Report on **Master Thesis**

Institute of Economic Studies, Faculty of Social Sciences, Charles University

Student:	**Bc. Ondřej Karlíček**
Advisor:	**PhDr. Jiří Kukačka, Ph.D.**
Title of the thesis:	**Simulation-based estimation methods in financial econometrics: Analysis of performance and comparison**

OVERALL ASSESSMENT *(provided in English, Czech, or Slovak):*

Short summary

This thesis explores the performance of simulation-based estimation methods in financial econometrics, specifically applied to agent-based models (ABMs). Traditional techniques often struggle with ABMs due to their nonlinear nature and complexity, making simulation-based methods essential. Using a large and computationally intensive Monte Carlo approach, the study compares the sets of two frequentists and two Bayesian methods for three benchmark models selected from the literature. Results reveal that while Bayesian methods generally outperform frequentist approaches, there's no clear overall winner, as performance varies by parameter. Frequentist methods provide less biased estimators, but likelihood methods offer more stable estimates across simulations. The study also highlights the need for further exploration into likelihood approximation for models with latent variables. Ultimately, the thesis emphasizes and quantitatively specifies the bias-variance tradeoff in the field of ABM financial econometrics: moments-based methods have lower bias but higher variance, while likelihood-based methods are more stable but may introduce bias.

Contribution

The main contribution lies in a comprehensive comparison of simulation-based estimation methods in the context of financial agent-based models (ABMs), a strongly underexplored area in econometrics. It provides new practical knowledge to the field by incorporating and extending existing methods—Simulated Method of Moments (SMM), Non-parametric Simulated Maximum Likelihood (NPSML), Approximate Bayesian Computation (ABC), and Bayesian Estimation (BE)—and applies them to both traditional econometric time-series models and more complex ABMs such as the Franke & Westerhoff (2012) model.

A key methodological innovation is the evaluation of the NPSML method's (pseudo-)empirical performance for models with latent variables, an area not yet studied in the field, especially in a frequentist framework. By comparing frequentist and Bayesian approaches, the thesis highlights critical trade-offs between bias and variance, offering researchers practical guidance on when to use each method based on specific model parameters. Additionally, it suggests further research avenues for improving likelihood approximation and adjusting Bayesian methods like ABC for better accuracy. This contribution is significant for the literature for advancing the estimation techniques used in financial ABMs.

Moreover, I have to specifically appreciate Ondrej's honest approach to elaborating the entire work. Ondrej spent a whole year working on the thesis; we had regular meetings and discussed the topic intensively, via which we were able to arrive at the current well-designed composition of the work and a very coherent research approach leading to a set of contributive results. Ondrej often had to invest significant time and effort in various technical issues and complexities that finally might not be obvious from the smooth flow of the text, but that made the continuation of the work possible. I believe Ondrej thus learned a lot. The computational processing of the codes was indeed non-trivial. Ondrej had to explore the option of renting computation capacities from commercial providers like Amazon or Google and finally conducted the simulations using the MetaCentrum, a virtual organization of the Czech National Grid open to academic staff and students to proceed with computationally heavy research.

Methods

The study compares two frequentist methods: Simulated Method of Moments (SMM) and Non-parametric Simulated Maximum Likelihood (NPSML) with Bayesian approaches such as Approximate Bayesian Computation (ABC) and Bayesian Estimation (BE). It further examines two benchmark models, AR(2) and ARMA-GARCH alongside, with the main focus on the well-known Franke & Westerhoff (2012) ABM. The implementation of the estimation methods is perfectly described in detail and, in general, surpasses the master-level IES curriculum. The extension of the NPSML method for latent variable models clearly extends the current methodological base of the field of ABM econometrics. The main results are supported by a sensitivity analysis regarding the intensity of the stochastic noise entering the system, a robustness analysis studying the impact of different definitions of the final point estimate (medians and modes instead of means),

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and detailed visual elaborations of the trajectories for the likelihood approximation for latent variables models. A complete code-base of the work allowing for replication of the results is well documented and publically available on GitHub.

Literature
The literature review is standardly elaborated and considers both main areas of interest: financial agent-based models (ABMs) and estimation techniques. A good selection of the associated research papers, primarily the seminal ones for each topic, is provided to summarize brief history and state-of-the-art. However, especially Section 2.1, is rather brief and only written in a "positive manner," meaning that while it demonstrates that the author is familiar with the related literature, it does not go much more profound and does not delve into the history of the field deeply enough. This imperfection is, nonetheless, partially offset by the extent of the methodological Chapter 3, which introduces another literature associated with the details of the estimation methods. Formally, citations are adequately done using a standard style for economic papers.

Manuscript form
The thesis is written in sound English, standardly structured, and typeset in LaTeX. The writing style is clear and coherent, and the whole works read well. All formatting comments from my side were considered. The bibliography section is complete and well-formatted. Referencing tables and figures is done correctly in the text, the tables are very well designed, and both figures and tables are self-contained. The use of generative AI technologies in the writing process is properly declared.

Overall evaluation and suggested questions for the discussion during the defense
The assessed thesis cleraly surpasses the IES, Faculty of Social Sciences, Charles University master-level standards. Thus, I can confidently recommend it for the defense and suggest a grade of A.

The results of the Turnitin analysis do not indicate significant text similarity with other available sources.

Additional topics for the discussion:
- Based on your findings, what overall recommendations would you provide to practitioners intending to use estimated financial agent-based (FABMs) for policy decision-making? What practical steps should they follow to ensure effective implementation?

SUMMARY OF POINTS AWARDED (for details, see below):

CATEGORY		POINTS
Contribution	*(max. 30 points)*	30
Methods	*(max. 30 points)*	30
Literature	*(max. 20 points)*	17
Manuscript Form	*(max. 20 points)*	20
TOTAL POINTS	*(max. 100 points)*	**97**
GRADE	**(A – B – C – D – E – F)**	**A**

NAME OF THE REFEREE: Jiří Kukačka

DATE OF EVALUATION: 9. 9. 2024

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Referee Signature

EXPLANATION OF CATEGORIES AND SCALE:

CONTRIBUTION: *The author presents original ideas on the topic demonstrating critical thinking and ability to draw conclusions based on the knowledge of relevant theory and empirics. There is a distinct value added of the thesis.*

METHODS: *The tools used are relevant to the research question being investigated, and adequate to the author's level of studies. The thesis topic is comprehensively analyzed.*

LITERATURE REVIEW: *The thesis demonstrates author's full understanding and command of recent literature. The author quotes relevant literature in a proper way.*

MANUSCRIPT FORM: *The thesis is well structured. The student uses appropriate language and style, including academic format for graphs and tables. The text effectively refers to graphs and tables and disposes with a complete bibliography.*

Overall grading:

TOTAL	GRADE
91 – 100	A
81 - 90	B
71 - 80	C
61 – 70	D
51 – 60	E
0 – 50	F