PhDr. Jiří Kukačka

Dissertation topic:
Empirical Validation of Heterogeneous Agent Models

Anotation

In recent financial literature, the Representative Agent Approach and the Efficient Market Hypothesis, dominating in the past, are being replaced by more realistic agent based computational approaches. Moreover, recent financial markets events pointed at the deficiency of knowledge about functioning of this crucial segment of global economy. Although consequences of market fluctuations are worldwide, the essence of problems remains on the level of individual market agents with their heterogeneous beliefs and expectations.

Core idea of the heterogeneous agent modelling is the well documented departure from agents' full rationality. HAMs employ interacting groups of boundedly rational agents to model the financial world and this reasonably realistic methodology appears very successful in replicating observed stylized facts of financial time series.

The aim of the project is to develop algorithms for empirical validation of particular HAM designs. Resulting model will additionally be examined via the out-of-sample verification and contrasted to other 'competing' approaches (VAR, GARCH 'family'...) to assess whether HAMs outperform these well-known models in terms of fitting real financial data and the forecasting performance power. So far only a few proper attempts have been made in this pioneering and highly challenging research field, requiring innovative algorithmic solutions combined with extensive computational capacity.

The current state of knowledge:

In recent academic financial literature, the Representative Agent Approach and the Efficient Market Hypothesis, which dominated the field in the past, are being replaced by more realistic agent based computational approaches. The crucial idea of all HAMs is the abandonment of agents' full rationality towards bounded, limited rationality. HAMs employ interacting groups of boundedly rational heterogeneous agents using simple but reasonable heuristics or rules of thumb to model the financial world and this methodology appears very successful in replicating observed stylized facts in financial time series (e.g. excess trading volume, heavy tails, volatility clustering and others). Moreover, HAM methodology is able to produce models which are, considering the inner logic of economic modelling, much closer to the real world then the 'efficient' models can ever be. This is one of the intrinsic goals economics aspire to achieve.

While many different HAMs has been developed and studied, surprisingly, not many attempts have been already made to properly estimate a HAM on real market data. Moreover, only few of those have been compared in terms of forecasting power performance or fitting the real data with alternative 'competing' approaches such as ARIMA, VAR, GARCH family or alternative 'rational' models. On the one hand the reason is straightforward. While the heterogeneity of agents approach can be viewed as intellectually satisfying and reasonably realistic, the nonlinear nature of HAMs, evolutionary switching among trading strategies and a large number of variables which can be set, estimated and studied make the empirical

validation of HAMs rather challenging issue. Namely one has to consider trade-offs between efforts to get closer to reality against necessary sacrificing certain real-life market details and dispose of enough computational capacity and time. On the other hand, since the complexity of HAMs often prevents an analytical solution, the empirical validation of such systems remains one of the most important tools of analysis and a few scholars have already set off this uncertain research journey. From the most recent contributions, notably Boswijk et al (2007), who reformulated the Brock & Hommes (1998) model in terms of price to cash flow ratio and estimated their HAM employing the annual S&P500 data from 1871 to 2003. Additionally, Ellen & Zwinkels (2010) or Kouwenberg & Zwinkels (2010) can be mention as first pioneering articles critically discussing and comparing the forecasting abilities of HAMs with other time series modelling approaches.

Bibliography:

Boswijk, H. P., Hommes, C. H., Manzan, S. (2007): Behavioral Heterogeneity in Stock Prices, Journal of Economic Dynamics and Control, 31, pp. 1938–1970.

Brock, W.A, Hommes, C.H (1998): Heterogeneous Beliefs And Routes To Chaos In A Simple Asset Pricing Model. Journal of Economic Dynamics and Control, 22, pp. 1235–1274.

Ellen, S., Zwinkels, R. C. J. (2010): Oil Price Dynamics: A Behavioral Finance Approach With Heterogeneous Agents. Energy Economics.

Kouwenberg, R. R. P., Zwinkels, R. C. J. (2010): Chasing Trends in the U.S. Housing Market. Technical report, Erasmus University Rotterdam, Erasmus School of Economics.

