# „Benefits of Computer based Simulations for Financial Markets“

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## Introduction

Financial markets are highly elaborated and have been subject of many studies and research. The investigation of the impact of trading rules (market structure) on the market quality is addressed by the research discipline "market micro structure theory (MMST)" [O'Har97]. Degree of automation, price discovery, settlement and visibility of order book are examples for parameters of the market structure. The specification of market structure affects market outcome (e.g. trades, prices) strongly. The resulting quality of a market (market quality) can be measured with the aid of evaluation criteria like informational efficiency, liquidity, price volatility, and wealth effects of different groups of traders [O'Har97].

An example for a typical research topic of MMST is given by analysing the change in market quality resulting from the introduction of electronic trading at the Toronto Stock Exchange in the year 1996 [FrLa97]. In this case, accomplishing simulations would have led to the insight that (informational) efficiency does not increase as a result of the introduction of electronic trading.

## Research questions

In spite of the obvious benefits of simulations within the area of MMST the method "computer based simulation" has been less applied in the huge amount of theoretical work as well as in practical scenarios. Due to this fact we analyse in *research question one*: Are computer based simulations applicable within the area of MMST from an epistemological point of view?

The *second research question* scrutinizes concrete application areas (e. g. automation of the trading process) for computer based simulations. It basically investigates: Which application areas can be addressed by different types of simulation scenarios? These application areas are ranged into a developed classification-framework for computer based simulations which consists of the two dimensions *"Degree of Innovation of Market Structure"* and *"Traders' Intelligence"*.

With our *last research topic* we answer the question: Which concrete insights about market design and which advices to modify the market structure of the analysed market (e.g. modification of volatility interruption) can be deduced by the adoption of computer based simulations within the domain of MMST? Our results mainly focus on the application areas mention above.

## Approach[1]

A computer based simulation can be regarded as a software-implementation of a formal model [Zeig76, 4 - 5; Saue99, 12 - 15]. Because of this, the general epistemological applicability of simulations depends on the fit of the applied formal model with reality. The fit can be measured by back testing the market outcome of the performed simulation against the market outcome of real world's financial markets. For discussing the general epistemological applicability of simulations we use a powerful general class of models which is suitable to represent the market structure of financial markets[2]. As shown in figure 1 (see appendix) the FMC consists of three main elements: *traders*, *market structure* and *market outcome*. Discussing the fit of FMC with reality on the basis of model theory [Zeig76; Troi90; GiTr02] and the philosophy of science [Büte95] gives conclusions about the general applicability of computer based simulations within the area of MMST (*research question one*). In this qualitative analyses both "*abundance class*" and "*praeterition class*" [Troi90, 14] are discussed.

Additionally to this verbal argumentation, we develop a suitable instance of FMC (I-FM). In reference to the classification of models in [Troi90, 12 - 21] the I-FM can be regarded as a micro-analytical, static, discrete, stochastic model. We use the implementation of I-FM within the

[1] Due to the limited space of this abstract we focus on *research question one* in the following.
[2] This general class of models is named Financial Market Model Class (FMC) in the following.

software prototype e-FITS[3] (**e**lectronic **FI**nancial **T**rading **S**ystem) to execute different test runs referring to different types of simulation scenarios.

On the basis of simulation-generated data a back testing of the underlying I-FM with the aid of statistical hypothesis tests (non-parametric Wilcoxon-Test and t-Test) can be accomplished. In terms of model theory, a test of I-FM's replicative validity is performed. Furthermore, the prior work dealing with back testing of formal models [e. g. FaPa03; SmFa03] similar to the I-FM is discussed critically in order to give a comprehensive answer to *research question one*.

*Research question two* is addressed by developing the two-dimensional classification-framework mentioned above. Its first dimension "*Degree of Innovation of Market Structure*" can be regarded as a continuum with the two boundary points "*Unmodified Market*" and "*First Setup of a New Market*". The second dimension "*Traders' Intelligence*" represents the degree of intelligence used within the bidding strategy of the traders. This dimension can also be regarded as a continuum, possessing the two boundary points "*Zero Intelligence (Random Walk)*" and "*High Artificial Intelligence*". Whereas an investment decision of a *Zero Intelligence* agent results from a stochastic process, an agent with *Minimal Intelligence* uses some market information (e.g. last price or best bid resp. best ask) within his inartificial bidding logic. Compared with this, an agent with *High Artificial Intelligence* uses highly sophisticated, learning algorithms to determine his investment decision.

Into this framework we classify the State-of-the-Art MMST-literature dealing with modelling and simulation by filling the appropriate entries and we give examples for "blank spaces". We further developed simulation settings for the examples bundle-trading in CDA and introduction of new order-types (see figure 2). Those simulations will be performed within further research. All entries in figure 2 represent different application areas addressable by computer based simulations.

