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Framing Complexity in Financial Markets

An Example of Portfolio Management

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Abstract

Financial markets are complex: Factors that affect their development and the associations between these factors are not clearly assignable. Nevertheless, every day thousands of investors face the task of mastering the complexity of the markets. How do they solve this problem in their daily practice? This paper discusses this question by investigating a special area of the capital markets, namely, portfolio management. Two possible methods of handling the complexity of financial markets are presented: first, the qualitative methods (heuristics), and second, the formal (mostly computer-assisted) models. The central finding of the paper is the high heterogeneity of the applied methods. There are free spaces that portfolio managers can use while framing complex market situations. It could be suggested that this diversity contributes to the emergence and self-preservation of the market complexity. This contribution is dedicated to the empirical argument for these mechanisms.

1 Introduction: Financial Markets Complexity

This article discusses the phenomenon *complexity* as applied to the case of financial markets. Financial markets are often used as an example to illustrate the assertion that the complexity of modern society increased dramatically over last decades. The term *complexity* is thereby applied as a synonym for *uncertainty, lack of control*, or *lack of transparency*. But what exactly is complexity and in what sense are financial markets complex?

Weyer (2009) suggests dividing the existing complexity theories into two groups: Some theories define complexity as an objective structural phenomenon at the macro level; others conceptualize it as a subjective construct. He also points to the fact that theories refer to two dimensions of complexity: quantitative and qualitative.

At the macro level, the quantitative dimension would mean that the complex phenomenon consists of too many components, with too many relations between them; the qualitative dimension indicates that specific interactions between components lead to unpredictable dynamics. Applied to financial markets, this classification would suggest that financial markets are complex because their behavior is determined by several factors that do not show clear associations. It could be easily demonstrated if one suggests that financial market behavior is reflected in asset prices. Asset prices and their trends depend on a large number of factors, whose influence can never be estimated with certainty. In the case of equities, for example, prices depend on the future stream of payments produced by the company, such as earnings and dividends. They are affected by the so-called fundamental factors, e.g., profit situation, product range, market position, and management quality. There are also other factors, such as the macroeconomic conditions (interest rates, inflation, currency developments, etc.), political expectations (tax policies, state subsidies, political stability, etc.), as well as the psychology of the market players (their expectations, risk preferences, etc.). It is not just impossible to specify all variables; rather, it must always be anticipated that new factors are added, such as new products, take-over rumors, etc.[1] A good example is the unexpected insolvency of a local bank in California in February 2007. The unexpected event led to a strong market correction. This example also suggests that small events can have a big influence at the macro level. In general, complex systems are characterized by non-linearity. This means that causes and effects are not proportional; there are back couplings and interdependencies that lead to emergence of unpredictable and chaotic[2] structures (Mainzer 2008, Richter/Rost 2004).

It is important to point out that financial markets' non-linearity and complexity are "man-made". The developments of the securities' prices depend on the behavior of several actors and their interaction in the market: investors, analysts, brokers, companies' executives, and investor relations, to name a few. The participation of different groups and individuals increases the complexity of the system. Those groups and persons are carriers of individual expectations and experiences that must be taken into consideration along with the investors' own expectations. Every player is observed in his or her decision making, while at the same time he is an observer him-

[1] This problem was analyzed by Nassim N. Taleb (2007) in his book "The Black Swan: The Impact of the Highly Improbable." He called the unexpected factors, that influence securities prices significantly, the black swans.

[2] This is the reason why chaos theory is now extensively applied to analyze financial markets. See Trippi (1994) for an overview.

self.[3] In the case of financial markets, Brian Arthur (1995: 3) described this problem as follows: "Where forming expectations means predicting an aggregate outcome that is formed in part from others' expectations, expectation formation can become self-referential." This self-referentiality of expectations, which determine investment prices, is one of the most significant factors that cause complexity of the financial markets.

In the social world, the intentional acting at the level of the individual participants often leads to the "conditions that are essentially the by-products" (Elster 1987: 141). The complex behavior of financial markets is not deducible from the actions of the individual players and is such a by-product. This is why complexity is an immanent feature of financial markets.

However, if we follow the Weyer's classification of complexity theories, the second group of those theories should be mentioned. Representatives of this group (Malik 2002; Schimank 2005) consider complexity as a feature of subjective decision situations. Individuals are limited in their knowledge as well as in their cognitive capacity to process huge volumes of information and to establish causal links between many factors. For example, the market correction due to the insolvency of the Californian bank could not be foreseen by most of the market players, since they had not been aware of the existence of this bank and therefore could not attribute to the event the significance which in the end was attributed to it by the market.

