Fordypning i investering, finans og økonomistyring

Financial Engineering, specialization

Fagkoordinator høst 2024 - vår 2025: Professor Stein-Erik Fleten

Formål:
Emnet gir fordypning innenfor bedriftsøkonomi.
Faggruppen ønsker å gi dere en mulighet til å arbeide i en lengre periode med et problem som er mer komplisert og detaljert enn de problemer som normalt tas opp i forelesningene. Kompleksiteten i problemene er vanligvis av en slik art at dere trenger å bruke kunnskap fra flere fag dere har tatt eller tar parallelt, i tillegg til å lese seg til ny kunnskap. Faget er også et tilbud til dere om veiledning i relasjon til problemstillinger som dere reiser selv, til forskjell fra forelesninger hvor det er foreleseren som kommer med problemene. Det er altså mulig å foreslå oppgaver selv – kontakt en av veilederne om dette.

Forutsetning:
Presise krav til emnekombinasjoner som kvalifiserer til IFØ-fordypningen er beskrevet på Emner på Nett. Vi forventer minst kunnskaper tilsvarende TIØ4145 Finansstyring, og en av følgende: TIØ4317 Empirisk finans, TIØ4140 Prosjektfinans.

Dette er en større skriftlig oppgave.
Arbeidet med oppgaven vil ofte bestå av følgende:

- Lese ny "teori".
- Klargjøre/forstå det praktiske/teoretiske problemet.
- Framskaffelse av data.
- Lage økonomiske modeller.
- Implementere disse.
- Skrive rapport.

Besvarelsen redigeres mest mulig som en forskningsrapport med et abstract, konklusjon, litteraturliste, innholdsfortegnelse etc. Ved utarbeidelse av teksten skal kandidaten legge vekt på å gjøre teksten oversiktlig og velskrevet. Med henblikk på lesning av besvarelsen er det viktig at de nødvendige henvisninger for korresponderende steder i tekst, tabeller og figurer anføres på begge steder. Ved bedømmelsen legges det stor vekt på at resultatene er grundig bearbeidet, at de oppstilles tabellarisk og/eller grafisk på en oversiktlig måte og diskuteres utførlig. Det er meget viktig at alle benyttede kilder, også muntlige opplysninger, oppgis fullstendig. (For tidsskrifter oppgis tittel, årgang, sidetall og evt. figurnr. For bøker oppgis forfatter, tittel, årgang, opplag, sidetall og evt.

figurnr.).

Valg av oppgave

Beskrivelsene av problemene er ment som en hjelp for å velge oppgave. De er ikke ment som komplette oppgavetekster. Det vil heller ikke bli laget noen oppgavetekst. Oppgaven vil bli til underveis i diskusjon mellom studenter, veileder(e) og eventuell bedriftskontakt. Oppgaven som velges skal i utgangspunktet videreføres i masterprosjektet. Erfaring har vist at studenter som gjør prosjekt- og masteroppgave i tilknytning til samme problemstilling blir mest tilfreds. Derfor ønsker vi ikke å gi prosjektoppgaver som vi ikke tror at det finnes en masteroppgave-oppfølging til.

Hver oppgave er beskrevet med en kort tekst. Deretter følger informasjon om eventuell samarbeidspartner samt veileder. En person er listet som hovedveileder og det er denne som skal kontaktes om det er spørsmål knyttet til oppgaven. Videre er oppgaven merket med hvilken eller hvilke av IØTs strategiske forskningsinitiativ oppgaven er koplet mot. De strategiske forskningsinitiativene er; Technology-based organization design, Leading Transitions: Co-create a sustainable future, Green Value Creation – Circular Economy og Health and the Public Sector. Oppgaven er merket med «Sustainability» om bærekraft er et viktig tema i oppgaven.

Det vil bli arrangert workshops relatert til de strategiske forskningsinitiativene og bærekraft. Studenter som får tildelt oppgaver som er merket med forskningsinitiativ eller bærekraft vil bli invitert til disse workshopene. Det er frivillig å delta. Andre studenter vil også kunne delta med forbehold om plass og ressurser.

Valg av oppgave gjøres i et nettskjema. Nettskjemaet innebærer et valg av fem ulike oppgaver i prioritert rekkefølge. Studentene må velge oppgaver med minst tre ulike hovedveiledere. Studentene må forvente å få tildelt hvilket som helst av disse, inkludert 5. valget.

Studenter som vil skrive egendefinert oppgave må avklare oppgaven med veileder før de velger. Studenter med egendefinert oppgave velger IFØ1 som en av de fem valgte oppgavene. Se mer informasjon om egendefinert oppgave under IFØ1 senere i dokumentet. Det må i så fall også oppgis veiledere i nettskjemaet. Det er ikke sikkert at en student blir tildelt en egendefinert oppgave. Dette avhenger av den totale ressurssituasjonen blant veilederne.

Der det er oppgitt biveileder kan denne på grunn av ressursmessige årsaker bli hovedveileder for oppgaven. Det er ikke mulig å ønske seg eksplisitt en av veilederne blant de som er listet. Der det er angitt kontaktpersoner i samarbeidsinstitusjoner skal disse ikke kontaktes før det eventuelt er gitt klarsignal fra oppgitt hovedveileder (med mindre annet er angitt i oppgaveteksten).

I prosessen med tildeling av oppgaver vil det tas hensyn til fordelingen mellom de ulike veilederne og studentenes prioritering. Der en person står som hovedveileder på mange oppgaver, kan det tenkes at personen ikke vil ha kapasitet til å ha studenter på alle oppgavene. Dersom dette blir tilfelle kan en annen veileder bli tildelt av de som står listet i oppgaveteksten. Vi vil enda en gang understreke at dersom det er mange studenter som har valgt de samme oppgavene, må en være forberedt på at en får tildelt oppgave som står lenger ned på prioriteringslisten. En studentgruppe kan altså bli tildelt sitt femtevalg, til tross for at andrevalget ikke er tildelt en gruppe. En forklaring på dette kan være at veilederen på oppgaven ikke har kapasitet til å veilede flere oppgaver.

Det er sterkt anbefalt at studentene utfører arbeidet i grupper på to studenter, selv om det er mulig å være 1 eller 3 studenter i en gruppe. Vi anbefaler at dere selv finner en student å samarbeide med i prosjektet. Studenter som ønsker å skrive med noen, men som ikke har funnet noen å skrive med, kan oppgi dette i kommentarfeltet i nettskjemaet.

Det kan også være mulighet for å fortsette på doktorgradsstipend i etterkant av mastergraden. Dersom noen ønsker å forhøre seg om muligheten for dette, anbefaler vi at de tar kontakt med de aktuelle veiledere, helst så snart som mulig.

Mulige veiledere

Førsteamanuensis II Einar Belsom, tlf 41 50 97 67, Einar.Belsom@oslomet.no
Hans hovedstilling er ved Oslomet. Hans doktorgrad innenfor industriell økonomi omhandler metoder for måling av produktivitet når det er behov for samtidig evaluering av flere faktorer. Hans faglige interesser ellers er rettet mot bedriftsøkonomiske temaer med vekt på styrings- og insentivsystemer, bedriftsfinans/fusjoner og oppkjøp, dvs i skjæringspunktet mellom finans og strategi. Flere ganger mottaker av IØTs pris for beste veileder. Bakgrunn fra bla McKinsey.

Professor Peter Berling, lars.p.berling@ntnu.no

In my research I work on developing models and methods to support operational and tactical decision making under uncertainty and risk. A special focus has been devoted to inventory control and the interface between operations and finance, but it also includes research on related fields such as transportation and contracts. I have been at IØT since the summer 2021 and have previous experience from Lund and Linnaeus University as well as MIT/ZLC.

Professor Stein-Erik Fleten, tlf. 46 69 47 93, Stein-Erik.Fleten@ntnu.no
Stein-Erik arbeider innen kvantitativ bedriftsøkonomi; beslutninger under usikkerhet og realopsjoner: teori, casestudier og empiriske analyser. Anvendelser er ofte innenfor kraftsektoren (investeringsanalyse, risikostyring, driftsplanlegging/ produksjonsoptimalisering, prisanalyse) og andre råvaremarkeder. Typiske oppgaver innebærer kombinasjon av mikroøkonomi/finans, optimering og ingeniørkunnskap, gjerne beregningsorientert.

Professor Verena Hagspiel, verena.hagspiel@ntnu.no

Verena holds a Ph.D. in Economics and a Dipl.-Ing. in Technical Mathematics as well as a M.Sc. in Quantitative Finance and Actuarial Sciences. After working as a postdoctoral researcher at the University of Lausanne and the Technical University of Lisbon, she joined IØT as an Associate Professor in 2013. Her primary fields of interest are microeconomics, industrial economics, energy economics and quantitative finance. She applies financial and operational methods for analyzing investment decisions under uncertainty and is interested in how dynamics and uncertainty affect the firm's investment, operations and innovation. Her main field of research lies in the area of real options analysis. Here contributions range from the development of novel theoretical models to applications in industry. She has collaborated with several energy companies from the renewable as well as oil & gas sector and has worked on applications related to the Norwegian aquaculture industry, deep sea mining or automotive industry.

Professor II Franziska Holz, fholz@diw.de

Franziska Holz is an International Adjunct Professor in the NTNU's Energy Transition Programme (NETI). Franziska studied economics at Paris 1 University Panthéon-Sorbonne (1998-2003) and obtained her PhD in energy economics in 2009 from TU Berlin. Franziska's main affiliation is with the German Institute for Economic Research (DIW Berlin) where she is Deputy Head of the Department of Energy, Transportation, and Environment and coordinates the research area resource and environmental markets in the department. Her research deals with international natural gas, coal, and oil markets. She focuses on the interaction of these markets with climate policies, mostly by using numerical equilibrium models (also see www.diw.de/cv/en/fholz).

Førsteamanuensis Maria Lavrutich, tlf 73 59 31 89, maria.lavrutich@ntnu.no

Maria holds a PhD from Tilburg University (2016). Fields of interest include mathematical finance, industrial organization and decision theory (with applications to real options) and sustainable finance. In her research she focuses on firms' investment and innovation strategies and has developed models of investment under uncertainty and risk management, as well as their applications in different industries, including aquaculture, electricity, oil and gas, pharmaceuticals.

Associate professor II Malvina Marchese Malvina.Marchese@city.ac.uk

Malvina Marchese is a PhD and Associate Professor at Bayes Business School in London. Her field of specialization covers; Forecasting, with emphasis on commodity markets forecasting. Panel data Econometrics, with emphasis on quantile regressions for panel data models and applications to banking. Econometric Theory, with emphasis on asymptotic theory for fractionally integrated processes. Before entering academia, she has worked/work as a forecast consultant for Maersk Broker and head of risk management at Shell Oil.

