon VaR method by looking at E.ON, the largest utility company in Germany. The negative percentage changes from sectors indices in both short run and long run indicate negative impacts of carbon price increase towards basic resources, industrial, retail, technology and utilities industries using correlation analysis, which may guide Shcroders' future investments in Australia.

Recommendations

The recommendations will be focused within the carbon intensive sectors to address our primary aim: firstly, portfolio reconstruction; secondly, diversify investments; lastly, foster engagements.

Portfolio Reconstruction

We found that carbon price is negatively associated with carbon intensive sectors such as basic resources and industrials. The costs and profits are both affected as well in the future. Holding our assumptions valid, we would assume the effects of carbon pricing policy will have similar impacts towards those industries in Australia. Therefore, we would recommend Schroders weighting less of their portfolio on such carbon-intensive industries.

Diversify Investments

Looking at Germany, although the utilities industry is a carbon intensive sector, the industry is not affected by the carbon price movements. We examined the largest utilities companies, namely RWE and E.ON in Germany, finding they have diversified their operations towards cost efficient renewables while maintaining some coal interests to reduce the carbon effects. We found companies will financially perform better with such diversification compared to those who haven't (Dougans & Scalise, 2019). Schroders should invest in companies who have also adapted such a strategy in Australia within the utilities sector in its portfolio to avoid rising costs of carbon under an ETS.

Foster Engagements

10 out of 27 listed utilities companies in Australia have not engaged with such diversification (ASX Utilities Companies, 2020). Schroders could engage with the companies they are invested in and inform them on the benefits of diversification strategies to maintain economic performance.

By having a comprehensive understanding of the problem and thorough research of Schroders' current actions towards this area, our novel approach can be implemented by applying our research methodologies from Germany's case study in Australia's context to address potential unanswered questions for future work.

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APPENDIX

APPENDIX A: A Literature Review of Australia's Historical and Current Emissions Reduction Policies

Australia's responses to its international obligations in reducing carbon emissions had been insufficient. The 2011 Clean Energy Act introduced the carbon tax, stipulating that 500 of Australia's worst emitters were to surrender one carbon unit per tonne of emitted carbon dioxide equivalent (CO2-e) annually. These units were purchased from the Clean Energy Regulator, priced at AUD24.15 in 2013-14 (Irigoyen, 2017). Shortfall charges applied to insufficiently surrendered units and were priced slightly higher (AUD 31.395 per unit in shortfall in 2013-14) (Clean Energy Regulator, 2015).

The carbon tax was projected to reduce up to 12% of emissions in the short-run (Meng, Siriwirdana & McNeill, 2012). However, public support was weak, partly due to the policy's effects on the economy. The tax burden was passed on to households, with estimated household cost of living increasing by AUD9.90 per week, and the Consumer Price Index by 0.7% (Department of the Environment, 2014). Shareholder wealth, measured by abnormal returns, was negatively impacted across all sectors, with materials, industrial and financial sectors amongst the most significantly hit (Luo & Tang, 2014). Furthermore, electricity prices substantially increased, with retailer electricity prices rising by 25% (Meng, 2014). Although public confidence improved after its implementation, the tax was officially repealed after two years (Clean Energy Legislation (Carbon Tax Repeal) Act 2014).

The Emissions Reduction Fund (ERF) replaced the carbon tax (Carbon Farming Initiative Amendment Act 2014), with its three key elements involving crediting, purchasing and safeguarding. Crediting and purchasing involved organisations registering emissions-reducing projects to CER, earning Australian Carbon Credit Units (ACCUs) in the process. These units can be either sold to the Government through auctioning or sold to other businesses seeking to offset emissions (Department of the Environment and Energy, 2017). The Safeguard Mechanism mandates a baseline limit for Australia's largest greenhouse gas emitters – facilities with annual direct scope 1 emissions of more than 100,000 tonnes of CO2-e (Department of Parliamentary Services, 2018). This facility-specific baseline is reflected from the National Greenhouse and Energy Reporting (NGER), accounting for the highest level of reported emissions between

2009-10 and 2013-14, and variabilities that skew business-as-usual emissions such as economic growth.