According to Weyer, sociological theory of complexity should consider the entanglement of structural and cognitive factors. In the case of socio-technical systems like aircrafts, for example, it is dissatisfactory to restrict the analysis to the question of how individual cognitive acts are constructed. It is important to reconstruct the design of the system and the room for maneuvering within it (see also Grote 2005).

In this article, I would like to elaborate on the link between the structural and cognitive factors of complexity in the case of financial markets. I will refer to the structure or design of the markets as the market frame and analyze the room for maneuvering that individual investors have within those market frames. Based on empirical research, it can be shown that such room is quite significant. This finding suggests that, though market frames are socially embedded and shared, there are individual ways to reduce complexity within those frames. In other words, complexity reduction at the micro level is itself complex and contributes to the complexity emergence at the macro level.

Those topics will be approached in the article from an empirical perspective: Daily practices of portfolio managers as a specific group of financial market participants will be analyzed. In section 2, the concept of *market frame* will be discussed. In section 3, the distinctive characteristics of portfolio managers will be described. The central question will thus be examining exactly how this group of investors is exposed to the problem of complexity. In section 4, data samples will be presented. Afterwards, two specific ways of dealing with complexity within the field of portfolio management will be outlined: forming heuristics and the use of quantitative models. At the conclusion, all findings will be discussed.

2 Market frames

Social studies of finance have been busy in the last years investigating how different groups of financial mar-

[3] The players are aware of this fact: they include observations and expectations of outside observers into their own hypothesis and expectations. This increases the complexity even further: Luhmann (2002: 181) suggested using the term hyper-complexity for this phenomenon.

ket participants handle the markets' complexity, i.e., how they decide, if there are no "if - then" rules, and if no clear effect can be assigned to any of the factors. According to those studies, there are frames that help to reduce complexity while they "reduce the amount of possible worlds…, that is, reduce contingency" (Arnoldi 2006: 385). Frames limit decision possibilities, focus and structure the information, and help to interpret market events while they define boundaries for perception, meaning, and communication. Complexity is reduced through framing because a structure of possible "if-then" rules emerges.

As an answer to the question "Who constructs the market frame?" Hardie/MacKenzie (2007) suggest the concept of the "distributed framing": "By this we mean the involvement of multiple market actors in the process of sifting data and constructing ways of interpreting it" (Hardie/MacKenzie 2007: 391). This means that frames are formed not entirely individually but in the permanent interaction with other market participants. There are, for example, analysts, brokers, and investors. They develop practices with shared rules, codes, and networks that form frames (Knorr Cetina/Bruegger 2000). It should be added that the state also participates in framing processes by means of legal regulations. Institutional and organizational design is also important. An investor who is a member of a big investment bank has a frame that differs from the frame of a private investor, for example. The first one has the opportunity to receive support services from analysts and brokers or to talk to companies' management because he is an official member of an investment bank. There is also an official funding provided to conduct business trips to visit countries and companies, which means that there is the opportunity to talk to investor relations, companies' CEOs, as well as to state representatives. In other words, access is provided to special sources of information and thus framing possibilities that are inaccessible for private investors. There are also internal rules and rituals within organizations that shape market frames of investors (for example, different official meetings).

It should be also taken into consideration that investment banks employ people who enjoyed similar education at universities or business schools. Institutions also support a specific, business-related training of employees. This leads to the fact that employed investors share basically the same theoretical frames.

Extensive research has also been conducted on the topic of how diffusion of technology and financial formulae influence framing devices of the market participants (Callon 1998, MacKenzie 2001, 2006). In investment institutions, high-power computers as well as specific technical equipment like Bloomberg and Reuters are available (in addition to the telephone and internet).

Social studies of finance demonstrate that there are indeed multiple market actors (brokers, analysts, companies' management, investment organizations, the state, etc.) who participate in the distributed framing. Therefore, social, institutional, and technological conditions are considered to be equally important for framing processes in all types of financial markets: in the foreign exchange market, in the derivatives market, and in the capital market. Studies point to differences between the groups of institutional market participants: derivatives traders (Zaloom 2003, Arnoldi 2006), foreign exchange traders (Knorr Cetina/Bruegger 2000), bond traders (Abolafia 1996), arbitrage traders (Beunza/Stark 2004), as well as securities analysts (Beunza/Garud 2004, Langenohl/Schmidt-Beck 2007). At the same time, they concentrate on similarities of framing devices within those groups.