Olga Noshchenko – tlf 92 97 41 65; olga.noshchenko@ntnu.no

Olga is a Ph.D. candidate at the Department of Industrial Economics and Technology Management. She conducts her research in the field of petroleum economics. In particular, she is focused on multi-objective optimisation and decision making under uncertainty. Her research is aimed to improve economic and environmental performance of offshore field projects.

Farida Mustafina – tlf 45398985; Farida.mustafina@ntnu.no

Farida is a Ph.D. candidate at the Depart. of Industrial Economics and Technology Management. She conducts her research in the field of economics of deep-sea mining activities. In particular, she is focused on investment decision making under uncertainty. Her previous research experience is related to deep-sea mining as well.

Førsteamanuensis Carlos Oliveira carlos.m.d.s.oliveira@ntnu.no

Carlos holds a Ph.D. in Mathematics, a M.Sc. in Mathematical Finance, and a bachelor's in Applied Mathematics to Economics and Management. Before he joined IØT, he was a postdoctoral researcher in the Group of Mathematical Physics in Lisbon, and an Assistant Professor at Lisbon School of Economics and Management, where he did research in Quantitative Finance and Actuarial Science. He is particularly interested in the field of real options, reinsurance, and sustainable finance. He has also collaborated as a researcher on projects in insurance and investment in alternative energy sources.

Førsteamanuensis Rita Pimentel, rita.pimentel@ntnu.no

https://www.ntnu.edu/employees/rita.pimentel

Rita holds a Ph.D. in Statistics and Stochastic Processes as well as an M.Sc. in Mathematical Finance. After working as a researcher at the Research Institutes of Sweden (RISE), she joined IØT as an Associate Professor in 2020. At RISE she applied different machine learning techniques to make predictions for companies in different sectors (such as ABB, Bombardier, Holmen, among others). Currently, she researches sustainable finance, applications of artificial intelligence (AI) in finance, Fintech, and decisions under uncertainty. She is also the project manager of COMPAMA, an interdisciplinary project funded by The Research Council of Norway, which the main purpose is to understand the economic impact of decisions, made by both machines and human agents. She has been collaborating in the COST (European Cooperation in Science & Technology) action called Fintech and Artificial Intelligence in Finance funded by the European Union.

Morten Risstad, tlf 97 16 62 63, morten.risstad@ntnu.no

I hold a PhD from the Department of Industrial Economics and Technology Management at NTNU and a MSc in Finance from Nord University. I am also a Certified European Financial Analyst (CEFA) from NHH. I have previously held positions in consulting firms, multi-national industrial corporations and financial institutions; mainly related to financial reporting, corporate finance, trading and risk management. My research interests lie in the fields of empirical finance, asset pricing, derivatives and risk management. I am on the research team of Norwegian Open AI Lab.

Professor II Ståle Størdal, tlf 99 40 93 71, stale.stordal@ntnu.no

Ståle har hovedstilling på Høgskolen i Innlandet innenfor bedriftsøkonomi med hovedvekt på ressursbaserte næringer. Han har jobbet med studier av markeder for skogprodukter og energi, spesifikt med empiriske analyser av råvaremarkeder og finansielle beslutninger under usikkerhet, herunder investeringsanalyser. Han har tidligere jobbet 15 år innen energisektoren med kraftmarkedsanalyser, porteføljeforvaltning og hatt ansvar for finansiell handelsvirksomhet.

Professor Sjur Westgaard, tlf 73593511/ 91897096, sjur.westgaard@ntnu.no.

Sjur Westgaard forsker og underviser i ulike finansfag. Han er utdannet ved NHH og IØT-NTNU hvor han på også har sin PhD. Tidligere har han jobbet som kapitalforvalter, kredittanalytiker og prosjektleder ved ulike finans-/bankinstitusjoner. Hans forskningsinteresser omfatter risikomodellering og empirisk analyse av finans- og råvaremarkeder med for tiden spesiell fokus på energimarkedet.

Liste over prosjektoppgaver:

IFØ1. Egendefinert studentprosjekt

Studenter som vil skrive en egendefinert oppgave må avklare dette med en veileder på forhånd. For at dette skal fungere så bra og rettferdig som mulig gjelder følgende

Studenten må planlegge en egendefinert oppgave i god tid før valget skal tas 4. mai

Studenten må presentere en tydelig prosjektbeskrivelse til en potensiell veileder

Veilederen vurderer prosjektbeskrivelsen og om han/hun har kompetanse og mulighet for veiledning

Studenten bør ha fått godkjent fra veilederen før minglemøtet 26. april

Studenten kan etter godkjennelse fra veilederen velge IFØ1 som ett av sine fem valg. Navnet på veilederen må oppgis i kommentarfeltet i nettskjemaet

IFØ02. Analysis of the short-term markets for Norwegian crude oil

In this project we will analyse the short-term markets for crude oil delivered from the Norwegian continental shelf. This includes the market for physical cargoes, as well as the short-term financial markets. The motivation is that this is these are the main markets that generate the Norwegian oil revenues.

We take the perspective of an oil field operator or an industrial buyer, and aim at supporting their pricing and valuation challenges. Prospective sellers include Equinor, Vår Energi, Okea, DNO, Aker BP, and prospective buyers include Exxonmobil, Preem, Shell, BP, Mongstad (Equinor). Also large distributors or consumers of oil products, and professional trading firms, are relevant contact companies.

Example background problems:

What are good strategies for pricing the differential value associated with oil grades at different oil fields (what are the incentives for two-pack deals where the idea is to tax-optimize oil trades)?

What is the value of converting the Mongstad refinery into a terminal?

How efficient are the short-term markets for crude oil?

An important aim for the project thesis is to get an overview of the spot market for crude oil, and its connection to short-term financial markets. Although this market is accessible only for large industrial players and constitute a small share of oil product turnover, it is crucial as an underlying reference for derivative transactions. Trade happens over the phone, text or online, and is standardized in terms of delivery location, whether freight is included or not, cargo size, and delivery timing. On the other hand, there are price differentials depending on the oil quality and location. The two major price assessment agencies are Platts and Argus. The main spot index is Platts Brent Dated, and the main financial contracts are traded on the ICE exchange. There are two intermediate markets in between; a “contracts for differences” financial market, and an “exchange of futures for physical” market operated by ICE. Some of the forward contracts can be physically settled, and we would like to learn if, and to what degree, this creates opportunities for trading gains. We also want to understand the tradeoffs involved in the exact timing of selling or buying crude oil. Finally, we want to understand the risks associated with using the various buying/selling channels, and how these risks can be managed.

A project thesis will naturally aim at addressing the questions just mentioned, while a master thesis would aim for one of the example background questions or a similar challenge.

Unfortunately, NTNU does not subscribe to (all) data series from Platts. Students need to get in touch with a company that has access or rely on publicly available data and LREG databases that we subscribe to.

Contact firm: Students can contact a firm if desirable. I prefer this to be either a consultancy, governmental body, NGO or an industrial buyer. Not a producer, since I am a member of the Petroleum Price Board, and ties to producers must be avoided.

Main supervisor: Stein-Erik Fleten

For more information, please contact Stein-Erik Fleten, stein-erik.fleten@ntnu.no to schedule a meeting.

IFØ03. Assessment of long-term cash flow hedging in electricity markets

Actors in the energy market use different types of hedging instruments (e.g., electricity derivatives or physical or financial bilateral contracts) to secure part of their future income stream. A number of risk factors are present for electricity producer such as price risk, volume risk, FX-risk as well as asymmetric taxation. These factors will affect the effectiveness of hedging. In this project the students will assess the hedging effectiveness of traded products regarding investment horizon cash flows. Moreover, they will analyse how this effectiveness differs across Europe and hedge instruments?

This project can combine normative (theoretical) research with empirical work and simulations. For the latter part one should collect data relevant for the study, which in turn would be used to do simulations. This project work is highly relevant for energy companies and could be done in close collaboration with them.

Main Supervisor: Ståle Størdal

For more information, please contact Ståle Størdal, stale.stordal@ntnu.no, to schedule a meeting.

IFØ04. Approximating the exercise boundary for American options using machine learning

Monte-Carlo simulations are more suitable handling European option pricing problems if there are many stochastic variables. For American option pricing, as summarized in an overview by Kind (2005), a regression approach proposed by Longstraff and Schwarz (2001) and an exercise boundary parameterization approach proposed by Andersen (2000) are popular simulation methods.

In Andersen (2000), the early boundary is determined iteratively by starting at the maturity, with a known boundary of strike price, and going backward in time. More recent works using early exercising boundary approach can be found in, for example, Ibanez and Fernando (2004) and Ibáñez and Velasco (2018).

In this project, we investigate the exercise boundary approach for American option pricing using modern machine learning techniques. For example, a neutral network can be used to learn the hold and exercise regions, separated by the exercising boundary. Some pioneer work is done in Becker (2019).

Main supervisor: Rita Pimentel

Co-supervisor: Ying Ni, Mälardalens University, Sweden

References:

- Kind, A. (2005). Pricing American-style options by simulation. Financial markets and portfolio management, 19(1), 109-116.
- Longstaff, F. A., and Schwartz, E. S. (2001). Valuing American options by simulation: a simple least-squares approach. The review of financial studies, 14 (1), 113-147.
- Andersen, L. (2000). A Simple Approach to the Pricing of Bermudan Swaptions in the Multi-Factor Libor Market Model. Journal of Computational Finance, 3, 5–32.
- Ibanez, A., & Zapatero, F. (2004). Monte Carlo valuation of American options through computation of the optimal exercise frontier. Journal of Financial and Quantitative Analysis, 39(2), 253-275.
- Ibáñez, A., & Velasco, C. (2018). The optimal method for pricing Bermudan options by simulation. Mathematical Finance, 28(4), 1143-1180.
- Becker, S., Cheridito, P., & Jentzen, A. (2019). Deep optimal stopping. Journal of Machine Learning Research, 20, 74.

For more information, please contact Rita Pimentel, rita.pimentel@ntnu.no, to schedule a meeting.

IFØ05. Bayesian stock price forecasting using machine learning

Forecasting in the financial markets has a long history of related research and various approaches to predict future market states. Recently, advanced approaches such as methods based on neural networks have been actively studied as they are capable of discovering representations from raw data. Despite the remarkable potential of methods based on neural networks, the direct use of their outputs is limited due to the lack of reliable uncertainty estimates. Neural networks are prone to overfitting. Making decisions based on point prediction may provide incorrect predictions with spuriously high confidence. To address this problem, the neural networks need to provide uncertainty estimation as an additional insight to point estimates so as to improve the reliability in the decision-making process. By quantifying the uncertainty in stock price forecasting, investors can get a better understanding of the potential risks and rewards associated with a given investment in the face of complex and dynamic stock market conditions.