In order to answer *research question three* we analyse the simulation-generated data. We are sure that we will be able to describe different classes of insights which can be deduced from this data basis. We'll show that these insights can be used to derive advices for both traders and market owners (e. g. Deutsche Börse AG).

## Results

The epistemological applicability of simulations for analysing financial markets' quality has to be considered as very promising due to the fact that underlying formal models – in particular the market structure – are remarkable realistic. A qualitative analysis of FMC shows that both *abundance class* and *praeterition class* [Troi90, 14] are small. In reference to the tripartition (*traders*, *market structure* and *market outcome*) mentioned above (see figure 1) a 100% fit with reality concerning the market structure can be stated. This follows from the fact that the relevant market structure can be exactly copied from real world financial markets. Because of the unique conversion of order flow by *market structure* to *market outcome* the *market outcome* does ceteris paribus also fit 100% with reality.

In contrast to that, a difference between traders' behaviour in FMC and in the real world (*praeterition class*) can be observed. But this misfit can be regarded as less important because of the facts that lots of theoretical founded assumptions about the movement of stock prices exist (e.g. Markov's Random Walk, Intelligent Agents). All these assumptions can potentially be used for simulating traders' behaviour. For example, in the I-FM a Markov's Random Walk and a Wiener Process with and without drift are considered.

In connection with *research question two* it is shown that a broad range of different application areas can be addressed by varying the simulation setting. In figure 2 (see appendix) both, already analysed application areas as well as new use cases (printed in italic) are depicted. For clarity of figure 2 only a selection of the State-of-the-Art work and of innovative use cases are displayed.

[3] Further information about the underlying research project can be found at http://www.e-FIT.org.

Figure 2 has to be read as follows: Gode and Sunder [GoSu93] use random acting agents (Zero Intelligence traders - ZI) with uniformly distributed evaluation of the traded product. To show that the mechanism of the CDA and *not* the traders' intelligence leads to an equilibrium price they evaluate the lowest bound of traders' intelligence which is necessary to act comparably to human traders in a CDA [GoSu93].

As stated above, back testing of simulation-generated data shows the replicative validity of I-FM and thereby of FMC. Referring to *research question three* this means every evaluation criteria (including the above mentioned) known within the area of MMST can be applied. On this basis valuable insights and advises (e.g. correct working of trading strategies or the impact of changes in market structure to market outcome) for traders and market owners can be derived from computer based simulations within the "market engineering" research approach.

Comprising, it can be said that the method "simulation" is a powerful component of the market engineering toolset and provides rich benefits for the development and analysis of financial markets.