But if everybody within a particular investors' category is subject to similar constraints and uses the same technology and formulae, one should ask, as do Beunza/Stark (2004), "How can an investor recognize an opportunity?" and "How can he or she profit?". Relating to our topic, we should ask how complexity could be explained in particular financial markets if participants share the frames, i.e., reduce complexity in the same way. In this context, it is important to remember that the standard financial theory that assumes identical investors has difficulties explaining the complex paths financial markets develop, such as bubbles and crashes. How do chaotic structures emerge within different financial markets if actors use homogenous frames to reduce complexity?

The concept of the frame is not sufficient to answer those questions. The focus should be shifted to the room for maneuvering that exists within the frames. The paper at hand discusses the availability and the structure of that flexibility in the case of one additional group of investor professionals that has not previously been the explicit focus of social studies: portfolio managers. Their methods of dealing with complexity will be discussed. It will be demonstrated that although portfolio managers share certain social practices, use similar technologies, and are subject to organizational and institutional constraints, there is still flexibility within those frames. The suggestion of this paper is to take a closer look at flexibility within the frames. The hypothesis is that financial market participants exploit those free spaces in various ways. This means that complexity reduction through framing does not happen uniformly at the micro level. In turn, it is supposed that while portfolio managers exploit free spaces within their frames, they form diverse expectations and make different decisions. This heterogeneity of expectations and decisions as a result of complexity reduction contributes to the increase of complexity in the market. This other side of the coin – an emergence of complexity, not only its reduction – might also be of interest for social studies of finance. Complexity is not a given fact that the market participants find in the market and deal with. Complexity is generated while the market participants handle it in different ways within their frames.

3 Portfolio management

Portfolio managers are financial market professionals who invest the money of their clients in different assets, such as equities, bonds, derivatives and other financial instruments, in order to earn the maximum return for a given risk profile. If the money is provided by an individual client, a portfolio manager assesses the client's individual needs and exercises allocation of funds among assets and particular securities, meaning that the money is not invested in a single stock or bond but in a group of financial instruments, which is called portfolio. A portfolio is a diversified mix of securities. If the money of many investors is pooled in a portfolio, such a portfolio is called a mutual fund. In all cases, the task of a portfolio manager is to decide which and how many securities to buy, as well as to watch and to adjust the portfolio over the course of time.

The process of portfolio construction and adjustment is subject not only to clients' specifications but also to various legal, organizational and institutional constraints. First of all, there are laws that regulate how portfolios can be structured. For example, laws dictate in which securities a portfolio manager can invest at all, how to assure a proper level of diversification in order to protect investors (for example, which percentage of the fund assets is allowed to be invested in a single security), and so on. Portfolio managers are usually employees of investment companies. Investment companies specify

the investment products and the investment processes (investment goals, asset classes, reporting period, investment styles, etc.) as well as define how funds' performances will be measured and controlled. For example, if a portfolio manager is responsible for an Emerging Markets Equity Fund, he is allowed to invest only in the equities of particular emerging countries and has to follow a predefined investment process. Therefore, institutions further narrow the operating space of portfolio managers and shape their frames.

Still, within those constraints, a portfolio manager must choose assets that will bring the best return for a given risk profile. Return is the number that relates the final value of an investment to its initial value (in percent). The amount of money at the end of an investment period consists of the yield, like dividends, coupon or interest rate payments, as well as the earnings or losses due to price changes of the security. Those prospective flows of payment and movements of the asset price in the future are uncertain. To compare investment alternatives and to construct a portfolio, portfolio managers have to be able to forecast the returns of those instruments. At this point each portfolio manager faces the complexity problem. As discussed above, due to many unforeseeable factors that influence asset prices and companies' dividends, no reliable rules exist to predict returns and thus to select investments.

But is it not a problem that all financial market professionals face in their everyday practices? One question that may arise regards the specifics of portfolio managers as an investor group and where we should locate them within a broad landscape of social studies of finance. Langenohl/Schmidt-Beck (2007) differentiated two groups of investment professionals. The first group, which consists predominantly of traders, is short-term orientated and acts in the close proximity to the markets; long-term orientated market participants, for example, securities analysts, are not involved in the day-to-day interaction and are concerned with collection and processing of information in order to make investment decisions.

Traders find themselves under pressure to react immediately to the numbers that they observe on the screens. Those numbers are "interpreted not so much as information engendering reflection but more as an imperative to act – that is, to trade" (Langenohl/Schmidt-Beck 2007: 9). Those findings are confirmed by Zaloom (2003: 261): "The immediacy of the market dictates that attention remains on the bid-ask figures that represent the position of the market at that second…Traders can act with little information or understanding of the instrument they trade or the economic conditions of the countries that issue them." Traders have to rely on the immediate real-time market picture provided by the comprehensive technological systems. This means that they do not effectively deal with the future and are not interested in forecasting.