Unlike the carbon tax, the economic contraction resulting from the ERF is milder, with several studies predicting a real GDP decrease between 0.3% (Nong, 2019) and 0.55% (Nong & Siriwardana, 2018). However, the scheme is insufficient in achieving Australia's target emissions, with the current AUD2.55 billion budget only projected to decrease emissions by 225 Mt CO2-e between 2015 and 2020 (Nong & Siriwardana, 2018). With direct combustion of fossil fuels comprising 19% of Australia's 534 Mt CO2-e greenhouse gas emissions in 2017-18 (Climate Change Authority, 2019), a projected 15% increase of these emissions by 2030 will lead to Australia's unfulfillment of its obligations to the UNFCCC and Paris Agreement (Climate Analytics for the Australian Conservation Foundation, 2019).

If an ETS is implemented such that the Australian carbon market would be linked globally, and as the carbon tax was intended to transition towards (Clean Energy Act, 2011), the resulting emissions reduction would be more effective compared to the ETS. With the price of carbon permits projected to increase to AUD43.5 per tonne in 2030 (Nong, Meng & Siriwardana, 2017), outputs of brown coal and gas electricity would decrease by 22.89% and 12.6% respectively. Conversely, wind electricity generation is projected to increase by 16.62% (Meng, Siriwardana, McNeill & Nelson, 2018). However, an Australian ETS would slightly decrease real GDP more than the current ERF, lowering to 1.84% by 2030 (Nong, Meng & Siriwardana, 2017).

APPENDIX B: Variables Description Table and Pre-processing Methods

Variable name	mean	median	maximum	minimum	SD	SE	Skew	Kurtosis
EUA	10.33	6.81	27.93	3.54	7.53	0.81	1.15	-0.32
Banks	129	123.30	203.46	62.86	42.40	4.57	-0.01	-1.41
Basic Resources	3	1761.07	3011.55	1317.38	379.70	40.94	1.01	0.13
Chemicals	1883.93	2496.46	3015.11	1845.23	315.09	33.98	-0.25	-1.09
Financial	2486.68	1477.46	2633.74	754.75	539.66	58.19	0.13	-1.25

Services								
Industrial	1549.07	5210.83	7547.51	3415.34	1179.53	127.19	0.02	-1.35
Retail	373.19	375.89	509.32	236.91	62.99	6.79	-0.15	-0.55
Telecom	208.76	224.45	259.32	106.47	42.01	4.53	-1.10	-0.11
Technology	818.53	793.88	1330.34	375.10	281.80	30.39	0.08	-1.35
Utilities	687.51	719.73	961.10	443.38	132.60	14.30	-0.43	-0.92

We can see for EUA In terms of skewness and kurtosis, it does not follow a normal distribution, so a linear estimation from our use of a correlation analysis cannot be applied. Besides, the variation of EUA prices is comparatively larger than other variables. Hence, we normalised this data using log-transform.

Nearly all variables' kurtosis are less than 0 or very close to 0, which indicates they all follow Platykurtic distribution, hence we do not need to implement any additional data processes to conform data.

For missing value in variables, we applied Maximum Likelihood Estimations (Appendix C) to predict the missing value in EUA future price data, and removed outliers of each variable.

APPENDIX C: Maximum Likelihood Estimation

The maximum likelihood estimation is a critical step in data pre-processing, used to predict the missing values in all variables.

After normalising the EUA daily settlement price data, we got a new stationary univariate time series. To estimate the parameters of the missing value, the Maximum Likelihood Estimation is derived.

We assume processed EUA data follows Normal distribution, its likelihood function is

$$L(\mu,\sigma^2)=\prod_{i=1}^{N}\frac{1}{\sqrt{(2\pi)}\sigma}e^{-\frac{(x_i-\mu)^2}{2\sigma^2}}=(2\pi\sigma^2)^{-\frac{n}{2}}e^{-\frac{1}{2\sigma^2}\sum_{i=1}^{N}(x_i-\mu)^2}$$

Take its log transformation:

$$lnL(\mu,\sigma^2)=-\frac{n}{2}ln(2\pi)-\frac{n}{2}ln(\sigma^2)-\frac{1}{2\sigma^2}\sum_{i=1}^{N}(x_i-\mu)^2$$