Estimating uncertainty in neural network methods is challenging. To address this issue, we need to have an approach that quantifies the uncertainty in the neural network. This may be done using Bayesian neural networks (BNNs). Bayesian neural networks learn distributions over each of the network's weight parameters. There are, however, several methods for quantifying uncertainty in neural networks using the Bayesian approximation, for example, Markov chain Monte Carlo (MCMC) and variational inference (VI).

Main supervisor: Rita Pimentel

Co-supervisor: Energy Sonono, North-West University, South Africa

References:

- Abdar, M. et al., 2021. A review of uncertainty quantification in deep learning: Techniques, applications and challenges. Information fusion, Volume 76, pp. 243-297.
- Chandra, R. & He, Y., 2021. 2021. Bayesian neural networks for stock price forecasting before and during COVID-19 pandemic. Plos one, 16(7).
- Maeda, I. et al., 2021. Predictive Uncertainty in Neural Network-Based Financial Market Forecasting. International Journal of Smart Computing and Artificial Intelligence, 5(1), pp. 1-18.
- Olivier, A., Shields, M. D. & Graham-Brady, L., 2021. Bayesian neural networks for uncertainty quantification in data-driven materials modeling. Computer methods in applied mechanics and engineering, Volume 386.

For more information, please contact Rita Pimentel, rita.pimentel@ntnu.no, to schedule a meeting.

IFØ06. Decision support for low-carbon ship refueling in ports.

Maritime transport plays a crucial role in global trade, handling around 80% of total volume. This sector is also responsible for approximately 3% of global Greenhouse Gas emissions [1]. In light of the international commitments to achieve Climate neutrality by 2050 as set by the Paris Agreement, also ships will have to transition from using carbon-intensive to low-carbon fuels. The transition towards a decarbonized sector does not only entail equipping ships with low and net-zero carbon technologies but also significantly impacts the fuel market landscape. With the anticipated expansion of low- and net-zero carbon fuels, ports are strategically positioned to lead in decarbonization efforts.

Ports will have to transition to offer low- and zero-carbon fueling options for ships. The integration of new fuels into ports can be done by cables or pipelines or supplier ships for fuel delivery. Additionally, ports have some potential to engage in production of alternative fuels, taking advantage of the proximity to renewable energy resources (e.g., offshore wind), water access, and connections to significant industry clusters.

The project thesis aims to develop a decision support tool for the creation of strategic roadmaps for a port or several ports in a region to meet emission reduction targets of 2030 and 2050. Backdrop for the analyses are supply and demand scenarios for renewable energy and hydrogen-based fuels, such as ammonia, in North-West Europe. The strategic roadmap will inform the timing and sizing of port fueling infrastructure in the context of the local energy system(s). The research questions can be: What type of fuel technology should a port offer for bunkering? Which supply method should a port invest in based on costs and effectiveness? Should ports invest in fuel production, or should their role remain in providing bunkering services? What are the financial implications for shipping decarbonization for ports?

The project can include the following tasks:

- Review relevant literature on fleet decarbonization.
- Collect data and possibly discuss with stakeholders.
- Develop a decision support tool that suggests a decarbonization plan for ports.
- Perform computational experiments to test the tool with various port needs and settings.
- Analyze the results and assess the broader implications of implementing the suggested transition plan, including potential benefits and drawbacks for port operators.

This project is part of the research project NordH2ub https://csei.eu/nord_h2ub/. Knowledge of mixed integer optimization and programming skills (like Python) is expected.

Main supervisor: Ruud Egging-Bratseth

Co-supervisor: Kais Msakni

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

For more information, please contact Ruud Egging-Bratseth, rudolf.egging@ntnu.no, to schedule a meeting

IFØ07. Designing a mineral processing cooperation agreement between a seabed mining and a land mining company under uncertainty

The study of the value chain of marine minerals has focused mainly on exploration and offshore production: Though mineral processing plays a crucial role as it converts the mined ore into a sellable product. In land mining, the mineral processing plant represents a large portion of the mine CAPEX and requires several years of production to be rationalized. When a mine closes valuable minerals remain in the original deposit. But due to their relatively low metal content and/or location, these minerals are not extracted as they are considered economically non-viable (waste). By analogy, if seabed miners must invest and operate a dedicated mineral processing plant, several years of secured production would be required with increased constraints on exploration i.e. a minimum reserve portfolio. An increased minimum reserve criteria increases the exploration CAPEX and postpones production.

It is a hypothesis that compatible ores could be blend in an economically viable setup. Seabed ore is expected to exhibit relatively high metal grades and might be used as a "grade booster" for land sub-economic ore thus upgrading what was previously considered as waste. This could allow to prolong the LOM (Life of Mine) of onshore mines. From an ESG perspective, opening a new mine has an impact on the environment of the mine location. Prolongating the LOM of existing mines upgrades this initial environmental investment.

In this project we will analyze whether a cooperation of a land mining company and a seabed mining company on future ore processing could be economically viable for both sides given risks related to default of delivery, change in the delivered ore grade, and stop in the operation of one of the stakeholders. The students will model the related risks and the value of postponing mine closure for the land mining company using real options valuation as well as the decision situation of the seabed mining company. model the related risks. The aim is to identify fair terms for such a collaboration.

This thesis project is directly related to the project *The Deep Dilemmas: Deep-sea Mining for the new Deep Transition* (TripleDeep) which is part of the Interdisciplinary Sustainable Initiatives at NTNU (see https://www.ntnu.no/sustainability/calls/deep-sea-mining-dilemmas-by-tripledeep for more information). More specifically, this project is related to the work package on The Economics of Deep-sea Mining.

Industry partner:	Green Minerals
Main supervisor:	Verena Hagspiel
Co-supervisor:	Steinar Ellefmo (Professor at Department of Geoscience and Petroleum), Farida Mustafina (PhD candidate of TripleDeep project)
Industry Co-supervisor:	Maxime Lesage (Chief Engineer at Green Minerals)
Strategic research initiative:	Leading transitions: Co-create a sustainable future

For more information, please contact Verena Hagspiel, verena.hagspiel@ntnu.no, email, to schedule a meeting.

IFØ08. Dynamic subsidy and tax schemes in power markets

Given that the energy transition is driven by political ambitions, they have the potential to impact investments in renewable energies. Political uncertainties can manifest in various forms including introduction of novel forms of subsidies and taxes. While the effect of constant subsidies and taxes on investments are well understood, more research needs to be done to investigate the effect of dynamic subsidy and tax schemes on optimal investment strategies. In particular, this project will focus on the schemes that are dependent not only on sheer production volume and total revenue, but rather on certain conditions. For example, there are some subsidies and tax schemes that get triggered at a certain price level and some taxes that are only applied if revenues are accrued in specific markets. The project aims to investigate how different dynamic subsidy structures and their corresponding uncertainty can affect both the timing and/or size of an investment in the power sector and to identify what aspects are the most critical in terms of deterring or promoting investments (e.g. whether a cap on investments or the duration of the support has higher effect on investment decisions)?

The project can focus on one of the following or other cases:

- *Uncertainty about tax introduction.* In the Norwegian context, as of 2023, hydropower producers face a 45% tax, marking an increase from the previous rate of 37%. Furthermore, power producers are also subject to a 22% sales tax. In 2023, the government decided to extend this tax to the utilization of ocean resources, potentially impacting investments in offshore wind power. With new governments changes and developments in the power sector, applicable taxes become uncertain, and their effect on investment decisions need to be understood.
- *Contracts for differences (CfDs)*. CfDs state backed contracts that are used to guarantee a revenue stream to power producers. CfDs can help emerging technologies overcome entry barriers and promote costly green energy solutions. Given that in some instances the CfDs are specified against spot prices, they are considered a type of derivative product. CfDs can also include other contractual obligations that can introduce a degree of uncertainty in the projects, such as setting a cap on the total amount of support. This raises the question whether the introduction of those contractual differences can be counterproductive towards the CfD's main goal, e.g. applied to offshore wind investment.

Methodology: Real options analysis.

Industry partner: Hafslund Eco

Main supervisor: Maria Lavrutich

Industry contact: Stephany Paredes Pineda

Strategic research initiative: Leading transitions: Co-create a sustainable future

For more information, please contact Maria Lavrutich, maria.lavrutich@ntnu.no, to schedule a meeting

IFØ09. Economic effects of sustainability innovation in the wood manufacturing industry

As pointed out by Nilsen et al. (2023)[1] innovation activities such as digitalization of production processes and the upgrading of skills together with focus on bioeconomy, thus the need for a transformation towards sustainability have created opportunities for wood manufacturing industries. Both by utilizing renewable resources and being a symbol of environmental awareness, wood is being presented as a symbol for greening. However, there is lack of knowledge if sustainable innovation in this industry in fact promote positive economic effects for the firms. At the Inland Norway University of Applied Sciences, there is an ongoing large 4-year research project, REDINN, about innovation, profitability, and regional development. The project is funded by Sparebankstiftelsen Hedmark. This project has access to a larger database of the Norwegian manufacturing and service industries for the period 2004-2022, consisting of the Norwegian Community Innovation Survey (CIS) merged with the measure of economic performance (all drawn from Statistics Norway). Firm level innovation data can be used on economic performance data to analyze the economic effects and firm performance measures from innovation activities as reported in the CIS data, and how these evolve over time. Methods to be considered are econometric and/or machine learning.

A possible division into project thesis and master's is to carry out a literature study of the wood manufacturing industry, its sustainable innovation and economic effects which in turn maps possible problems and methods, and in the master's thesis to choose a specific problem and method and develop this.

Suitable for a group of two participants.

Main supervisor: Ståle Størdal

Strategic research initiative: Green Value Creation - Circular Economy

For more information, please contact `Ståle Størdal`, `stale.stordal@ntnu.no`, to schedule a meeting.

[1] Nilsen, T., Calignano, G., Lien, S., Nordli, A. (2023). Norwegian wood, isn't it good? Narratives of the lumber industry and development paths in the Nordic periphery. Journal of Rural Studies

IFØ10. Estimation and simulation of electricity forward curves and market spreads

This project will study and develop price simulation models for European electricity, focusing on the Nordics and Germany. Electricity is transmitted over cross-border cables, so the prices in different countries follow each other but are far from identical. We are interested in simulating the electricity prices in such a way that the simulated prices and spread of prices across markets are distributed consistent with information available in financial forward markets as well as relevant historical information.