The representatives of the second group analyze economic and companies' data and make forecasts, in order to give recommendations ("buy," "sell," or "hold"), i.e., to communicate forecasts to the other market participants. Analysts do not invest money effectively, i.e., they are not exposed to the market. Their time horizon averages to "several months up to one year" (Langenohl/Schmidt-Beck 2007: 11).

Portfolio managers find themselves between those two poles. However, it should be mentioned that this investor group is not homogenous. By dealing with complexity, i.e., by answering the question about how to forecast returns and how to select securities, portfolio managers use basically two methodologies: fundamental analysis based on processing economic data (compa-

nies' financial statements, market position, quality of management, etc.) and quantitative analysis that draws on the mathematical and statistical approaches to assess market movements.

Fundamental portfolio managers are similar in their approach to securities analysts. They not rely only on the permanently changing numbers on the screen but also collect and analyze economic data, perform forecasting, and decide to buy, to sell, or to hold. However, it is important that they must implement their decisions, which means that they enter the market with a particular amount of money. In this sense, portfolio managers are constantly exposed to the markets, like traders.

The frequency of interactions with the market depends, however, on the strategy that portfolio managers follow. There are on the one hand "buy-and-hold" investors who take a long-term view and trade less frequently; there are also short term oriented portfolio managers.

Due to the distinctive nature of their business, portfolio managers face specific challenges and develop specific solutions while dealing with complexity. Those particularities shall be discussed now based on the empirical research.

4 Data

Support for this article is based on research that was conducted in several German and Swiss asset management companies and banks during 2007. The data pool of the analysis encompasses seventeen guided in-depth interviews with financial market professionals. The respondents work as portfolio managers in Frankfurt/Main and in Zurich for major international investment banks (fourteen of the interviewees) and for small investment boutiques (two of them). One interview was conducted with a financial advisor and the owner of an independent investment company. All respondents have more than ten years of experience in their field.

Thirteen interviewees predominantly pursue a fundamentally driven investment strategy. Six of them are responsible for European blue chip portfolios, two for European small and mid-caps, four for emerging markets, and one for investments in bonds. Three interviewed portfolio managers elaborate quantitative strategies to allocate assets and to manage funds.

The duration of the each of the sixteen in-depth interviews was about 60 minutes. Most of the interviews took place in person, and only one was conducted by telephone. All interviews were recorded and transcribed. The evaluation included coding and categorizing (see Corbin/Strauss 2008).

5 Dealing with financial market complexity

The general task of portfolio managers while dealing with complexity consists in establishing "if-then" rules that enable them to forecast asset prices and to construct a portfolio. As mentioned above, there are two general methodologies to do this: fundamental and quantitative. We will discuss separately how complexity reduction at the level of the individual portfolio managers takes place in those two ways. This happens either by applying heuristics (simplified, non-formalized rules of data processing) or by utilizing formal models. In both cases, it can be shown how the "man-made" financial markets' complexity is maintained, while the market players exploit flexibility within their frames.

5.1 Fundamental portfolio management and heuristics

Decisions of portfolio managers – like those of other investor groups - are framed. Those frames are not individual products but are influenced by many social factors. Some of them

were already mentioned: there are laws, official rules and processes of the investment company, educational requirements, and technical equipment available within the organization.

Those are frames in which portfolio managers move to reach their goals. Within the frames they develop individual rules to deal with the market complexity, to which the term *heuristics* could be applied: "The term *heuristics* relates to rules or strategies of data processing, which often lead rapidly and at minor costs to a solution that is usually reasonably close to the best possible result, but does not guarantee it: rules of thumb" (Goldberg/von Nitzsch 2004: 49). The most common simplification rules such as mental accounting, anchoring heuristic, and so forth, were described by Kahneman and Tversky in the "Prospect Theory" (1979). In the present paper, the term heuristics is used to designate individual rules and tools for dealing with the financial market complexity, which portfolio managers develop and utilize for their own use. These rules are based on the individual experiences of each market player. Fund managers observe the market and define for themselves the most important factors of influence and causalities. Whenever they have to make decisions, they rely on these same factors of influence and causalities. They also check them continuously and learn from the results (mental back testing).

