

FINAL REPORT

Project number: 274569

Project title: Strategic Risk Adoption in Real Options under Multi-Horizon Regime Switching and Uncertainty

Project manager: Li, Yushu

Activity / Programme: FINANSMARK

Project owner: Matematisk institutt

1. **Progress report:** Update progress report up to project completion date. Completed
2. **Final accounts:** Give a summary of the financial status of the project Completed
3. **Outcomes and impacts:** I understand that the information entered into the field for Outcomes and impacts will be made publicly accessible* Completed
4. **Results report:** Attach results report Completed
5. **Other results:** List information about other results (publication in the media, organised events, newly established companies) Completed
6. **Special reports:** Any requests for special reports must be fulfilled. Have special reports been submitted? Not applicable
7. **Data management plan:** Has the final data management plan been uploaded? Not applicable

Final accounts

Actual costs (in NOK 1000)

Account	2018	2019	2020	2021	Total
Payroll and indirect expenses	380	395	17		792
Procurement of R&D services	68	272	76	30	446
Equipment					0
Other operating expenses	22	67	32	2	123
Sum	470	734	125	32	1361

Actual cost code (in NOK 1000)

Account	2018	2019	2020	2021	Total
Trade and industry					0
Research institutes					0
Universities and university colleges	402	521	49	2	974
Other sectors					0
Abroad	68	213	76	30	387
Sum	470	734	125	32	1361

Actual funding (in NOK 1000 kr)

Account	2018	2019	2020	2021	Total
The Research Council	290	193		86	569
Own financing	380	395	17		792
Public funding					0
Private funding					0
International funding					0
Deviations	200	-146	-108	54	0
Sum	470	734	125	32	1361

Comments

Det står 11000 kr igjen som er ubrukt: 6000 kr IT utstyr + 5000 reise penger som er satt til 2020 og 2021, mens det er ikke lett å reise fortsatt i 2020 og 2021 pga. Covid-19.

Når det gjelder IT utstyr, kan vi bare kjøpe inn noe fra UIBS leverandør og det finnes begrenset utvalg der:

Desktop: 7 625 kr eller 14 945 kr.

UiB Bærbar PC : 11 694 kr, 11 224 kr, 13 224 kr, eller 14 994 kr.

Så 6000 kr kan ikke dekke noe av de, og det blir ikke brukt.

1. Give a summary of the financial status of the project

Completed

Outcomes and impacts

Anticipated outcomes and impacts - from the grant application form

-

Achieved and potential outcomes and impacts - based on the project results*

We have 8 journal publications ,2 working papers with conference presentations (conference paper), and 2 working on the process (working paper). More detailed information of topics/links related to the journal publication/conference papers can be found in the attached Results Report at next side

5. I understand that the information entered into the field for Outcomes and impacts will be made publicly accessible* Completed

Results report

Message to the Research Council of Norway

Original file : Final report for project NFR.pdf

File reference: Resultat_rapport11820742.pdf

2. Attach results report Completed

Other results

Please provide information about other results (Events, Publication in the media, Companies.

3. List information about other results (publication in the media, organised events, newly established companies) Completed

Special reports

Alternative 1:

Alternative 2:

Original file :

File reference:

4. Any requests for special reports must be fulfilled. Have special reports been submitted? Not applicable

Final data management plan

Original file :

File reference:

6. Has the final data management plan been uploaded? Not applicable

PROGRESS REPORT

Project number:	274569
Project title:	Strategic Risk Adoption in Real Options under Multi-Horizon Regime Switching and Uncertainty
Project manager:	Li, Yushu
Activity / Programme:	FINANSMARK
Project owner:	Matematisk institutt
Project period:	01.01.2018 - 01.06.2021
Report period:	01.01.2020 - 01.06.2021

- Popular science presentation:** I understand that the text of the popular science presentation will be made publicly available* Completed
- Results:** Has information on publications been provided? Yes
- Performance indicators:** All results data that have emerged from the project are to be reported. Has this been done? Yes
- Fellowship grants:** Information regarding all fellowship grants must be complete and correct. Have you updated the man-months and other information for each fellowship-holder? Yes
- International:** The extent of international cooperation is to be indicated. Has any international cooperation taken place during the report period? Yes
- Special reports:** If any requests for special reports have been put forth by the case officer at the Research Council, these must be fulfilled. Have special reports been submitted? Yes

Popular science presentation

Popular science presentation (Norwegian)