The background is that electricity producers are looking to improve their in-house capabilities of commercially optimizing its reservoir operations by running optimizations based on high quality Monte Carlo price simulations.

A class of models that is popular among traders and middle-office managers is forward curve models, where the entire forward curve moves stochastically over time. This is used both in fixed income and for commodities, and typically serves as a building block in valuation and risk management systems. This project will develop forward curve models for electricity markets.

Possible candidates to investigate could be Ornstein–Uhlenbeck process adjusted for controlling spreads, or e.g. the method by Clewlow and Strickland in their book «Energy Derivatives: Pricing and Risk Management". Cointegration is another keyword here. We foresee that the candidates will set up different model alternatives and run a race to find best suited approaches. The machine learning technique known as autoencoders is relevant as a means to dimension reduction.

We have access to historical spot price forecasts as well as historical forward curves. A possible division of project vs master is to use a smaller dataset and more standard models in the project, focusing on the Nordic market and building a high-quality estimation model. For the master, to expand the focus to include the spread to Germany, using more extensive datasets and sophisticated methods.

One group is planned. Suitable for students with ICT technical direction, and with at least one of the students having had both TIØ4140 and TIØ4317. At least one of the students should have some interest in optimization, since we are planning to set up the estimation problem as a constrained quadratic minimization.

Main supervisor: Stein-Erik Fleten

For more information, please contact Stein-Erik Fleten, stein-erik.fleten@ntnu.no to schedule a meeting.

IFØ11. Evaluating Cryptocurrency-Market Efficiency using AI

March 4, 2024, Finansavisen published a piece on Anna Asset Management (AAM) after the hedge fund Anna Fund posted a 63,5 % return in February. AAM, founded by former students at the Department of Industrial Economics and Technology Management, NTNU, trades based on an algorithm designed to exploit momentum in the Bitcoin market. According to the efficient-market hypothesis (EMH) it should be impossible to consistently beat the market with such strategies. However, cryptocurrency markets may not be efficient to the degree that predicting price movements is hopeless. There is an evolving literature on the efficiency of cryptocurrency markets (see e.g. Yang, Jeong et.al (2023)*). The aim of this project is to evaluate the degree of market efficiency of cryptocurrency markets over time using novel artificial-intelligence models, like Temporal Fusion Transformers, that may detect patterns that traditional econometric approaches struggle to identify. In the project phase, students may choose to have a main focus on analysis based on the classical methods laying a good foundation for exploiting machine learning models in the master thesis phase. A more direct approach toward machine learning models is clearly also a viable option.

Main supervisor: Einar Belsom

For more information, please contact Einar.Belsom@ntnu.no, to schedule a meeting.

*Yi, E., Yang, B., Jeong, M. et al. Market efficiency of cryptocurrency: evidence from the Bitcoin market. Sci Rep 13, 4789 (2023). https://doi.org/10.1038/s41598-023-31618-4

IFØ12. Explaining Risk Premiums using Explainable AI

The Capital Asset Pricing Model (CAPM) and factor models that typically have two to four risk factors in addition to the market factor, are used to estimate risk premiums in financial markets and particularly in stock markets. The factor models tend to outperform the CAPM in explaining the cross-section of returns. However, approaches to estimate factors and the linear model structures seem not be equally well supported by market theory. The aim of this project is to use novel machine learning approaches, within so-called explainable AI, to shed more light on risk premiums in equity markets. In the project phase, students may choose to have a main focus on analysis using factor models within traditional econometric frameworks as to get a solid foundation before moving towards machine learning. A more direct approach toward machine learning models is clearly also a viable option.

Main supervisor: Einar Belsom

For more information, please contact Einar.Belsom@ntnu.no, to schedule a meeting.

IFØ13. Fair leasing contracts under default risk and uncertainties for deep-sea mining

In January 2024, the Norwegian government voted for the opening of the Norwegian Continental Shelf (NCS) for marine minerals industrial activities, i.e. exploration and production. This is a way for the Norwegian government to fuel exploration activities to understand whether responsible commercial deep-sea mining (DSM) based on a precautionary approach is possible.

In this project we will study an important aspect for a potential deep sea mining company considering the purchase of exploration licenses and potentially mining on the Norwegian Continental Shelf in the future. We will analyze how to design fairs terms for leasing agreements between an operator and a subcontractor under default risk and uncertainty.

The offshore production of marine minerals requires the integration of several marine assets and subsea equipment resulting in large capital expenditures. In offshore oil and gas projects, the production operators tend to charter equipment required for drilling, installation and sometimes for production (e.g. leasing FPSOs). Leasing equipment or subcontracting production also presents a viable alternative for seabed mining companies as the large CAPEX upfront are replaced by OPEX applying over the course of a project. There exist several risks factors in this setting for both sides, the operator and subcontractor, respectively. The default of one of the two partners severely threatens its counterpart. If the mining subcontractor would stop delivering its service, the production would stop. If the seabed miner could not secure enough ore, production would stop and the payment to the subcontractor would be at risk.

Methodology: Real options analysis, leasing evaluation

This thesis project is directly related to the project *The Deep Dilemmas: Deep-sea Mining for the new Deep Transition* (TripleDeep) which is part of the Interdisciplinary Sustainable Initiatives at NTNU (see https://www.ntnu.no/sustainability/calls/deep-sea-mining-dilemmas-by-tripledeep for more information). More specifically, this project is related to the work package on The Economics of Deep-sea Mining.

Industry partner:	Green Minerals
Main supervisor:	Verena Hagspiel
Co-supervisor:	Farida Mustafina (PhD candidate of TripleDeep project)
Industry Co-supervisor:	Maxime Lesage (Chief Engineer at Green Minerals)
Strategic research initiative:	Leading transitions: Co-create a sustainable future

For more information, please contact Verena Hagspiel, verena.hagspiel@ntnu.no, email, to schedule a meeting.

IFØ14. Finance, taxonomy and sustainability.

The transition towards green and sustainable technologies represents a crucial step in the global effort to combat climate change and promote environmental sustainability. However, this transition is often hindered by the fact that implementation of green and sustainable technologies is often more costly than established alternatives. To stimulate transition to sustainable technologies traditional ways of internalizing costs to society such as taxes and quotas for emissions are supplemented with new approaches. The EU Taxonomy is targeting the project financing, seeking to give sustainable project more advantageous conditions/easier access to capital. This thesis will explore how the EU Taxonomy influences the financial landscape for sustainable investments, focusing on its impact on the cost of capital and the risk and performance profiles of aligned portfolios.

Potential research questions include:

- Cost of Capital Across Taxonomy-Aligned Industries:
    - How does alignment with the EU Taxonomy influence the cost of debt and equity across different industries? What patterns emerge in the financing conditions of sectors that meet the taxonomy criteria compared to those that do not?
- Risk Profile of Taxonomy-Aligned Industries:
    - How does the risk profile differ between industries aligned with the EU Taxonomy and those that are not? Can alignment with sustainability criteria lead to a reduction in sector-specific risks?
- Performance of Taxonomy-Aligned Industries:
    - What is the financial performance of industries aligned with the EU Taxonomy compared to non-aligned industries? How do sustainability practices, as defined by the EU Taxonomy, impact sectoral economic performance and investor returns?

Methodology: Empirical analysis, employing regression models and risk assessment tools; and/or Machine learning methodologies.

Industry partner: SINTEF

Main supervisor: Maria Lavrutich

Industry Co-supervisor: Lars Hellemo

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation

For more information, please contact Maria Lavrutich, maria.lavrutich@ntnu.no, to schedule a meeting.

IFØ15. Forecasting commodity prices with econometrics and machine learning algorithms

Commodity prices are widely believed to influence price levels more broadly, and thus are of interest to central banks, policy makers, firms and consumers whose decisions depend on their expectations of future inflation.1 It is therefore of interest to explore whether commodity prices can be predicted, and, if so, by which variables.

In this project you will investigate and compare the forecasting performance of various econometrics and deep learning approaches. Moreover, you will investigate whether macroeconomic and financial variables are useful in this regard, considering evidence across monthly, quarterly, and annual horizons, as well as across recession and expansion states.

Why might macroeconomic and financial variables help to forecast movements in commodity prices? The predictability of commodity spot prices can be expected to be driven by time-varying storage costs and convenience yields. Both of these can be influenced by the state of the economy through short-term mismatches between demand and supply for commodities, and through financing costs. Time varying risk-premia form another possible source of predictability for commodity prices.

With few exceptions, relatively little empirical work has been undertaken on the predictability of commodity spot prices by means of macroeconomic and financial variables s your dissertation will potentially present innovative findings.

The ability to code in Python for deep learning is required, willingness to use Matlab or R for econometrics is also helpful.

Main supervisor: Malvina Marchese

For more information, please contact Malvina Marchese, Malvina.Marchese@city.ac.uk, to schedule a meeting.

IFØ16. Forecasting methods in power market applications: Long-term forecasting of reserve market prices and volumes

The rise of renewable energy for net-zero goals is increasing the demand for balancing services, creating opportunities for flexible generation like hydro-power. Norwegian producers saw a significant revenue boost from the reserve market in 2022. However, forecasting reserve prices is challenging due to factors like evolving energy landscapes, uncertain demand, and high price volatility. To assess the business case for flexible resources, a robust forecasting model is needed, considering the relationship between power prices and reserve markets.

This project aims to develop suitable forecasting methods for Nordic reserve market revenues, analyzing key drivers and historical volatility. The methodology includes exploring statistical approaches, such as Markov regime switching and mixed Brownian motion-jump processes, along with a hybrid fundamental-econometric model. Future developments, like increased renewable capacity, will also be considered. While these methods serve as a starting point, further literature study is required for optimal incorporation into a real options analysis framework using Least Square Monte Carlo. This creates the need for development of a consistent framework for multivariate simulations of all risk factors and their dependencies. This involves identifying factors, what stochastic process each factor follows and how they are correlated. It also involves calibrating these processes to data.

Data: Montel database

Programming language: R and Pyton

Starting references:

[1] Fleksibilitet som kilde til verdiskaping og forretningsutvikling. Oslo: **Statnett,** Sept. 2023.

[2] Rapport fra systemansvarlig 2022, **Statnett,** 2022

[3] Monte Carlo Methods in Financial Engineering" by Paul Glasserman (2004), Springer

[4] Financial Risk Forecasting: The Theory and Practice of Forecasting Market Risk with Implementation in R and Matla" by Jon Danielsson (2011), Wiley

[5] Simulation and the Monte Carlo Method" by Reuven Y. Rubinstein and Dirk P. Kroese (2016), Wiley

Industry partner: Hafslund Eco (Stephany Paredes, Analyst)

Main supervisor: Sjur Westgaard NTNU

Co-supervisors: Maria Lavrutich NTNU

Strategic research initiative: Leading transitions: Co-create a sustainable future sustainability

For more information, please contact Sjur Westgaard, sjur.westgaard@ntnu.no to schedule a meeting.

