

Report on Bachelor Thesis

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

Student: Jan Vainer
Advisor: Jiří Kukačka
Title of the thesis: Extending Hotelling's location model into Agent-based domain

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

Please provide your assessment of each of the following four categories, summary and suggested questions for the discussion. The minimum length of the report is 300 words.

The bachelor thesis of Jan Veiner "Extending Hotelling's location model into Agent-based domain" thoroughly designs and consequently analyses a complex model in which adaptive agents without perfect information guided by the Nash-Q learning algorithm interact within environment inspired by Hotelling's location model. The main aim of the thesis is to examine and describe whether such simulated adaptive behaviour brings different results from the theoretical model under otherwise similar conditions.

Contribution

The thesis skilfully and innovatively combines three areas of Economic, namely microeconomic theory, game theory, and agent-based simulations, and provides an original modelling approach interconnecting these three fields into a rigorous framework. To the best of our knowledge, such a study relaxing strong microeconomic assumptions of the Hotelling's location model and transferring it into agent-based domain has not been proposed and examined so far. Results of the work are thus contributive to the related literature and deserve attention of economists in general as the model is able to produce endogenous evolutionary dynamics between the stages of "maximum differentiation", when the agents locate themselves as far as possible from each other, and stages of "minimum" differentiation", resembling an aggressive market strategy in which differentiation attempts diminish and firms only compete in price in order to eliminate the opponent from the market. While the original Hotelling's model as well as its adjusted version with different consumer cost function offer only a static solution, Jan's contribution is able to mimic, based on a theoretically well-founded framework, periodic fluctuations of the "innovation-imitation" dynamics in highly competitive fields such as (just the first ideas coming to my mind) the smart phone market or bus service market (Jančura's Student Agency vs. "traditional" bus service providers in the past —> Jančura's Student Agency vs. FlixBus these days).

The cooperation with Jan from my advisor's point of view was excellent and stimulative. Jan showed strong theoretical as well as programming skills, ability to independently suggest solutions to many non-trivial issues emerging during the research as well as to focus on a detailed and very elaborate solution of the research task defined only in general terms at the beginning of our cooperation. At the end of works, Jan also managed to critically interpret the results and to come to interesting and economically valuable (even surprising) conclusions which I believe might be beneficial for future development of models of economic competition.

Methodology

Jan managed to get familiar with an intellectually demanding fields with ease, designed the extended model and coded it himself from scratch using Python programming environment. Jan also had to consider and finally suggest several non-trivial solutions (single-agent learning, learning in multi-agent environment, Nash-Q learning implementation into agent-based framework, and others) and change the principles of the original model significantly to allow implementation. Computationally intensive simulations were then conducted with the help of computational server capacities at he Czech Academy of Sciences. I have to stress here that only a minor part of the thesis content is part the bachelor curriculum at the IES FSV UK.

Very importantly, Jan was also well able to critically and fairly consider and openly discuss potential weaknesses of his newly suggested approach (e.g. a possible of non-uniqueness of Nash equilibrium, issues related to mixed strategy Nash equilibrium), to which section 5.2 and partially section 6 are devoted.

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With this respect, his research resembles much more a fundamental research in Economics than an application.

Literature

The literature review section introduces the reader step-by step to important concepts further implemented in the thesis. Academic resources are selected so that only highly relevant papers for elaboration of the research question are considered. Formal citation are then conducted in a proper way. Although this section well demonstrates author's understanding of the most relevant literature, it could have been enlarged to some extent to cover also some related areas to introduce broader concepts (agent-based modelling, market competition literature) within which the specific research topic is nested.

The work additionally offers to other researchers a survey of learning algorithms for use in small-scale discrete economic agent-based simulations. Nash-Q learning and Reinforcement learning are carefully presented and discussed as adaptive methods for agent-based simulations with application in Economics. Jan suggests that these methods are well motivated for use in small-scale discrete economic agent-based simulations because they do not require extensive complete knowledge of the environment or the opponents. Instead, dynamics of the model is governed by agents' repeated interactions and induced learning which is a reasonably realistic scenario.

Manuscript form

The work is well structured and formally meets high academic standards of quality for an academic text of this level. The overall layout is well designed, the aim of the works is clearly stated and carefully elaborated. I highly appreciate the use of typographic software LaTeX not only for text of the thesis but also almost professional LaTeX-coded graphics (Fig. 1-4). All figures and tables are high-quality formatted, self-contained, and properly referenced in the text. Referencing to academic resources is complete and final Bibliography section is consistent and in accordance with citation standards. The text is written in decent English without needles typos and offers some enjoyable paragraphs of explanations (e.g. try searching "octopus"). The text of the thesis is supplemented by an electronic archive containing complete model source codes and documentation for the analysis so that everyone can verify or replicate the results.

Summary and suggested questions for the discussion during the defense

- Explain technically what model principles drive the dynamically stable fluctuations between the "minimum" and "maximum" differentiation stages. In what real-world industries/markets can you observe these strong tendencies?
- One of the rather surprising results is that the "principle of minimum differentiation" could be justified based on repeated interaction of the agents and long-run optimisation. On the other hand, the same principle is a well known textbook example and result of the very original Hotelling's model know to almost every student of microeconomics. Can you explain how this is achieved within the extended agent-based model and how these principles differ compared to the theoretical model?

Finally, I do find this thesis more than surpassing academic standards for bachelors theses written at IES FSV UK. Personally considered, the ability of the author to suggest almost entire original and complex design of the work himself is the most distinctive quality of the work. If the analysis is enlarged a bit, I believe the thesis could well compete in terms of quality with many master theses defended at IES FSV UK.

I am very pleased I can with no doubts recommend the thesis of Jan Vainer to defense at the IES FSV UK and if Jan manages the defense procedure well, I feel confident to suggest the highest grade "A".

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

CATEGORY	POINTS
<i>Contribution</i> (max. 30 points)	28
<i>Methods</i> (max. 30 points)	28
<i>Literature</i> (max. 20 points)	16
<i>Manuscript Form</i> (max. 20 points)	20
TOTAL POINTS (max. 100 points)	92
GRADE (A – B – C – D – E – F)	A

NAME OF THE REFEREE: Jiří Kukačka

DATE OF EVALUATION: 4. 6. 2018

Referee Signature

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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.

<i>Strong</i>	<i>Average</i>	<i>Weak</i>
30	15	0

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.

<i>Strong</i>	<i>Average</i>	<i>Weak</i>
30	15	0

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

<i>Strong</i>	<i>Average</i>	<i>Weak</i>
20	10	0

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.

<i>Strong</i>	<i>Average</i>	<i>Weak</i>
20	10	0

Overall grading:

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