Prosjektets første mål er å forene økonomiske og statistiske metoder i et realopsjonsrammeverk for å kunne analysere komplekse investeringsmuligheter, som inkluderer ikke-diversifiserbar risiko, endogene kapasitetsbeslutninger og strategiske interaksjoner, innenfor et regimeskiftende økonomisk miljø med forskjellige relaterte usikkerhetsfaktorer. Det andre målet for dette prosjektet er å utvikle moderne tidsserie-metodologier eller statistiske modeller for å håndtere ikke-stasjonære tidsserier og fange opp eller forutsi usikkerheten i tidsserieprosessen. Fram til slutten av september, 2019, er det totalt 9 artikler som er relatert til dette med anerkjennelse av prosjektmidler fra forskningsrådet (feks. XXX gratefully acknowledges funding from the Finance Market Fund, Norwegian Research Council (Project number 274569)). De 9 artiklene inkludert 3 arbeidsdokumenter med konferansepresentasjoner, 3 tidsskriftpublikasjoner og 3 artikler som vi jobber fortsatt på.

Tre prosjektmedlemmer (Lars Hegnes Sendstad, Michail Chronopoulos; Yushu Li) arbeider med temaene for å utvide tradisjonelle realopsjonmodeller til ikke bare å håndtere holdninger til risiko, men også ta hensyn til regimeavhengig oppførsel av økonomiske indikatorer når sannsynligheten

mellom forskjellige regimene er enten konstante eller stokastiske. Det er tre working paper med konferansepresentasjon i disse emnene er:

1. Chronopoulos, M (2018), "The Value of Modular Design and Project Scale for Alternative Green Investment," in the 41st IAEE International Conference, 10-13 June, Groningen.
2. Sendstad, Lars Hegnes; Chronopoulos, Michail.
Strategic Technology Switching under Risk Aversion and Uncertainty. 30th EUROPEAN CONFERENCE ON OPERATIONAL RESEARCH; London, UK; 2019-06-23 - 2019-06-26
Workshop on Investments, Energy, and Green Economy; Brescia, Italy; 2019-04-26 - 2019-04-27
3. Sendstad, Lars Hegnes; Chronopoulos, Michail; Li, Yushu.
The Value of Turning-Point Detection for Optimal Investment. The 23rd Annual International Real Options Conference; Dublin, Ireland; 2019-06-27 - 2019-06-29

Som planlagt utvikler dette prosjektet også moderne tidsseriemetodologier som kan håndtere ikke-stasjonære data som for eksempel datasett med langt minne, strukturelle breaks (en type regimeskifte), samt implementeringer i finans og økonomi. En sentral del av disse prosjektene er prediksjon av usikkerhet gjennom for eksempel sannsynlighetsfordelinger og evaluering av prediksjonene i etterkant. Vi har tre publikasjoner:

1. Fredrik N.G. Andersson and Yushu Li (2019): Are Central Bankers Inflation Nutters? A MCMC Estimator of the Long-Memory Parameter in a State Space Model, (Accepted), Computational economics
2. Yushu Li and Jonas Andersson (2019): A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting, (published on line 17 May 2019), Journal of forecasting
3. Hyunjoo Kim Karlsoon, Yushu Li and Ghazi Shukur (2018): The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", Sustainability 2018, 10(8), 2792; <https://doi.org/10.3390/su10082792>

Prosjektmedlemmene har også tre artikler som er under forberedelse for å bli sendt til vurdering av vitenskapelige tidsskrifter eller som fremdeles er work in progress:

1. Fredrik N.G. Andersson and Yushu Li (2019) Are real effective exchange rates real mean-reverting? Long memory and structural breaks (is prepared for being sent to journals for consideration of publication).
2. Bjørn Gunnar Hansen and Yushu Li (2019) Mean reverting properties of milk prices in EU countries ----Problem of misidentification under structural break (has already been sent out for consideration of publication)
3. Pär Henrik Sjölander, Yushu Li and Peter S Karlsson (2019) A simple panel causality test in the presence of cross-section dependence (working on progress).

Basert på ovennevnte resultat fra prosjektet, kan vi si at utnytttere av prosjektet er beslutningsteoretikere og økonomiske matematikere, makroøkonomer, økonometrikere og empirisk statistikere.

Popular science presentation (English)

This project's first object is to incorporate the financial and statistical methods within a real options framework in order to facilitate the analysis of complex investment opportunities, involving non-diversifiable risk, endogenous capacity sizing and strategic interactions, within a regime-switching economic environment of various interacting uncertainties. The second object for this project is to develop modern time-series methodologies or statistical models to deal with non/stationary time series and capture or forecast the uncertainty in time series process.