Goals & Objectives:

Financial markets are one of the fundamental motive forces of global development and recent evens pointed again at the deficiency of knowledge of how this important segment of global economy works. On the one hand, extreme market events are followed by serious macroeconomic consequences of the world-wide importance. On the other hand, the essence of the problem remains on the level of individual market agents with their heterogeneous needs, beliefs and expectations.

The evidence that people widely and systematically depart from the notion of fully rational `homo economicus' (see e.g. Barberis & Thaler, 2003 for an overview) and that both professional and private speculators rely on simple trading strategies (see Reitz & Westerhoff, 2007 for an overview), which are the core ideas of the heterogeneous agent modelling, has been documented in many studies. Therefore since the crucial assumptions of the chartist-fundamentalist approach of the majority of HAMs have been verified, it makes very good sense to conduct further research in this area. Moreover, as ongoing evolutionary competition between heterogeneous trading strategies seems to be a major engine for the strong fluctuations observed in financial markets (Reitz & Westerhoff, 2007, pg. 241), some real world implications or comprehension of real markets emanating from related academic research are likely to emerge in the future.

The aim of the project is to develop and debug algorithms for empirical validation and estimation of particular HAM designs. To the best of our knowledge, so far only a few proper attempts have been made in this recently developing and challenging research field. As even one single particular theoretical HAM design offers almost infinite number of different possible settings, our effort will be heading towards the ultimate goal of a reasonably realistic, but

computationally feasible model, i.e. a model with reasonably larger number of both agents and strategies, but consuming (from the computational point of view) only the rational amount of time.

Methodology:

The character of this project is mainly theoretical and empirical research combined with a development of computational algorithms. The outline of the project is as follows. Considering HAM methodology, we plan to follow the Brock & Hommes (1998), Hommes (2006) and Hommes & Wagener (2009) approach and its extensions, which the principal investigator got familiar with during the work on his Master Thesis. As only the most simple HAMs appear analytically tractable, it is inevitable to employ the computational simulations approach. For this purpose, we plan to work in the Wolfram Mathematica environment and a combination of empirical estimation and trial and error calibration of key parameters needs to be employed. Therefore, at the moment, the multidimensional grid search in connection with usual statistical and econometric tools of data analysis seems to be the optimal possible approach. Considering data, the U.S. stock market are likely to be the preferred source of benchmark samples, but also commodity markets might appear useful.

When having the model estimated, which will admittedly be the most challenging part of our research, we plan to extend the work in three ways. First, additional model settings are intended be studied and estimated on similar datasets so that we could compare result of several different approaches. Second, various forecasting horizons of the model will be examined via the out-of-sample verification. Last, the model is intended to be contrasted to other 'competing' approaches (e.g. ARIMA, VAR, GARCH 'family' etc.) to assess whether HAMs can outperform these well-known models in terms of fitting the real financial data and the forecasting performance power.

Thesis outline:

The overall research will be summarised in the dissertation thesis. The thesis will consist of three essays based on published/submitted research articles.

The first part - 'Current Approaches to the Empirical Validation of HAMs – Critical Comparison' (working title) will focus on the current state of the research area of heterogeneous agent modelling with the special emphasis on existing attempts to estimate HAMs empirically and their comparison.

The second part will broaden the topic of the second research article 'New Approaches to the Empirical Validation of HAMs – Algorithmic Solution' (working title). The main effort will be aimed at developing and presenting first versions of an innovative algorithm combining the empirical estimation and trial and error calibration of key parameters of the particular HAM design.

Finally, the third part will be based on the work on the third research article 'Multidimensional Grid Search Model for the Empirical Validation of HAMs' (working title). In this paper the algorithm developed in the second research article will be extended, debugged and tested on various empirical datasets via the out-of-sample verification. Moreover, the model will be examined in terms of comparison with other 'competing' approaches (e.g. ARIMA, VAR, GARCH 'family' etc.) to assess whether HAMs can outperform these well-known models in

terms of fitting the real financial data and the forecasting performance power.