Report on Master Thesis

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

Student:	**Bc. Marek Lipán**
Advisor:	**doc. PhDr. Jozef Baruník, Ph.D.**
Title of the thesis:	**Artificial Prediction Markets, Forecast Combinations and Classical Time Series**

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.

Contribution

The diploma thesis of Marek Lipán is an excellent piece of work. Its contribution lies in several aspects that each would be rather sufficient for a standard level master thesis but their combination make the work to a large extent extraordinary. First, Marek collects, properly presents, and skilfully applies a large set of general forecast methods and their combinations and runs an extensive horse race to potentially solve the so called “forecast combination puzzle”. i.e. to discover superior approaches that would be able to consistently beat the “naive” simple average forecast that has, however, a strong position in the historical literature. The thesis contributively shows that simple average forecast can be significantly outperformed by specific forecast combinations in both a macro as well as financial data applications. Second, at the top of that, Marek suggests a new original approach to combining forecast that he calls a “Market for Kernels”, describes its working algorithm, and shows that this new method of combining forecast is generally comparable to the best forecast combinations. Third, an extensive horse race is performed using both the macroeconomic (ECB Survey of Professional Forecasters, an annual frequency of the real GDP, inflation, and unemployment dynamics forecasts) as well as daily financial data (volatility of the U.S. Treasury futures underlaid by the U.S. Treasury notes and bonds). The last is a very important practical robustness check significantly increasing confidence in presented results when a method proves itself superior for both cases as the dynamics of the two datasets has to a large extent different drivers.

Moreover, I have to reckon and highlight that Marek provides the complete archive of python scripts related to his analysis publicly available at github.com, allowing other researches to use his know-how and gained knowledge.

Methods

The methodology is more than legitimate for a high-quality master thesis at the IES FSV UK. The set of applied forecast methods is extensive (the author claims that it is the largest set ever collected in the literature and there is no reason not to believe him). Both “standard” methods for combining forecasts (Bates-Granger, BMA combinations, etc.) as well as “alternative” machine learning methods (Artificial Neural Network, AdaBoost algorithm, and newly employed Artificial Prediction Markets), that are not much examined in the related literature so far, are presented in detail. The “Market of Kernels” method employs a discrete agent-based motivated approach calibrated using results of spectral analysis. The data are very properly described, displayed, and treated. For the U.S. Treasury futures and their unobserved volatility, a set of econometric approaches such as the realized volatility, GARCH, HAR, and VAR models, or the Risk Metrics estimator has been used. Econometrics test (Augmented Dickey-Fuller, Diebold Mariano) are properly applied. For measuring the forecast accuracy, three familiar metrics (RMSE, MAE, MAPE) in combination with a rigorous DM test are applied to avoid potential impacts of subtle differences between these otherwise to a large extent similar forecast accuracy measures.

As a final remark, I have to highlight that Marek is on the other hand clearly aware of some unavoidable imperfections of the analysis. Section 6.2 of the concluding discussion is devoted to these aspects such as the limited amount of data, limited number of iterations in the training period, or the limited size of the setup grid. With a high level of fairness and openness Marek also suggests some theoretical improvements that need to be done to complete the newly proposed “Market for Kernels” method. All these important details add to the quality of the overall research results.

Literature

The literature review covers the area of combining forecasts completely and each of the method applied further in the analysis has its own section. To the extent I am able to assess, the overview of the state-of-the-art of the combining forecast literature is extensive. What I am only missing a bit is some attempt to go a bit deeper into the analysis of the literature (e.g. to discuss potential interesting comparisons: similarities and differences between

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individual branches of the literature, to search for some trends and their development in the historical literature, to detect and stress some interesting disagreements in the literature if there are any, etc.). I am not sure whether the suggested strategies in the previous sentence are feasible, but it would add to the otherwise very thorough literature review at the level of individual papers. An additional literature review sections the "diffuse" also other chapters of the work where necessary, starting with the most important pieces in the Introduction, additional referencing of all methodological concepts in Chapter 3, and some additional important references also within the section with the application and analysis.

Manuscript form

There is not much to criticise here, although personally I am very demanding with respect to the editing and formal quality of theses. The works reads very well, there has been only few minor typos noticed, the structure of sections is well-considered, referencing to the literature is complete and correct, bibliography section is consistent even up to the level of caps, all graphics are nice and well described, and all tables are well formatted and reasonably self-contained. Only minor points here: Tables 4.1 and 4.2 should definitely not be solitary object on a page, the text should runaround, some of the Tables 5.1-5.10 should rather belong to Appendix, it is not "nice" to have 5 pages of solely numerical results in sequence. These tables present an almost overwhelming amount of numerical results and thus it is difficult for the reader to orientate in. Maybe using bold formatting for the important results would help. Also using the same set of colours for different sets of best combinations of forecasts (all Figures 5.X) make direct visual comparison a bit complicated.

Summary and suggested questions for the discussion during the defense

In case Marek Lipán manages the defense presentation and discussion well, I am fully confident to suggest the defense committee to asses the thesis by the grade A, i.e. "Excellent".

I also suggest the two topics of my interest for the discussion:

1. Do you already have an idea of how to structure or on what principle to base the formal proof of the agent-based "Market for Kernels" convergence to the optimal forecast weights?
2. I noticed that the "Market for Kernels" exhibits clearly the steadiest dynamics in many cases, especially for the two-year horizon macro data (see e.g. Fig. 5.1-3., Harmonised Inflation 2-Y, where other combining forecasts as well as the "red ECB lines" fluctuate rater strongly but the "green MfK" lines move sluggishly along the 2% ("target") level and only "react" by a slow downward shift in the second half of the examined period. Can you discuss this observation?

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

CATEGORY		**POINTS**
Contribution	*(max. 30 points)*	29
Methods	*(max. 30 points)*	30
Literature	*(max. 20 points)*	18
Manuscript Form	*(max. 20 points)*	19
TOTAL POINTS	*(max. 100 points)*	**96**
GRADE	**(A – B – C – D – E – F)**	**A**

NAME OF THE REFEREE: Jiří Kukačka
DATE OF EVALUATION: 11. 9. 2018

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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.*

Strong	*Average*	*Weak*
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.*

Strong	*Average*	*Weak*
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.*

Strong	*Average*	*Weak*
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.*

Strong	*Average*	*Weak*
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**