Until end of September, 2019, totally 9 articles can be related to this project with acknowledgement to the funding of the project. The formation of the acknowledgement is: XXX gratefully acknowledges funding from the Finance Market Fund, Norwegian Research Council (Project number 274569). Those 9 articles including 3 working paper with conference presentations, 3 journal publications and 3 paper working on progress.

Three project members (Lars Hegnes Sendstad, Michail Chronopoulos; Yushu Li) have been working on the topics to extend traditional real options models to account not only for attitudes towards risk but also for the regime-switching behavior of economic indicators when the probability of switching between different regimes is both fixed and stochastic. There are three working papers with conference presentation in those topics, they are:

1. Chronopoulos, M (2018), "The Value of Modular Design and Project Scale for Alternative Green Investment," in the 41st IAEE International Conference, 10-13 June, Groningen.

2. Sendstad, Lars Hegnes; Chronopoulos, Michail.
Strategic Technology Switching under Risk Aversion and Uncertainty. 30th EUROPEAN CONFERENCE ON OPERATIONAL RESEARCH; London, UK; 2019-06-23 - 2019-06-26
Workshop on Investments, Energy, and Green Economy; Brescia, Italy; 2019-04-26 - 2019-04-27

3. Sendstad, Lars Hegnes; Chronopoulos, Michail; Li, Yushu.
The Value of Turning-Point Detection for Optimal Investment. The 23rd Annual International Real Options Conference; Dublin, Ireland; 2019-06-27 - 2019-06-29

As planned, this project also develops modern time-series methodologies with can deal with non-stationary data such as dataset with long memory, structural break (a type of regime switch), as well as the implementation in finance and economics. The topic of uncertainty forecasting (eg density forecasting) as well as evaluation are also included in the project. We have already three publications:

1. Fredrik N.G. Andersson and Yushu Li (2019): Are Central Bankers Inflation Nutters? A MCMC Estimator of the Long-Memory Parameter in a State Space Model, (Accepted), Computational economics

2. Yushu Li and Jonas Andersson (2019): A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting, (published on line 17 May 2019), Journal of forecasting

3. Hyunjoo Kim Karlsoon, Yushu Li and Ghazi Shukur (2018): The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", Sustainability 2018, 10(8), 2792; <https://doi.org/10.3390/su10082792>

The project members also have three papers which are prepared for being sent for consideration of publication or working on progress:

1. Fredrik N.G. Andersson and Yushu Li (2019) Are real effective exchange rates real mean-reverting? Long memory and structural breaks (is prepared for being sent to journals for consideration of publication).
2. Bjørn Gunnar Hansen and Yushu Li (2019) Mean reverting properties of milk prices in EU countries ----Problem of misidentification under structural break (has already been sent out for consideration of publication)
3. Pär Henrik Sjölander, Yushu Li and Peter S Karlsson (2019) A simple panel causality test in the presence of cross-section dependence (working on progress).

Based on the above output of the project, we can say that the beneficiaries of project are decision theorists and financial mathematicians, macro-economist, econometricians and empirical statisticians.

Popular science presentation - Updated (Norwegian)

Prosjektets første mål og andre målet for dette prosjektet er samme som før oppdatering, her har vi en oppdatering for artikler:

Fram til Juli, 2021, er det totalt 13 artikler som er relatert til dette med anerkjennelse av prosjektmidler fra forskningsrådet (feks. XXX gratefully acknowledges funding from the Finance Market Fund, Norwegian Research Council (Project number 274569)). De 13 artiklene inkludert 2 arbeidsdokumenter med konferansepresentasjoner, 8 tidsskriftpublikasjoner og 3 artikler som vi jobber fortsatt på.

Tre prosjektmedlemmer (Lars Hegnes Sendstad, Michail Chronopoulos; Yushu Li) arbeider med temaene for å utvide tradisjonelle realopsjonmodeller til ikke bare å håndtere holdninger til risiko, men også ta hensyn til regimeavhengig oppførsel av økonomiske indikatorer når sannsynligheten mellom forskjellige regimene er enten konstante eller stokastiske. Det er to working paper med konferansepresentasjon i disse emnene er:

1. Chronopoulos, M (2018), "The Value of Modular Design and Project Scale for Alternative Green Investment," in the 41st IAEE International Conference, 10-13 June, Groningen.

2. Sendstad, Lars Hegnes; Chronopoulos, Michail; Li, Yushu.
The Value of Turning-Point Detection for Optimal Investment. The 23rd Annual International Real Options Conference; Dublin, Ireland; 2019-06-27 - 2019-06-29

Og 3 publikasjon:

1. Sendstad, Lars Hegnes; Chronopoulos, Michail (2021), Strategic technology switching under risk aversion and uncertainty, Journal of Economic Dynamics & Control, Vol.126.