IFØ17. Forecasting Value at Risk and Expected Shortfall for energy futures positions

Value at Risk (VaR) and Expected Shortfall (ES) (known as Expected Tail Loss or Conditional Value at Risk) are popular risk measures used in finance to quantify the potential losses of a portfolio or investment over a given time horizon. VaR provides an estimate of the maximum amount of money a portfolio is expected to lose over a specified time horizon with a certain probability. ES is a risk measure that provides information about the tail behavior of the distribution of losses.

Various forecasting models will be employed for energy commodity futures (electricity, natural gas, coal, oil, emission etc.) to estimate and forecast these risk measures. These methods include: Riskmetrics, Filtered Historical Simulation, Cornish Fisher Approximation, GARCH type models with various error terms (normal, student-t, extreme value statistics), and Quantile Regression.

VaR testing are performed by comparing the calculated VaR with the actual losses observed during the same historical period. Several tests are available such as Kupiec, Christoffersen, Engle and Manganelli, and more recent techniques. The main idea behind testing ES is to assess the accuracy of the ES model in estimating the average loss that occurs beyond the VaR level. These tests are more challenging and involve methods such as Acerbi and Szekelys' (Non-parametric Test), Constanzino and Curran's (Traffic Light Tests), Emmer, Kratz and Tasche's (Approximative Quantile Test), Moldenhauer and Pitera's (Secured Position Test), Righi and Ceretta's (Truncated Distribution Tests).

From these models, we will also perform scenario analysis and stress testing for energy commodities along with the forecasting applications.

Data: Montel database

Programming language: R and Python

Starting references:

[1] Peter Christoffersen, 2013, Elements of financial risk management, **Academic Press**

[2] Yannick Hoga, Matei Demetrescu (2023) Monitoring Value-at-Risk and Expected Shortfall Forecasts. **Management Science**, 69(5):2954-297

[3] Zaichao Du, Juan Carlos Escanciano, 2017, Backtesting Expected Shortfall: Accounting for Tail Risk. **Management Science**, 63(4):940-95

Industry partner: Hafslund Eco (Hetal Mistry, Head of Risk Methodology)

Main supervisor: Sjur Westgaard NTNU

Co-supervisors: Morten Risstad NTNU, Ståle Slørdal, HINN og NTNU

Strategic research initiative: Leading transitions: Co-create a sustainable future sustainability

For more information, please contact Sjur Westgaard, sjur.westgaard@ntnu.no to schedule a meeting.

IFØ18. Hedging strategies in the Nordic electricity market

The Nordic electricity market is characterized by significant volatility and uncertainty, stemming from the stochastic nature of a weather-dependent electricity generation system. Electricity producers have traditionally secured their future cash flows through futures markets. Recent times have seen a decline in hedging volumes, attributed to a growing disconnect between the system price—a collective price for Finland, Sweden, Denmark, and Norway—and the area prices within these countries. This gap has widened due to the influx of unregulated wind power and the establishment of new interconnecting cables facilitating electricity exchanges between Norway and the UK, as well as Germany.

Using the system price for hedging has led to financial losses for some producers in the northern regions whose actual production revenue was undermined by low spot prices. A possible hedging strategy would involve using contracts for difference based on area prices to secure future production.

This project explores optimal hedging strategies within the Nordic electricity market's evolving landscape. Using data from the Nordic electricity market, continental electricity markets and hydrological data students will investigate if at any point in time the timing of hedges could improve the risk reduction of the hedging activity using market futures prices.

Main supervisor: Anne Neumann

Co-supervisor: Bjarne Sæther

Please contact me for more information or to schedule an (online) appointment (anne.neumann@ntnu.no).

IFØ19. Improving automated real estate valuations using ANNs

Supervised machine learning methods have successfully been employed for the purpose of valuing real estate. Tree-based methods in general, in particular XGBoost, have traditionally proven to be more accurate than Artificial Neural Networks. Recently, versions of ANNs have been developed which are better suited to deal with high-dimensional time series data; including LSTM, transformers and others.

This project will address one or more of the following research questions:

ANNs in automated real estate valuations: Compare the predictive performance of tree-based methods to recently developed ANNs.

Temporal stability: A general property of machine learning models is that they might be unstable over time, leading to noisy valuation estimates. Hence, investigating different approaches to increase the stability of model estimates, for instance by means of feature selection or smoothing techniques.

Regional vs national models: Intuitively, ANNs benefit from increased amounts of data. At the same time, the bias-vs-error tradeoff must be addressed. In the context of this research project, training models on irrelevant data (i.e. using transactional data from irrelevant geographic areas) will not improve model predictions out-of-sample. Hence, defining the appropriate feature space is paramount.

This study will use a high-dimensional dataset provided by industrial partner Hjemla/Boligmappa.

Industry partner: Hjemla/Boligmappa

Main supervisor: Morten Risstad

Co-supervisor: Are Oust

For more information, please contact morten.risstad@ntnu.no, to schedule a meeting

IFØ20. Innovation for the Energy Transition

Sustainable Development Scenarios tend to map out a path to meeting key international energy and climate goals. In these close to 10 000 gigawatt-hours of batteries across the energy system and other forms of energy storage are required worldwide by 2040 – 50 times the size of the current market.

One way of mastering this ambitious goal is to spur innovations related to renewable electricity generation, distribution and storage, and the heating, industry and transport sectors. Understanding the innovation processes of technologies is thus an essential factor for research itself and an issue for public policies for a magnitude of reasons. First, there is enormous economic potential for improved and innovative technologies. Second, policy-makers seek for technology leadership by their countries for which they need information about their national performance with respect to technology innovation. Third, utilities and energy system researchers are interested in getting insights, which energy technologies could dominate their field of application in the future.

In this project students look at patent data to identify trends in inventions in the field of electricity storage. Patents are filed many months, sometimes even years, before products appear on the market. Information on patent serves as an early indicator of which technologies could be poised to play ground-breaking roles in the future.

Students will collect patent data and employ quantitative and qualitative concepts of patent analysis and indicators.

Main supervisor: Anne Neumann

Please contact me for more information or to schedule an (online) appointment (anne.neumann@ntnu.no).

Literature:

Baumann M., Domnik, T., Haase, M., Wulf, C., Emmerich, P., Rösch, C., Zapp, P., Naegler, T. and Weil, M. (2021): Comparative patent analysis for the identification of global research trends for the case of battery storage, hydrogen and bioenergy, Technological Forecasting and Social Change, Volume 165, 120505, https://doi.org/10.1016/j.techfore.2020.120505

Metzger, P., Mendonça, S., Silva, J. and Damásio, B. (2023): Battery innovation and the Circular Economy: What are patents revealing?, Renewable Energy (209), 516-532, https://doi.org/10.1016/j.renene.2023.03.132.

EPO and IEA (202): Innovation in batteries and electricity storage: A global analysis based on patent data. ISBN 978-3-89605-256-8

IFØ21. Investment Decisions in Renewable Energy Projects under Policy Uncertainty

Power companies face high uncertainty about potential renewable energy support schemes since they do not know if any new support schemes will be provided and how such new policies would look. Currently, there is a discussion in Norway about possible support schemes for offshore wind power since the government targeted to open up new areas for offshore wind power production to generate 30000 MW by 2040. Additionally, there has been a global shift towards Contracts for Difference (CfD) auctions to support emerging technologies like offshore wind energy or low-carbon hydrogen production. However, a few studies have examined these auctions and found that they incentivize speculative bidding and too little investment. This creates additional uncertainty (policy uncertainty) for power companies that intend to invest in this market. The traditional approaches to capital budgeting do a poor job of analyzing such situations but are nevertheless still used by many practitioners. Real Options analysis takes methods developed to value financial derivatives and uses them to analyze real-world business decisions. As opposed to traditional discounted cash flow valuation, real options analysis accounts for the fact that decision-makers use all available information when making decisions in the future. This provides better decision support than using only traditional techniques for which models are based on assumptions neglecting this managerial flexibility. In this project, students will examine problems related to investment decisions in renewables under policy uncertainty by applying a real options approach. We are particularly interested in including possible continuous revisions of support schemes since it has already happened in the past. Examples of papers that deal with policy uncertainty using a real options approach are provided below.

Methodology: Real options analysis, financial derivative pricing

References:

1. Sendstad, L. H., Hagspiel, V., Mikkelsen, W. J., Ravndal, R., & Tveitstøl, M. (2022). The impact of subsidy retraction on European renewable energy investments. Energy Policy, 160, 112675.
2. Nagy, R. L., Hagspiel, V., & Kort, P. M. (2021). Green capacity investment under subsidy withdrawal risk. Energy Economics, 98, 105259.
3. Dalby, P. A., Gillerhaugen, G. R., Hagspiel, V., Leth-Olsen, T., & Thijssen, J. J. (2018). Green investment under policy uncertainty and Bayesian learning. Energy, 161, 1262-1281.
4. Hagspiel, V., Nunes, C., Oliveira, C., & Portela, M. (2021). Green investment under time-dependent subsidy retraction risk. Journal of Economic Dynamics and Control, 126, 103936.
5. Oliveira, C., & Perkowski, N. (2020). Optimal investment decision under switching regimes of subsidy support. European Journal of Operational Research, 285(1), 120-132.

Main supervisor: Carlos Oliveira

Co-supervisor: Verena Hagspiel, NTNU

Strategic research initiative: Sustainability

For more information, please contact Carlos Oliveira, carlos.m.d.s.oliveira@ntnu.no, to schedule a meeting.

IFØ22. Machine learning for forecasting commodity prices

In times of a world in crisis, proper valuation of derivatives written on commodity prices becomes even more important. The fluctuation of the prices in daily commodities has an impact on the cost of living as shown by the recent development of energy prices. But also, prices for metals (input material to new technologies), agricultural products and gold have taken off recently.

Prediction of price can help to control prices by monitoring and adjusting the price in the market in a timely manner so that the commodity market operates in a stable way. This enables suppliers and manufacturers to choose to produce or supply commodities accordingly. It can help to balance inventories and profitability as well as improve availability to consumers. Therefore, commodity price prediction is related directly to interests of both, consumers, and producers.