## Appendix

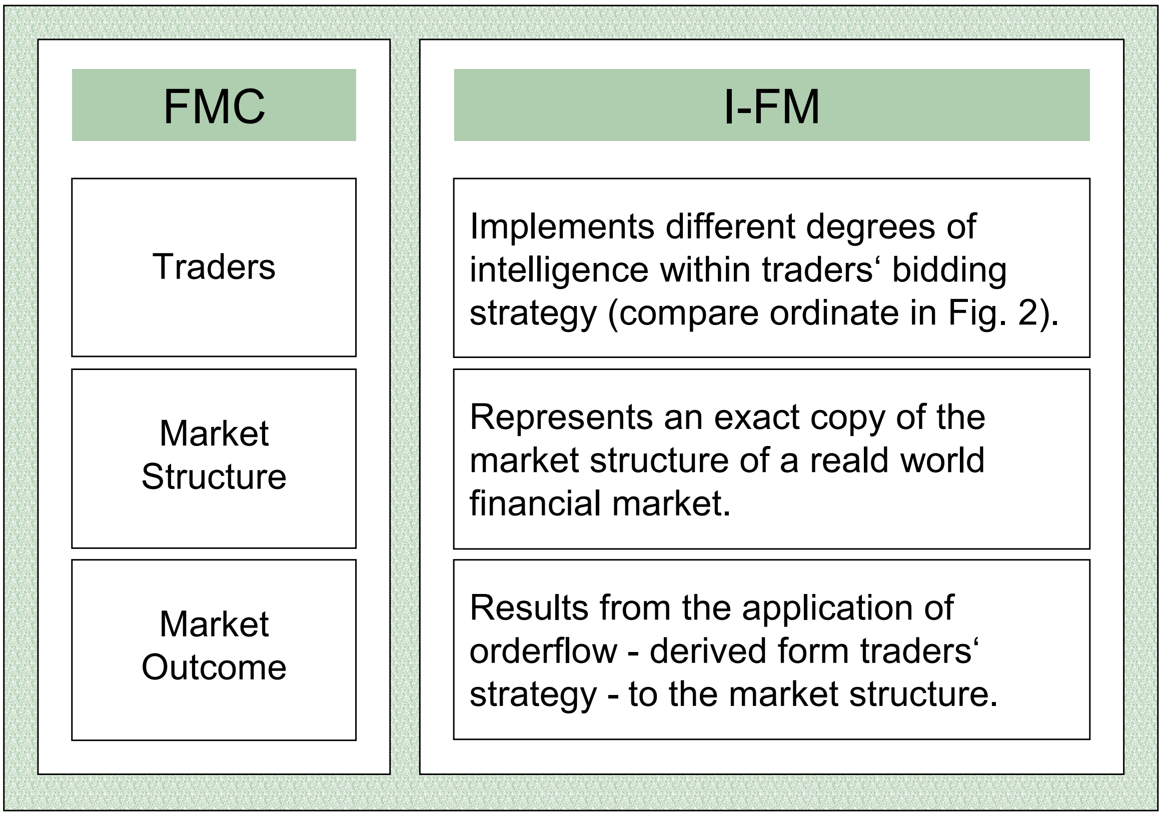


**Figure 1: Coherence of Financial Market Model Class and instances of FMC (I-FM)**

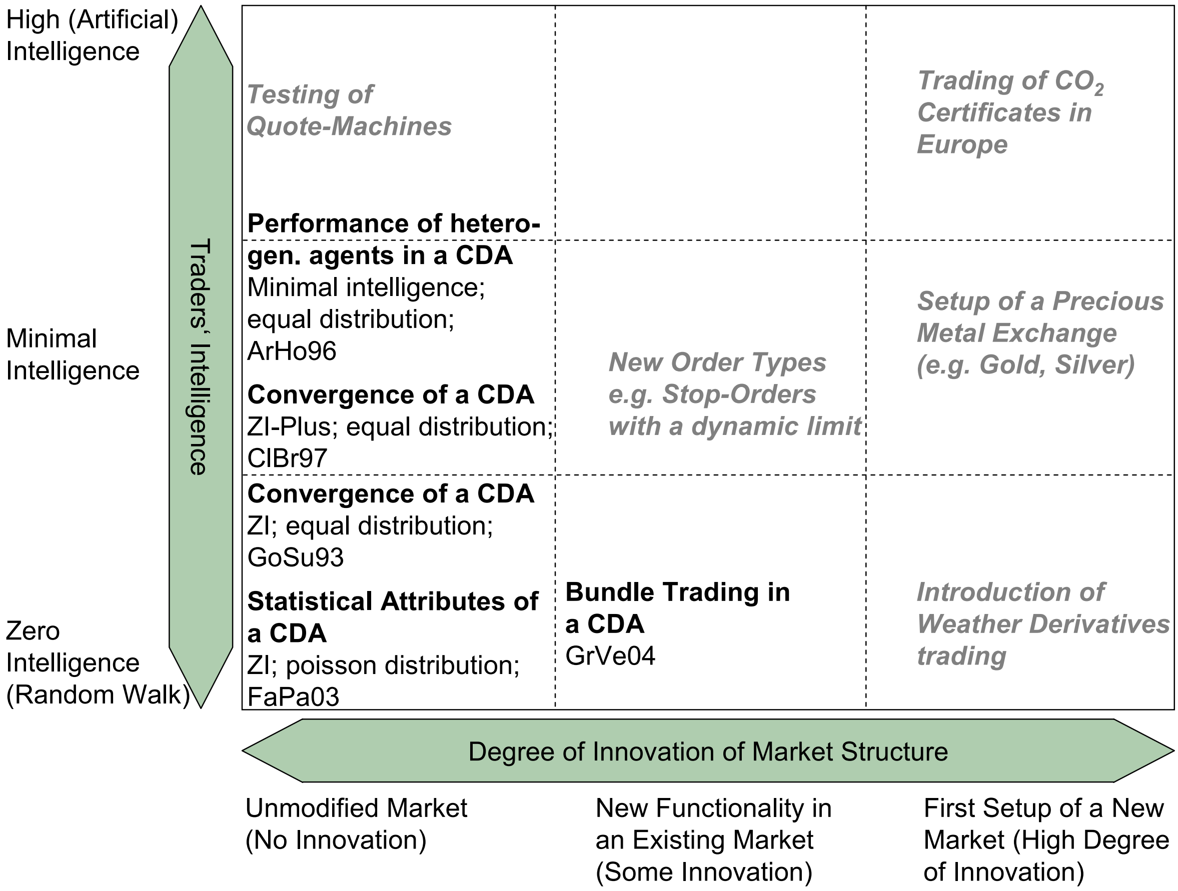


**Figure 2: Classification-Framework of computer based simulations**

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