2. Sendstad, Lars Hegnes; Chronopoulos, Michail and Verena Hagspiel (2021), Optimal Risk Adoption and Capacity Investment in Technological Innovations,IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT

3. Sendstad, Lars Hegnes; Chronopoulos, Michail, (2020) Sequential investment in renewable energy technologies under policy uncertainty, Energy Policy, Vol 137.

Som planlagt utvikler dette prosjektet også moderne tidsseriemetodologier som kan håndtere ikke-stasjonære data som for eksempel datasett med langt minne, strukturelle breaks (en type regimeskifte), samt implementeringer i finans og økonomi. En sentral del av disse prosjektene er prediksjon av usikkerhet gjennom for eksempel sannsynlighetsfordelinger og evaluering av prediksjonene i etterkant. Vi har 5 publikasjoner:

1. Yushu Li and Fredrik N.G. Andersson (2020)

A simple wavelet-based test for serial correlation in panel data models, (Online 22. Feb.), Empirical Economics

2. Fredrik N.G. Andersson and Yushu Li (2019)

Are Central Bankers Inflation Nutters? A MCMC Estimator of the Long-Memory Parameter in a State Space Model, (Online 19 June 2019), Computational economics

3. Yushu Li and Jonas Andersson (2019): A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting, (published on line 17 May 2019), Journal of forecasting

4. Hyunjoo Kim Karlsoon, Yushu Li and Ghazi Shukur (2018): The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", Sustainability 2018, 10(8), 2792; <https://doi.org/10.3390/su10082792>

5. Talha Omer, Pär Sjölander, Kristofer Månsson, B. M. Golam Kibria (2021), Improved estimators for the Zero-inflated Poisson regression model in the presence of multicollinearity: Simulation and application of maternal death data (2021), accepted, Communications in Statistics ? Case Studies and Data Analysis

Prosjektmedlemmene har også tre artikler som fremdeles er work in progress:

1. Fredrik N.G. Andersson and Yushu Li (2021) Are real effective exchange rates real mean-reverting? Long memory and structural breaks (is prepared for being sent to journals for consideration of publication).

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3. Pär Henrik Sjölander, Yushu Li and Peter S Karlsson (2021) A simple panel causality test in the presence of cross-section dependence (working on progress).

Basert på ovennevnte resultat fra prosjektet, kan vi si at utnytttere av prosjektet er beslutningsteoretikere og økonomiske matematikere, makroøkonomer, økonom

Popular science presentation - Updated (English)

This project's first object and second object is illustrated before updating. Here is articles' information updating:

Until July, 2021, totally 13 articles can be related to this project with acknowledgement to the funding of the project. The formation of the acknowledgement is: XXX gratefully acknowledges funding from the Finance Market Fund, Norwegian Research Council (Project number 274569).

Those 13 articles including 2 conference papers, 8 journal publications and 3 papers working on progress.

Three project members (Lars Hegnes Sendstad, Michail Chronopoulos; Yushu Li) have been working on the topics to extend traditional real options models to account not only for attitudes towards risk but also for the regime-switching behavior of economic indicators when the probability of switching between different regimes is both fixed and stochastic. There are two conferences paper in those topics:

1. Chronopoulos, M (2018), "The Value of Modular Design and Project Scale for Alternative Green Investment," in the 41st IAEE International Conference, 10-13 June, Groningen.

2. Sendstad, Lars Hegnes; Chronopoulos, Michail; Li, Yushu.
The Value of Turning-Point Detection for Optimal Investment. The 23rd Annual International Real Options Conference; Dublin, Ireland; 2019-06-27 - 2019-06-29

and 3 publications:

1. Sendstad, Lars Hegnes; Chronopoulos, Michail (2021), Strategic technology switching under risk aversion and uncertainty, Journal of Economic Dynamics & Control, Vol.126.

2. Sendstad, Lars Hegnes; Chronopoulos, Michail and Verena Hagspiel (2021), Optimal Risk Adoption and Capacity Investment in Technological Innovations,IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT

3. Sendstad, Lars Hegnes; Chronopoulos, Michail, (2020) Sequential investment in renewable energy technologies under policy uncertainty, Energy Policy, Vol 137.