Aim of this project is to compare the long-horizon forecast performance of traditional econometric models with machine learning methods for the main agricultural and energy commodities in the world using prices provided by i.e. the International Monetary Fund (IMF) and/or the World Bank. The specific research question to be answered is if machine learning methods outperform traditional econometric methods. The project will i) define relevant commodities, ii) collect (and process) data, iii) estimate forecasts using traditional models, iv) forecast using machine learning methods, v) identify and calculate a suitable metric for performance evaluation.

Students are expected to use R for this project.

Main supervisor: Anne Neumann

Please contact me for more information or to schedule an (online) appointment
(anne.neumann@ntnu.no).

IFØ23. Optimal inventory control under stochastic prices

Theoretically, one should not be able to retrieve any excess value from raw material speculation. This since the market should adjust the price so the expected return from buying and selling raw material minus out-of-pocket holding cost corresponds to the risk associated with the keeping the goods on stock. However, for a producing firm there is an additional value beyond pure speculation to keep inventory of raw material as this inventory can be used to produce refined goods to meet customer demand.

The optimal amount of raw material to buy at any point in time depends on several factors. From classical inventory theory we know that we should balance holding cost and shortage cost so the relationship between these and the demand distribution do affect the optimal policy. The holding cost consist of an out-of-pocket holding cost and a capital cost, and the latter depends on the risk adjusted interest rate, the current price and expectation about how this price will evolve.

The structure of the optimal policy as well as closed form solutions to determine the state-dependent policy parameters has been derived for the scenario where raw material bought on the open market cannot be sold back. The derivation is based on a dynamic programming approach which provides a series of partial differential equations that can be solved under these assumptions. Unfortunately, no solutions to the corresponding partial differential equations have been found if one extends the problem to one where the company is allowed to sell raw material back on the open market.

It is apparent that the opportunity for a company to sell raw material will increase the value of keeping inventory. But it is not apparent how much nor how this will affect the optimal policy. The current project aims to shed light on these matters. The complex nature of the problem indicates that more advanced machine-learning methods can be used with benefit to attain numerical solutions that then can be interpreted.

The project includes:

- Review the relevant literature on replenishment under stochastic methods.
- Develop a mathematical formulation for the problem.
- Develop a solution procedure that provides the optimal policy.
- Analyze and discuss the structural results of such a policy.

Main supervisor: Peter Berling

Strategic research initiative: Leading transitions: Co-create a sustainable future / Sustainability.

For more information, please contact Peter Berling, lars.p.berling@ntnu.no, to schedule a meeting

IFØ24. Optimal project portfolio selection under uncertainty for energy companies

In the evolving landscape of the offshore energy sector, companies are now evaluating a spectrum of investment opportunities contributing to sustainable energy production. Historically, the industry focus was predominantly on oil and gas projects. However, the shift towards sustainability is steering these companies to diversify their project portfolios. Emphasizing the commitment to net zero targets and innovation in renewable energy technologies, investments in offshore wind, carbon capture and storage (CCS), and electrification initiatives are becoming increasingly central. The new investment opportunities have fundamentally different characteristics compared to the companies' traditional business. However, they must become an integral part of the transformative journey of offshore energy companies in Norway, aligning with global efforts to combat climate change.

In this project we aim to develop a methodology to identify an optimal project selection among existing and prospective energy projects given uncertainty about several framework conditions (e.g. commodity prices, new technologies and regulation) and the company's emission targets. The students will apply such as real options valuation using simulation-based approaches, and portfolio optimization. We will focus on developing a methodology that is application oriented and designed for decision support in practice.

This project is linked to the BRU21–NTNU Research and Innovation Program on Digital and Automation Solutions for the Offshore Energy Industry (www.ntnu.edu/bru21). This will give students access to the multidisciplinary network of the program. The thesis is also linked to the innovation project ProDecs (https://prodecs.no/), where we develop a software solution for financial analysis under uncertainty with the vision to contribute to better investment decisions in complex energy and infrastructure projects. The students will get the opportunity to work in collaboration with our partners at the Norwegian Offshore directorate (NOD) and OKEA ASA.

This project will build upon the results in earlier related projects. A background in computer science will be beneficial.

Collaborator: OKEA ASA

Main supervisor: Verena Hagspiel

Co-supervisor: Semyon Fedorov (Post-doc of NTNU's BRU21 program and co-inventor of ProDecs)

Strategic research initiative: Leading transitions: Co-create a sustainable future; Sustainability

For more information, please contact Verena Hagspiel, verena.hagspiel@ntnu.no, email, to schedule a meeting.

IFØ25. Optimal Transfer Pricing with Autonomous Investment Centers

The combination of decentralization and needs for transfers of products and services between responsibility centers, give rise to transfer pricing systems and the difficult problem of finding optimal transfer prices in real-life settings where decision making units are to be stimulated both to be efficient in the short-term perspective and to invest based on longer-term profitability effects in the value-chain. The aim of this project it to analyze the transfer pricing problem in settings where decentralization implies that the organization consists of relatively autonomous responsibility centers that have investment authority. One example may be highly successful electronic-gadget firm Haier that has been described as “Ecosystems of Micro Communities – EMCs” where transfers are governed by a contacting framework: “EMC Contract reflects another important feature of blockchain – decentralized automated value transmission. In an EMC contract, all values and all nodes are interconnected.” Another example is the Norwegian grocery chain COOP. Many COOPs across the country collectively own COOP Norge SA which is responsible for sourcing, distribution and marketing functions that are fundamental for the profitability of the individual COOPs. The markup on transfers of products to the COOPs creates a difference between local and value-chain profitability effects of day-to-day decisions as well as investments decisions. This is a special case of the well-known variable-versus-fixed-costs dilemma of transfer pricing. The aim of the project is to create new insights into the question of optimal transfer prices in organizations where transfer prices will affect investment behavior. Students will have substantial freedom in deciding on actual approach to analyze the issues. It is natural to consider both theoretical analysis and simulation models as tools.

Main supervisor: Einar Belsom

For more information, please contact Einar.Belsom@ntnu.no, to schedule a meeting.

IFØ26. Portfolio optimization in the insurance business

The modern theory of portfolio optimization was initiated by Markowitz when he wrote his Ph.D. thesis on Portfolio Selection in the early 1950s. Since then, portfolio optimization has been considered one of the most challenging problems in finance. It consists of a sequence of decisions of allocating/reallocating funds in different financial products with different objectives: optimizing the return of the portfolio, managing the risk of a fund, etc.

Portfolio optimization is also important in the insurance business, given the large amount of funds. The main task of insurers (and reinsurers) is to manage risk. Clients transfer their risk to insurers against the payment of a premium. As a consequence, insurers are liable for part of the client's losses when negative events occur. Thus, a criterion often used by insurers when they make financial decisions is the minimization of the ruin probability. The regulatory framework, Solvency II, is also a constraint to managing the insurer's portfolio. In this project, we will analyze the optimal investment strategies for insurers. The empirical analysis will be developed using data from Eikon Datastream.

Methodology: Portfolio optimization

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3. Chen, An, Thai Nguyen, and Mitja Stadje. "Optimal investment under VaR-regulation and minimum insurance." *Insurance: Mathematics and Economics* 79 (2018): 194-209.

Main supervisor: Carlos Oliveira

For more information, please contact Carlos Oliveira, carlos.m.d.s.oliveira@ntnu.no, to schedule a meeting.

IFØ27. Portfolio optimization using robust statistics

The modern theory of portfolio optimization was initiated by Markowitz when he wrote his Ph.D. thesis on Portfolio Selection in the early 1950s. Since then, portfolio optimization has been considered one of the most challenging problems in finance. It consists of a sequence of decisions of allocating/reallocating funds in different financial products with different objectives: optimizing the return of the portfolio, managing the risk of a fund, etc.

The mean-variance analysis is the more classical approach for portfolio selection, despite the disadvantages of the use of variance as a risk measure. Researchers and practitioners have been addressing these issues by proposing different risk measures according to the goal of the portfolio manager. Another drawback of this approach is the lack of robustness of the estimators used for the mean and variance. Researchers have shown that the use of adequate estimators can improve the portfolio's return.

In this project, we will address this topic by considering different moment estimators to evaluate their impact on the portfolio's return. This can be done in different risk measures as well, such as Value-at-Risk, Expected Shortfall, and Sharp ratio. The empirical analysis will be developed using data from Eikon Datastream.

Methodology: Time series and portfolio optimization

References:

1. Yang, Liusha, Romain Couillet, and Matthew R. McKay. "A robust statistics approach to minimum variance portfolio optimization." *IEEE Transactions on Signal Processing* 63.24 (2015): 6684-6697.

2. Huo, Lijuan, Tae-Hwan Kim, and Yunmi Kim. "Robust estimation of covariance and its application to portfolio optimization." *Finance Research Letters* 9.3 (2012): 121-134.

3. Deshmukh, Samruddhi, and Amartansh Dubey. "Improved covariance matrix estimation with an application in portfolio optimization." *IEEE Signal Processing Letters* 27 (2020): 985-989.

Main supervisor: Carlos Oliveira

Co-supervisor: M. Angeles Carnero (University of Alicante, Spain)

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IFØ28. Power Market Analysis: Evaluating the impact on the Nordic power market areas of a split of the German power market into two price zones

Power price dynamics and market design have become crucial during the energy transition with increased intermittent renewables causing increased price volatility and the need to redesign certain elements of the European power market.

Amidst long discussions and political pressure in Germany and from the EU, the current single zone power market could be split into two: one price zone with a high share of offshore wind production and low consumption and a second price zone with low renewable generation and high consumption due to industrial activity and a denser population.

This project will investigate:

1. The German power market today and towards 2030.
2. The impact of splitting Germany into two price areas on Southern Norway (NO2) and potentially other neighboring price areas, including investigating price impact and the impact such a split could have on Norwegian hydropower profitability.
3. The trend in price volatility with and without a German market split

We expect that this project will use existing large-scale power market models to conduct the analyses.

Industry partner: Volt Power Analytics

Main supervisor: Stein-Erik Fleten

Industry Co-supervisor: Katinka Bogaard, Managing Director, kbo@voltpoweranalytics.com

IFØ29. Probabilistic AI for improved uncertainty estimates in financial time series

Traditional time series models, such as ARIMA, have long been prevalent among academics and practitioners when forecasting future probability distributions of financial variables, such as stock prices, bonds, energy prices and many others. The parametric nature of these models, however, limit their accuracy, in particular when it comes to risk quantifications. Recently, a number of supervised machine learning algorithms, for instance LSTM and XGBoost, have proved to be helpful for this purpose. Still, these ML models are fundamentally built to provide point forecasts, as opposed to full conditional probability distributions. One possible remedy for this, is probabilistic AI. This area is rapidly evolving, and includes Bayesian neural networks, transformers and large-language models.