Take derivation, get our equation set as:

$$\begin{cases}\frac{\delta lnL(\mu,\sigma^2)}{\delta\mu}=\frac{1}{\delta^2}\sum_{i=1}^{N}(x_i)-\mu\\ \frac{\delta lnL(\mu,\sigma^2)}{\delta\sigma^2}=-\frac{n}{2\delta^2}+\frac{1}{2\sigma^4}\sum_{i=1}^{N}(x_i-\mu)^2\end{cases}$$

With result as:

$$\begin{cases}\mu^*=\overline{x}=\frac{1}{n}\sum_{i=1}^{n}x_i\\ \delta^{*2}=\frac{1}{n}\sum_{i=1}^{n}(x_i-\overline{x})^2\end{cases}$$

Then we get maximum likelihood estimation result (μ^*,σ^{*2})

APPENDIX D: Empirical Mode Decomposition (EMD)

In Empirical Mode Decomposition (EMD), to find Intrinsic Mode Functions (IMFs), first we need to find the maximas and minimas of time-series data $x(t)$. By linking all the maximas as the upper envelope and all the minimas as the lower envelope, we can find the average value m_1 and the difference h_1 between the data and the average value.

$$h_1 = x(t)-m_1$$

The number of extremas and zero-crossing points of h_1 should be the same or at most differ by one. And then we test if h_1 satisfy the conditions (small standard deviation) of IMF.

$$SD_k = \sum_{t=0}^{T} \frac{|h_{k-1}(t) - h_k(t)|^2}{h^2{}_{k-1}(t)}$$

If h_1 does not meet the criteria of IMF, we then find the maximas and minimas of h_1, find the mean of the extremas m_{11}, and then get new difference h_{11}.

$$h_{11} = h_1 - m_1$$

$$h_{12} = h_{11} - m_{11}$$

.....

We then keep this procedure until we find an h_{1k} that meet the criteria of IMF. And finally, we get the first IMF.

$$IMF_1 = h_{1k}$$

To get the other IMFs, we first subtract IMF_1 from $x(t)$, and then repeat the procedure of how we find IMF_1, until we cannot find any h which satisfies the condition of the number of extremas and zero-crossing points. At this point, we have sifted out all the IMFs, we can get the residual.

$$residual = x(t) - \sum IMF$$

APPENDIX E: Fine-to-coarse Reconstruction

To group IMFs into high frequency, low frequency and trend layers, first, we calculated the sum of the first iIMFs.

$$\vec{S}_i = \sum_{k=1}^{7} I\vec{M}F_k$$

The vector signs (arrows) indicate they are time-series data instead of a number.

And then tested whether the true difference in means of $\vec{s_i}$ is significantly differ from zero using the Welch two-sample t-test.

$$H_0 : mean\ of\ \vec{s_i}\ is\ zero; \qquad H_1 : mean\ of\ \vec{s_i}\ is\ not\ zero$$

After finding the first $\vec{s_i}$ which is significant, the first IMF to the ith IMF are grouped together as the high frequency layer,

$$\vec{f_{high}} = \sum_{k=1}^{i} \vec{IMF}_k$$

leaving the left IMFs grouped into the low frequency layer.

$$\vec{f_{low}} = \sum_{k=i+1}^{7} \vec{IMF}_k$$

Residue is the trend layer.

APPENDIX F: Carbon VaR: Correlation Analysis

First, we need to standardise time-series data of EUA price and sectors' indices by subtracting the average $\bar{x}$ and then dividing the standard deviation $\sigma(x)$.

$$z_{EUA} = \frac{EUA - \bar{EUA}}{\sigma(EUA)}$$

$$z_{sector} = \frac{sector - \bar{sector}}{\sigma(sector)}$$

And then correlation $cor(z_{EUA}, z_{sector})$ is calculated. For linear regression, the slope b could be calculated from correlation.

$$b = cor \times \frac{\sigma(sector)}{\sigma(EUA)}$$

As our time-series data is standardised, $\sigma(z_{EUA}) = \sigma(z_{sector})$, we can use the correlation straightly as b.

$$b = cor(z_{EUA},\ z_{sector})$$

After finding the b, we can get the prediction of sectors' standardised changes.

$$\Delta z_{sector} = b \times \Delta z_{EUA}$$

Sectors' indices change is calculated by converting Δz_{sector} into unstandardised values.

$$\Delta sector\ =\ \Delta z_{sector} \times \sigma(sector) + \bar{sector}$$

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