As planned, this project also develops modern time-series methodologies with can deal with non-stationary data such as dataset with long memory, structural break (a type of regime switch), as well as the implementation in finance and economics. The topic of uncertainty forecasting (eg density forecasting) as well as evaluation are also included in the project. We have already publications:

1. Yushu Li and Fredrik N.G. Andersson (2020) A simple wavelet-based test for serial correlation in panel data models, (Online 22. Feb.), Empirical Economics

2. Fredrik N.G. Andersson and Yushu Li (2019) Are Central Bankers Inflation Nutters? A MCMC Estimator of the Long-Memory Parameter in a State Space Model, (Online 19 June 2019), Computational economics

3. Yushu Li and Jonas Andersson (2019): A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting, (published on line 17 May 2019), Journal of forecasting

4. Hyunjoo Kim Karlsoon, Yushu Li and Ghazi Shukur (2018): The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", Sustainability 2018, 10(8), 2792; <https://doi.org/10.3390/su10082792>

5. Talha Omer, Pär Sjölander, Kristofer Månsson, B. M. Golam Kibria (2021), Improved estimators for the Zero-inflated Poisson regression model in the presence of multicollinearity: Simulation and

application of maternal death data (2021), accepted, Communications in Statistics ? Case Studies and Data Analysis

The project members also have three papers working on progress:

1. Fredrik N.G. Andersson and Yushu Li (2021) Are real effective exchange rates real mean-reverting? Long memory and structural breaks (is prepared for being sent to journals for consideration of publication).
2. Bjørn Gunnar Hansen and Yushu Li (2021) Mean reverting properties of milk prices in EU countries ----Problem of misidentification under structural break (has already been sent out for consideration of publication)
3. Pär Henrik Sjölander, Yushu Li and Peter S Karlsson (2021) A simple panel causality test in the presence of cross-section dependence (working on progress).

Based on the above output of the project, we can say that the beneficiaries of project are decision theorists and financial mathematicians, macro-economist, econometricians and empirical statisticians.

6. I understand that the text of the popular science presentation will be made publicly available* Completed

Message to the Research Council of Norway

Output summary:

13 articles can be related to this project with acknowledgement to the funding of the project. The formation of the acknowledgement is: XXX gratefully acknowledges funding from the Finance Market Fund, Norwegian Research Council (Project number 274569). Those 13 articles including 2 conference papers, 8 journal publications and 3 papers working on progress (working paper). The titles of the 13 articles are listed on the next side "Results". The topics/links of the publications and conference papers can be found in attached "Results report" file on side "Results report"

Results

Please provide information about scientific publications, other publications and lectures by retrieving information registered in CRISStin. Manual registration by 'Select type' must only be used if the publication cannot be registered in CRISStin pursuant to the applicable rules.

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Bjørn Gunnar Hansen, Yushu Li	Mean reverting properties of milk prices in EU countries ----Problem of misidentification under structural break	working paper	2021				

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Chronopoulos, Michail	The Value of Modular Design and Project Scale for Alternative Green Investment	conference paper	2018				

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume

Fredrik NG Andersson, Fredrik NG Andersson	Are real effective exchange rates real mean-reverting? Long memory and structural breaks.	working paper	2020				
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Type
Academic article

Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Kim Karlsson 1, Hyunjoo; ; Li, Yushu; Shukur, Ghazi	The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods	Sustainability	2019		8/2792		

Type
Academic article

Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Lars Sendstad, Michail Chronopoulos	Strategic technology switching under risk aversion and uncertainty	Journal of Economic Dynamics and Control	2021		article/pii		126

Type
Academic article

Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Lars Sendstad, Michail Chronopoulos	Sequential investment in renewable energy technologies under policy uncertainty	Energy Policy	2021		article/pii		137

Type
Academic article

Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Li, Yushu; Andersson, Lars Jonas	A likelihood ratio and Markov chain-based method to evaluate density forecasting	Journal of Forecasting	2019		10.1002/ for.2604	1-9	

Type
Academic article

Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Omer, Talha; Sjölander, Pär; Månsson, Kristofer; M. Golam Kibria, B.	Improved estimators for the Zero-inflated Poisson regression model in the presence of multicollinearity: Simulation and application of maternal death data	Communications in Statistics - Case Studies and Data Analysis	2021		10.1080/ 23737		7

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Sendstad, Lars; Chronopoulos, Michail; Hagspiel, Verena	Optimal Risk Adoption and Capacity Investment in Technological Innovations	IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT	2021		document/9364749		

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Sendstad, Lars; Chronopoulos, Michail; Li, Yushu	The Value of Turning-Point Detection for Optimal Investment	conference paper	2019				