This study will investigate the relevance of probabilistic AI and compare the empirical performance of this approach when compared to traditional econometric models. To ensure generalizability and validity we will use data from a broad range of markets.

Main supervisor: Morten Risstad

Co-supervisor: David Baumgartner

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IFØ30. Salmon farm valuation and scheduling via reinforcement learning

Over the past decades, aquaculture has become one of Norway's most important industries. The opportunities for expansion are, however, limited due to environmental challenges that the industry is facing today. Due to these challenges, Norwegian authorities impose stringent regulations on salmon farmers in order to limit the industry's growth. Under these circumstances, the key to achieving economic and environmental sustainability is to ensure profitability of the industry by both innovation toward land-based farms, and also by optimizing the farming processes.

The process of salmon farming is inherently uncertain because salmon prices are uncertain, further, the development of biomass over time cannot be completely controlled by the salmon farmer. Salmon farmers therefore rely on (one or more) different growth models, as well as measurements, for estimating the size of a salmon at any point in time during the production process. Production schedule decisions, for example such as when and where to harvest, are then based on these estimates. The value function of the harvesting problem needs to be determined; it constitutes the fair values of lease and ownership of the fish farm when correctly accounting for price risk. The data set used for this analysis contains a large set of futures contracts with different maturities traded at the Fish Pool market.

The machine learning technique known as reinforcement learning is well suited to tackle this joint valuation and scheduling problem. The goal is to maximize the value of the operational cash flows. The scheduling is subject to the following constraints; the list may not be exaustive:

- The maximum allowable biomass quota for the facility must be respected
- Tank density is upper bounded
- Fish batches cannot be mixed
- Tanks must be cleaned for 2-3 weeks between batches

Decisions being planned include

- When to release smolt in each tank
- When, how many and which (size) fish to harvest from each tank
- What size of smolts to buy
- When and how to move fish between tanks, if the facility is designed for this option

An important challenge is to design the reinforcement learning algorithm so that the computation time is acceptably low. It is possible to divide the project and master thesis such that the single-tank problem is addressed in the project, while the whole facility scheduling is tackled in the master thesis. Another possible division is to address a version of the problem with fewer decision levers in the project, and more realistic versions in the master. The students are challenged to contact industry firms to cooperate with.

This project is suitable for groups consisting of both IFØ and AØO students.

Main supervisor: Stein-Erik Fleten

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IFØ31. Regulatory capital for credit risk in bond portfolios

Financial institutions (banks, life insurance companies and pension funds) are subject to regulatory capital requirements. When investing in fixed income securities, for instance in bonds issued by sovereigns or corporates, the financial institution will have to set aside capital to cover the potential loss if the obligor defaults. This capital requirement is referred to as "spread-risk". The capital requirement is computed as a function of potential increases in the credit spread of the issuer, expressed in basispoints (0.01% = 1 basispoint).

Financial institutions in Norway are currently subject to the EU-area capital requirements (Solvency II). The "spread-risk" under Solvency II is based on historical data from European bond markets, more specifically a 1 year/99,5 % confidence level Value-at-Risk model. In this project we will investigate whether this requlatory risk model is appropriate for the Norwegian bond market.

The first stage of the project will comprise of defining an appropriate Value-at-Risk model for a portfolio of bonds issued by Norwegian banks. Finding suitable volatility models for credit spreads will be crucial for this purpose. The empirical analysis will be based on market data supplied by Trondheim Kommunale Pensjonskasse.

Industry partner:	Trondheim Kommunale Pensjonskasse
Main supervisor:	Morten Risstad
Co-supervisor:	Petter Eilif de Lange
Industry Co-supervisor:	Erik Skjetne, CRO

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IFØ32. Reinsurance: an optimal strategy to protect against risk

Insurance companies are essential players in the financial sector. Their business relies on retaining the risk of policyholders upon paying a premium. In normal conditions, the premium received is sufficient to cover the losses the insurance company may have. However, losses can be significant, and the insurance company can become insolvent. To protect from large losses, insurers commonly transfer part of the risk of their portfolios to other insurance companies through the payment of a premium. These companies are called reinsurers.

There are different ways to transfer the risk between policyholders, insurance companies, and reinsurers. Whenever an insurer buys a reinsurance policy, it has to decide how much of its risk will transfer to the reinsurer. There are many factors that can interfere with this decision, such as

1. the amount of the premium charged by the reinsurer;
2. the criteria used by the insurance company to optimize its profit versus its risk (minimizing the ruin probability, maximizing the utility of the wealth process, among others).

In this project, we intend to analyze the problem of how much reinsurance should a given insurance company buy. There are mainly two types of reinsurance, proportional and non-proportional reinsurance. We propose to consider a particular type of proportional reinsurance, the surplus treaty. This treaty has remained unexplored, although some insurance companies use it. Combinations between proportional contracts and stop-loss treaties, which are non-proportional, are also used by companies and may also be studied. Additionally, we would like to explore how dependencies can affect the optimal reinsurance policy. Catastrophic events are examples of events that can impact more than one business line, and consequently, risks are correlated.

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4. Schmidli, H. (2001). Optimal proportional reinsurance policies in a dynamic setting. Scandinavian Actuarial Journal, 2001(1), 55-68.
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Main supervisor: Carlos Oliveira
Co-supervisor: Alexandra Moura, ISEG – Lisbon School of Mathematics and Management

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IFØ33. Revisiting the spanning hypothesis with machine learning methods

It has long been assumed that three factors, commonly interpreted as level, slope and curvature factors. are enough to explain the cross-sectional variation of yields. More recent papers such as Duffee (2002), Cochrane & Piazzesi (2005), Cochrane & Piazzesi (2008) and Adrian et al. (2013) advocate the importance of additional factors to explain excess returns and term premia. One important subject is whether all relevant factors needed to explain term structure dynamics can be derived from the yield curve. There is a growing consensus in the literature that this spanning hypothesis can be rejected by data. This evidence comes from predictive regressions of bond returns on various predictors, controlling for information in the current yield curve. The variables that have been found to contain additional predictive power in such regressions include measures of economic growth and inflation (Joslin et al. 2014), factors inferred from a large set of macro variables (Ludvigson & Ng 2009,0), long- term trends in inflation or inflation expectations (Cieslak & Povala 2015), the output gap (Cooper & Priestley 2009), and measures of Treasury bond supply (Greenwood & Vayanos 2014). These results suggest that there might be unspanned or hidden information that is not captured by the current yield curve but that is useful for forecasting. Unspanned factors do not improve the cross-sectional fit of yields but do affect the time variation of prices of risk through their predictive power for the yield curve factors. Still, the spanning hypothesis is debated in the literature. Duffee (2013) questions the robustness of these results based on inherent uncertainty in statistical inference of model parameters. Bauer & Hamilton (2018) claim that small sample properties invalidate rejection of the spanning hypothesis in a number of the studies mentioned above. Huang & Shi (2022), on the other hand, show that a latent variable derived from a large number of macro variables, has predictive poser for excess returns. Bauer & Rudebusch (2020) derive a Bayesian Markov Chain Monte Carlo model to account for time varying trends in the fundamental determinants of the yield curve and find support against the spanning hypothesis.

The most prominent trend in the recent asset pricing literature is the utilize machine learning techniques, such as LASSO, Ridge and LSTM, to better understand the complexity of excess returns. For instance, a recent study reports that approximately 460 different factors have been identified by researchers to carry risk premia.

This study will assess the spanning hypothesis using modern machine learning techniques, including causal inference, in combination with high-dimensional data.

Industry partner: SpareBank 1 Markets

Main supervisor: Morten Risstad

Industry Co-supervisor: Kristian Semmen

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IFØ34. Sustainable investment in the aquaculture industry

An increase in the global population has created a growing demand for high-quality marine proteins. Fisheries, however, are reaching their limits in providing a foundation for further production growth. This creates potential for the salmon aquaculture industry to satisfy the need for expansion in seafood production. Nonetheless, several environmental challenges the industry is facing today limit its growth potential. Considering these challenges, it is imperative for the industry to define acceptable boundaries for future growth achieving the dual objective of profitability and environmental sustainability. Investment into new technologies provides a way to improve sustainability performance and address existing inefficiencies of aquaculture companies. As a result of noticeable increase in R&D investment activity in Norway, several new technologies have been and are being developed that have the potential to solve many industry problems. These include improvements to traditional sea cages, such as, for example, lice skirts, snorkel barriers and closed floating cages, as well as more radical solutions such as offshore and land-based facilities. Investments in these technologies are typically very capital-intensive and their profitability is subject to multiple sources of uncertainty. For these investments to be effectively realized, it's crucial that companies are equipped with the right tools and methods to correctly value such investments. Traditional capital budgeting methods, such as discounted cash flow (DCF) analysis, are no longer suitable for well-informed decision-making in the industry, not only due to their inability to incorporate multiple sources of risk correctly and the lack of focus on the importance of managerial flexibility to shape and design investment strategies, but also because they fall short in accounting for multiple objectives, for example, related to sustainability. The latter is particularly important as aquaculture firms seek to attract capital from investors that increasingly value sustainability and need to comply with more stringent regulations. However, there is still lack of studies that attempt to measure and identify company level sustainability impacts and performance. This project will focus on developing models to analyze technology investments that assess the inherent risks and potential for efficiency improvement and environmental constraints correctly. The need to develop such methodologies in aquaculture context is especially pertinent when considering that technological innovation can to some extent remove certain biological risks for operation of aquaculture facilities, such, e.g., land-based aquaculture, while at the same time potentially introduce new risks, including the ones related to sustainability. The project can focus on one or more of the aspects below.

Potential research questions include: What are the most relevant sustainability impacts of individual aquaculture companies across the value chain? How to measure and quantify them? How to correctly measure and quantify multiple risks the aquaculture companies are exposed to? How should aquaculture companies optimally deal with these risks in new investments? How to correctly quantify the value of these investments in the presence of multiple risk sources (including, market risk, biological risks, policy risk etc.)? How to incorporate sustainability considerations into investment processes for aquaculture firms?

Methodology: Real options and potentially Least Squares Monte Carlo simulations for investment models; For risk and impact modelling: Empirical analysis, employing regression models and risk assessment tools; and/or Machine learning methodologies, e.g. clustering.

Main supervisor: Maria Lavrutich

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation

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IFØ35. Tactical Supplier Selection Under Exchange Rate Uncertainty

A common problem in tactical supplier selection is the trade of between more distant supplier offering a low price and local suppliers that provides a shorter lead-time. The shorter lead-times have a cost benefit as it reduces the lead-time demand uncertainty and thus the shortages and or need for safety stock. It is fairly straight forward to determine which supplier is optimal, i.e., minimizes the total cost, if demand is the only source of uncertainty.