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Yushu Li, Fredrik N.G. Andersson	A simple wavelet-based test for serial correlation in panel data models	Empirical Economics	2020		article/10.1007%2Fs00181	2351-2351	60

Type							
Academic article							
Author(s)*	Title*	Publication title*	Year*	ISSN/ISBN	DOI	Pages from - to	Volume
Yushu Li, Fredrik NG Andersson	Are Central Bankers Inflation Nutters? An MCMC Estimator of the Long-Memory Parameter in a State Space Model	Computational Economics	2019	0927-7099	article/ 10.1007%2Fs10614	10614	

5. Has information on publications been provided?

Yes

Performance indicators

Results	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Cumulative number
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Dissemination measures for the general public

Popular science publications (articles/books, books/articles in the public debate, documents formally circulated for review, exhibitions, fiction, etc..)

	4	4									8
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Dissemination measures for users

Reports, memoranda, articles, presentations held at meetings/conferences for project target groups (public sector, trade and industry, organisations)

	6	4									10
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Industry-oriented R&D results

New/improved methods/models/prototypes finalised

	1	2									3
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Scientific/scholarly publications

Book/report

	0	0									0
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Article

	1	4	2	5							12
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2. All results data that have emerged from the project are to be reported. Has this been done?

Yes

Fellowship grants

Fellowship grants funded under the project

1. Information regarding all fellowship grants must be complete and correct. Have you updated the man-months and other information for each fellowship-holder?

Yes

International cooperation

International cooperation funded under the project (in NOK 1000)

Amount in NOK 1000

Country	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Canada	80									
United Kingdom	90	90								
Sweden		240								

3. The extent of international cooperation is to be indicated. Has any international cooperation taken place during the report period? Yes

Special reports

Alternative 1:

No special reports

Alternative 2:

Original file :

File reference:

4. If any requests for special reports have been put forth by the case officer at the Research Council, these must be fulfilled. Have special reports been submitted? Yes

Final report for project “Strategic Risk Adoption in Real Options under Multi-Horizon Regime Switching and Uncertainty”

This final report contains two main parts, the first part is “Popular summary for project”, and the second part is “Links to the 8 Popular science publication, Comments on the Dissemination measures for users and Industry-oriented R&D results”.

Part One: Popular summary for project

The project’s objective is two-fold: first, it aims to extend real options theory in order to facilitate the analysis of complex investment opportunities, involving non-diversifiable risk, endogenous capacity sizing and strategic interactions, within a regime-switching economic environment of interacting uncertainties. Second, this project develops several novel empirical time-series methodologies and statistical models to capture the uncertainty in non/stationary time series.

To demonstrate the application potential of the work developed in this project, we emphasize the relevance of the underlying methodologies within the context of financial, economic, and environmental problems, and provide access to the data utilized in the empirical models as well as the relevant software codes to facilitate technology transfer.

To achieve the aforementioned objectives, the project members cooperated with each other and worked on two main directions. The first direction aims to achieve the project’s first object, and, in this direction, the following frameworks are developed:

- (1) First, we develop a real options framework to analyze the impact of technological, policy and electricity price uncertainty on the decision to invest sequentially in successively improved versions of a renewable energy technology. Technological uncertainty is reflected in the random arrival of innovations while policy uncertainty is modelled via the likely provision or retraction of a subsidy. To demonstrate and emphasize the application potential of this framework, we develop a case study on offshore wind. In turn, this facilitates the derivation of key policy-making insights on how to introduce market incentives within a post-liberalized setting, taking into account the implications of timing, technological uncertainty, and operational flexibility on investment behavior. Within the area of public policy, understanding the implications of such features is critical in terms of mitigating the regulatory risk of corrective policy actions.
- (2) Next, to emphasize the implications of deregulation for investment under economic and technological uncertainty, we develop a utility-based, real options framework for sequential investment under duopolistic competition. The goal is to analyze how economic and technological uncertainty interact with risk aversion to impact the sequential adoption of successively improved technology versions under pre-emptive and non-pre-emptive competition. By allowing for operational flexibility in the form of sequential investment decisions, this work provides novel insights on the implications of technological

uncertainty for investment under duopolistic competition. Additionally, by considering different investment strategies (compulsive, leapfrog, and laggard) under different types of competition (pre-emptive and non-pre-emptive), this work offers novel insights on the interaction of scenarios, decisions, option to delay and investment choice.

- (3) Subsequently, we extend the notion of managerial flexibility to allow for discretion over timing and investment scale. Thus, we develop a utility-based, regime-switching framework in order to analyze how a firm with discretion over the time of investment and the size of the project may choose to abandon an existing market regime to enter a new one. One of the key contributions of this framework is to extend existing utility-based real options models that consider an exogenous price process, and, effectively, price-taking firms. This is achieved via the integration of an inverse demand function within a utility-based framework, which, in turn, facilitates further analysis of the feedback effect of capacity expansion on the price process. Thus, the contribution of this work is relevant within the area of financial mathematics and economics, since it not only provides an analytical framework for analyzing investment options under market incompleteness but also accounts for critical aspects underlying the deregulation of many industries.

The second direction corresponds to the second objective of this project. In this direction, several methods/models/estimators are developed to analyze empirical data from economics and finance. Most of the developed methodologies and empirical data are in the field of time series econometrics. To prove the efficiency of the method, simulation studies are carried out. The R code for simulation and empirical study are accessible from authors upon requirement. More description of the methods proposed in this direction and their implementation with empirical examples are listed as follows:

- (1) A maximum overlap discrete wavelet transform (MODWT) based method to tests for serial correlation of unknown form in the residuals from a panel regression model. The tests can be applied to both static and dynamic time series - panel models. Panel time series data are widely utilized in economics and finance, while serially correlated errors in panel regression models have several implications for econometric modeling, such as making parameter estimation inefficient. The method proposed in this paper is quite simple and easy to be implemented, and can reveal the serial correlations in panel data effectively.
- (2) A Bayesian Monte Carlo Markov Chain (MCMC) method to construct estimator for fractional integration parameters in autoregressive fractionally integrated moving average (ARFIMA) time series model. The fractional integration order is a parameter which can measure how flexible the inflation target is, assuming that the central bank controls the long-run inflation rate. For econometric implementation, we use this proposed Bayesian MCMC method to estimate fractional integration order for seven economies (Canada, Euro area, Germany, Norway, Sweden, the United Kingdom, and the United States) between 1993 and 2017 using monthly data. All countries have central banks with inflation targets and our estimation results show that all central banks have flexible targets and are no “inflation nutters”.

- (3) A likelihood ratio-based method to evaluate density forecasts, which can jointly evaluate the unconditional forecasted distribution and dependence of the outcomes. The proposed method does not require a parametric specification of time dynamics and can be used to evaluate out of sample density forecasts of daily returns on different stock market indices from models of financial returns used in the financial industry. We believe this proposed method has potential for further applications in density forecast evaluation in both macroeconomics and finance. In macroeconomics—for example, we can evaluate how accurate is the forecast of the distribution for inflation and output growth. In risk management in finance, the well-known value-at-risk (VaR) analysis is one type of interval forecast, which can be viewed as special case of density forecast.
- (4) A framework with combine wavelet multi-resolution analysis (MRA), two types of causality tests, and impulse response functions to investigate causal relationships real oil price, real interest rate, and unemployment in Norway, and examine effects of innovation in one variable on the other variables. This framework unveils and systematically distinguishes the nature of the time-scale dependent relationship between real oil price, real interest rate, and unemployment in Norway under a time horizon of about two years.
- (5) A Liu-type shrinkage estimators for the zero-inflated Poisson regression model in the presence of multicollinearity. This estimator is a remedy to the problem of inflated variances for the maximum likelihood estimation technique—which is a standard approach to estimate these types of count data models.

In summary, the first direction's topics correspond to the project's first object, and those topics concentrate on extending traditional real options models to account not only for attitudes towards risk but also for the regime-switching behavior of economic indicators, when the probability of switching between different regimes is fixed. The topics on the second direction contain developing novel time-series methodologies that can deal with non-stationary data, such as dataset with long memory, structural breaks, as well as the implementation in finance and economics. The topics of uncertainty forecasting (e.g., density forecasting) as well as evaluation are also included in the second direction. Each of the above developed frameworks/methods/models/estimators has been published and the links of the publications can be found in Part 2. Prior to publication, they were presented at different conferences and seminars by the project members.

Part 2: Links to the 8 Popular science publication, Comments on the Dissemination measures for users AND Industry-oriented R&D results

A. The 8 Publication with links:

The mentioned 8 topics in Part 1 end up in 8 research papers that have been published in decent or top academic journals. Detailed references are included below:

1. Sendstad, Lars Hegnes; Chronopoulos, Michail (2021), Strategic technology switching under risk aversion and uncertainty, *Journal of Economic Dynamics & Control*, Vol.126.