However, many of the suppliers, particularly the ones providing a lower cost per, operates abroad and thus there also exists a price uncertainty due to fluctuating exchange rates. To complicate the problem further there is a correlation between the exchange rate and the demand that must be accounted for when optimizing the decision of from where to source. We can currently see anecdotal evidence of this as smaller currencies as NOK have lost value against the US$ and € as we have entered an economic down-turn linked to the Russian invasion of Ukraine.

This project aims to develop optimization models for determining the optimal supplier (i.e., the supplier that minimizes the total cost alt. maximizes the total profit) taking the demand and price uncertainty as well as the correlation between these into consideration. The work can also be extended to include other sustainability aspects.

Tasks within the project can include:

- Study of existing models and solution methods under price and demand uncertainty.
- Formulation and implementation of a stochastic optimization model.
- Empirical study of the correlation between exchange-rate fluctuations and demand.

Collaborator: IESE-Business School – Barcelona, Spain

Main supervisor: Peter Berling

Industry Co-supervisor: Prof. Alejandro Serrano

Strategic research initiative: Leading transitions: Co-create a sustainable future / Sustainability.

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IFØ36. The dependency structure of interbank swap rates and credit spreads

For fixed-income investors the codependency between interbank swap rates and credit spreads is important for portfolio allocation and risk management. At the same time, this relationship has complex, time-varying non-linear dynamics and represent a risk modelling challenge.

This project will analyze the dependency structure of interest rate swaps and credit spreads in the Norwegian bond markets.

The potential contribution from the paper is twofold. First, this particular market and related data has, to the best of our knowledge, not previously been researched. Second, our methodological approach will be novel, and potentially applicable to other markets.

We will use time series data retrieved from Bloomberg and Nordic Bond Pricing (NBP). NBP provides credit index data for six different rating classes from 2014 until today. This data includes different classes of debt instruments; including covered, senior, senior-unsecured and non-preferred bonds. This enables us to analyze different sections of the bank capital structure.

We will consider models capable of capturing time-varying parameters, including traditional econometric models and state-of-the art machine learning techniques, including explainable AI.

Main supervisor: Morten Risstad

Co-supervisor: Sjur Westgaard

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IFØ37. The economics of gas storage: lessons from natural gas for hydrogen

Three types of geological underground formation are used for storing natural gas today: depleted oil / gas fields, aquifers, and caverns. Cavern storage typically is done in salt formations which are also apt to host hydrogen storage, unlike the two other natural gas storage types (e.g., Ozarslan, 2012, Amirthan & Perera, 2022). Salt caverns for natural gas storage are man-made structures. In other words, there can be investment in more of these caverns if a future hydrogen economy requires more storage capacity.

In Europe, in particular in Germany, there has been a vast expansion of salt cavern gas storage capacity in the past two decades (see GIE). Stronzik et al. (2008) and Neumann and Zachmann (2009) provided an analysis of this investment "wave" in its early phases. Yet, more updated research on the European case is scarce. The task of this project is to identify the economic factors that have driven the construction of salt caverns for natural gas storage in the past decades in order to deduct whether the same drivers can help the expansion of hydrogen storage.

Generally, gas storage operators can be thought of as actors that optimize the gas supply between periods of low demand / prices (when there is injection in storage) and periods of high demand / prices (when there is extraction from storage) (e.g., Chaton et al., 2008). The arbitrage (storage cycle) can be between summer and winter, but can also be on a much shorter time scale to benefit from price variations (e.g., de Jong, 2015).

The aim of the project is for students to develop an empirical model of storage operations and investments that examines the factors of high profit expectations of storage operators. Activities include:

- Familiarization with the topic, relevant literature and methods, including software tools;
- Familiarization with the European natural gas storage data;
- Application of relevant econometric model to the case of European or German natural gas storage since the 2000s;
- Analysis and discussion of results.

There will be an opportunity to spend time in Berlin and work as guest researcher at the German Institute for Economic Research (DIW Berlin) in downtown Berlin .

Main supervisor: Anne Neumann

External partner: Franziska Holz (adjunct professor at NTNU and deputy head of department at DIW Berlin (German Institute for Economic Research), supervision mainly online

References:

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IFØ38. Towards Net-Zero: Decision Support for Decarbonizing Port Operations

Decarbonizing the maritime industry is often associated with transitioning ships to low and zero-emission fuels, mainly driven by the urgency to meet emission reduction targets for 2030 and 2050. However, also port operations are energy-intensive, with large equipment traditionally fueled by diesel fuels. Policy and planning strategies are essential for setting guidelines and roadmaps towards decarbonization goals. Ports, in particular, hold a central role in decarbonizing the maritime sector, as they provide the infrastructure to enable refueling of ships, and will be the hubs where different energy carriers are supplied, stored, used, and possibly transformed (fuel production).

Some ports are making great progress in sustainability development. The case of Port of Roenne exemplifies this proactive approach as it aims to become the most sustainable commercial port in the Baltic Sea [1]. The port operator has set an ambitious target to achieve CO2 neutrality across its entire value chain by 2030. This goal includes not only the direct emissions from the combustion of fossil fuels (e.g., cranes, ships, and vehicles), but also the indirect emissions from energy purchased for building heating and lighting, as well as activities at both the upstream and downstream levels, including business trips, waste management and product disposal.

This project thesis aims to provide tools to help a port operator moving its value chain towards net-zero emissions. Through analysis and modeling, the project will calculate outline plans for the timing and sizing of investment in equipment to decarbonize port operations, including cost assessments and CO_2 emissions.

The project includes the following tasks:

- Reviewing relevant literature
- Identifying port operations and priorities in decarbonization
- Collecting data on CO_2 emissions from operations and potential alternatives.
- Developing a model to assist port operators in progressively decarbonizing their operations
- Performing computational experiments on a real-world case
- Evaluating the results from both economic and environmental perspectives

This project is part of the research project NordH2ub https://csei.eu/nord_h2ub/. Knowledge in mixed integer optimization and programming skills (e.g., Python) are expected.

Industry partner: Port of Roenne A/S

Main supervisor: Ruud Egging-Bratseth

Co-supervisor: Kais Msakni

Strategic research initiative: Leading transitions: Co-create a sustainable future / Green Value Creation - Circular Economy

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References

[1] Port of Roenne, "Sustainability report," 2022, https://portofroenne.com/media/4lvnqhlp/sustainability-report-en-final-6-0.pdf [Accessed on 05-03-2024].

IFØ39. Transition risk and company valuation

The transition to a low-carbon economy and the associated risks are becoming increasingly important in corporate financial analysis. As governments implement policies aimed at reducing carbon emissions, companies are faced with the dual challenge of adapting their operations and managing the financial implications of increased CO2 costs. Understanding the impact of these costs on company valuations is important for investors, regulators, and policymakers. This project will focus on quantifying the financial implications of estimated future CO2 prices under various climate scenarios and contribute to a better understanding of how transition risks may affect the financial stability and valuation of companies. There are several CO2 price projections consistent with achieving various transition scenarios. These price paths represent various levels of effort and policy scenarios to move towards a greener economy. The differences in CO2 prices are directly linked to financial risks companies face as the world shifts away from fossil fuels, and thus to transition risks. Understanding the range and potential trajectory of CO2 pricing is important, as these are grounded in detailed climate models and policy frameworks. They encapsulate the expected economic signals that will drive investment decisions, operational changes, and strategic shifts necessary to align with a carbon-constrained world. The projections serve as a critical input for financial analysis, allowing companies to simulate and prepare for the impact of transition risks on their operations and valuations.

In this project, we will examine the impact of varying CO2 pricing as projected by climate scenarios on the valuation of companies, focusing effect on companies' equity valuation. This would entail developing a model to calculate the NPV of future CO2 liabilities for companies under different carbon pricing scenarios and analyzing how companies might pass these costs to consumers and the associated impact on demand and revenue. The final step involves applying the option pricing theory to understand the potential changes in equity valuation under different scenarios of transition risk, considering equity as a call option on the company's assets. This allow allows to study the implications for default probabilities. This framework can be extended in various ways, for example, by addressing more detailed modelling of transition risks, estimate how different carbon pricing mechanisms (e.g., carbon tax, emissions trading systems) affect company valuations or how and whether the exposure to transition risk can be reduced by investing in green technologies. Another potential application is studying the effect of transition risks for company's debt.

Industry partner: NBIM

Main supervisor: Maria Lavrutich

Industry contact: Lars Hegnes Sendstad

Strategic research initiative: Leading transitions: Co-create a sustainable future

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IFØ40. Using probabilistic AI to improve credit risk assessments in banks series

Predicting creditworthiness is an important task in the banking industry, as it allows banks to make informed lending decisions and manage risk. Banks have traditionally used credit scoring models to assess the creditworthiness of customers when they apply for loans or credit. These models perform significantly worse when used on potential new customers than existing customers, amongst other things, due to the lack of financial behavioral data for new bank customers. Machine learning techniques have emerged as a potential remedy to these problems, as they have the capability to deal with the complex dependencies that characterize customer behavior and related data. One significant shortcoming of many proposed machine learning algorithms, however, is that they typically produce point forecast, without providing any guidance as to the associated uncertainty. This study will investigate whether probabilistic AI is appropriate to capture this uncertainty and hence improve credit risk management in banks.

Industry partner: Sparebanken Møre

Main supervisor: Morten Risstad

Co-supervisor: David Baumgartner

Industry Co-supervisor: Lars Ole Hjelkrem

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IFØ41. Valuation of energy producers

A common approach to valuing common stock is to employ some kind of discounted cash flow (DCF) analysis. Typically, this boils down to a two-step procedure, where the first step is to project nominal cash flows and the second step is to compute the present value of these cash flows applying an appropriate discount factor. Generally, neither of these steps are straightforward, and involves significant judgement. Expectations for relevant state variables (such as prices and production volumes) need to be formed. Very often these expectations are taken in the empirical / physical probability measure, and the discount rate is estimated from CAPM. However, in many energy markets, well-developed derivatives markets exist, from which future price expectation can be derived. Since these expectations are in the risk-neutral measure, the associated appropriate discount rate would be the risk-free rate. In effect, the latter approach circumvents two major valuation problems, namely those of estimating price expectations and discount factors. This has potentially interesting implications for improved accuracy in valuations.

This study will investigate the accuracy of risk-neutral valuations of energy producers.

Industry partner: Rann Rådgivning AS

Main supervisor: Morten Risstad

Co-supervisor: Verena Hagspiel

Industry Co-supervisor: Halvor Hoddevik

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