<https://www.sciencedirect.com/science/article/pii/S0165188920300865>

2. Sendstad, Lars Hegnes; Chronopoulos, Michail and Verena Hagspiel (2021), Optimal Risk Adoption and Capacity Investment in Technological Innovations, IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT

<https://ieeexplore.ieee.org/document/9364749>

3. Sendstad, Lars Hegnes; Chronopoulos, Michail, (2020) Sequential investment in renewable energy technologies under policy uncertainty, Energy Policy, Vol 137.

<https://www.sciencedirect.com/science/article/pii/S0301421519307384>

4. Yushu Li and Fredrik N.G. Andersson (2020). A simple wavelet-based test for serial correlation in panel data models, (Online 22. Feb.), Empirical Economics

<https://link.springer.com/article/10.1007%2Fs00181-020-01830-6>

5. Fredrik N.G. Andersson and Yushu Li (2019) Are Central Bankers Inflation Nutters? A MCMC Estimator of the Long-Memory Parameter in a State Space Model, (Online 19 June 2019), Computational economics

<https://link.springer.com/article/10.1007%2Fs10614-019-09900-3>

6. Yushu Li and Jonas Andersson (2019): A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting, (published on line 17 May 2019), Journal of forecasting

<https://onlinelibrary.wiley.com/doi/10.1002/for.2604>

7. Hyunjoo Kim Karlsoon, Yushu Li and Ghazi Shukur (2018): The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", Sustainability 2018, 10(8), 2792;

<https://www.mdpi.com/2071-1050/10/8/2792>

8. Talha Omer, Pär Sjölander, Kristofer Månsson, B. M. Golam Kibria (2021), Improved estimators for the Zero-inflated Poisson regression model in the presence of multicollinearity: Simulation and application of maternal death data (2021), Communications in Statistics? Case Studies and Data Analysis. Vol7, Issue 3.

<https://www.tandfonline.com/doi/full/10.1080/23737484.2021.1952493>

B. Comments on the Dissemination measures for users, Reports, memoranda, articles, presentations held at meetings/conferences for project target groups (public sector, trade and industry, organizations):

There are 10 articles from 2018 and 2019, including the aforementioned publications. Before their publications in journals, these articles were made available as working paper (e.g., SSRN) and/or presented at different conferences. In addition, we have the following two working papers that are not published but are presented at conference:

- (1) Sendstad, Lars Hegnes; Chronopoulos, Michail; Li, Yushu. The Value of Turning-Point Detection for Optimal Investment. Presented at the 23rd Annual International Real Options Conference; 2019-06-27 - 2019-06-29
- (2) Chronopoulos, Michail, The Value of Modular Design and Project Scale for Alternative Green Investment. Presented at the 5TH INTERNATIONAL CONFERENCE ON ENERGY, SUSTAINABILITY AND CLIMATE CHANGE ([ESCC 2018 – ESCC \(uth.gr\)](#))

C. Comments on Industry-oriented R&D results --- New/improved methods/models/prototypes finalised

Apart from its methodological contribution, the output of this project demonstrates an important application potential, via its empirical models and case studies. The software packages that support these models are not only available as part of the corresponding publications but will also be made available in public repositories. Thus, we facilitate technology transfer by ensuring that the empirical results are accessible to and reproducible by a wide range of industry participants.

- (1) A strategy which uses wavelet multi-resolution analysis (MRA) and two types of causality tests, to investigate causal relationships between real oil price, real interest rate, and unemployment in Norway. The related paper is Hyunjoo Kim Karlsruen, Yushu Li and Ghazi Shukur (2018): "The Causal Nexus between Oil Prices, Interest Rates, and Unemployment in Norway Using Wavelet Methods", *Sustainability* 2018, 10(8), 2792;
- (2) Evaluation method for out of sample density forecasts of daily returns on different stock market indices from models of financial returns used in the financial industry. The related paper is: Yushu Li and Jonas Andersson (2019): "A Likelihood Ratio and Markov Chain Based Method to Evaluate Density Forecasting", (published on line 17 May 2019), *Journal of forecasting*.
- (3) A real options framework to analyse the impact of technological, policy and electricity price uncertainty on the decision to invest sequentially in successively improved versions renewable energy. The related paper is: Sendstad, Lars Hegnes; Chronopoulos, Michail, (2020) "Sequential investment in renewable energy technologies under policy uncertainty", *Energy Policy*, Vol 137.

Under the whole project process, the project members (Lars Hegnes Sendstad, Michail Chronopoulos Yushu Li, Fredrik N.G. Andersson and Pär Sjölander) are actively involved and hold meetings online/on site constantly. The cooperation will continue after the project is finished.