The interviews with the portfolio managers showed that these simplification rules and tools are quite heterogeneous; i.e., handling the financial market complexity differs substantially from investor to investor and from investment company to investment company. Peter Bernstein (1992) reports on the experience of Jack Treynor, a famous financial theoretician of the 20th century. Treynor was working at the beginning of his career at the foundation of the University of Yale and in the 1960s visited the most important investment organizations in the USA: "He was astonished by the diversity he discovered: No two were doing alike, but every one of them thought they were doing it the right way. This was very perplexing" (Bernstein 1992: 184). Exactly the same picture emerged from the analysis of the interviews with today's portfolio managers: They pursue the goal to predict future prices of securities and arrive at these predictions in completely different ways.

First of all, portfolio managers have room for maneuvering to further limit their investment universe and to reduce the number of securities and factors, about which they are constantly concerned. This is demonstrated in the following interview with a portfolio manager in the bond market (Zurich):

> In general, in order to observe my market universe, I use the same data for quite some time. For example, in the US I look at the two-year and the ten-year treasury[4]. I do not look at the five-year and the thirty-year. I could have done this. It sometimes expands a little… the universe, but I try to keep everything the same and clearly arranged.
>
> *Question:* And the economic data? How do you collect it?
>
> What I do, I always look at the same data… Of course, I have a subjective picture of the priority of the data. For me, for example, the job market numbers in the USA have a high priority. Concerning the inflation… I look at the core CPI[5] and such things. Other people do this a bit differently. Not all people are of the opinion that the job market numbers are important. With the inflation, they look at normal inflation. Or with housing[6]… there I look a little at everything, and then I look at the leading indicators for housing. Then there are some economic data… I do not pay attention to them, I notice them, then I look at "over or

[4] Government bonds with a maturity of two and ten years.

[5] CPI means consumer price index. It is used as a measure of inflation. Core CPI is a measure of inflation that excludes certain volatile items like food and energy prices.

[6] Housing refers to the monthly number of new residential construction projects and is considered to be a key indicator of economic strength.

under expectations" but I leave them actually aside… and… that way I get my picture.

This interview excerpt clearly shows that this investor pays attention consistently to certain factors, sorts them according to their priority in his own mind, and is aware of the fact that competitors and colleagues consider different criteria.

Portfolio managers also limit the flood of information while they carefully select the sources of information that they use. As mentioned above, available sources of information such as conversations in person or by phone with analysts and brokers, company meetings and press conferences, and meeting with colleagues are elements of frames. However, individual investors attach different importance to them, and, in doing so, define their heuristics. For example, some equity investors believe that regular meetings with the corporate management are crucial for success, while others regard such meetings purely as a waste of time; some rely on the corporate earnings guidance, while others ignore those and concentrate on the assessments of analysts and brokers, with whom they are in touch on a daily basis, either by phone or email. Some investors rely exclusively on external databases and services. Differing significance is also assigned to the information exchange with colleagues. In large investment companies, there is a meeting each morning, an investment meeting each week or month, regular meetings or conference calls with the buy-side analysts. Those different modes of information exchange are regarded by the employees of the organizations either as useful or a waste of time. An interview partner (small and mid-caps, Frankfurt/Main) from a small asset management company reported that there are no formal meetings within his organization: The informal exchange between the colleagues takes place only if necessary; this allegedly saves a lot of time.

The received information is also systematized completely differently. Some portfolio managers simply write memos. Some use "home-made" tools such as Excel spreadsheets that assist them to monitor and evaluate the corporate and market data. Which data are included in those spreadsheets and which key numbers are computed are likewise heuristic: Each portfolio manager decides the matter individually, relying on his own experience. Thus, consensus expectations, expectations built by particular analysts, companies' forecasts as well as actual numbers already published by companies, and the prognoses of the fund managers are utilized as input data for the spreadsheets. Depending upon the individual portfolio manager, calculations include relative key numbers like PE[7], cash flow key numbers, growth rates, etc. According to one interview partner (an independent financial advisor, Frankfurt/Main), even professional investors, who apply the same investment styles (growth or value), calculate different key numbers in their spreadsheets. The regularity of updates also depends on the individual investor: The spreadsheets are updated before or after the meeting with the company management, after the publication of the quarterly reports, after ad-hoc news, etc.

To evaluate the companies and to make investment decisions, some fund managers use informal, individually designed scoring models, in which the fundamental quality and valuation of an enterprise are given a score. The final score is used as a base for an investment decision. This approach is applied systematically; however, the assignment of the scores is not subject to any systematization or calculation, but rather to a purely subjective judgment.

Each portfolio manager tries to generate a picture of the market or of a

[7] PE is the relation of the price to the earnings and is used as a valuation tool.

company based upon his own individual rules and tools. These tools must be "comfortable" and fit into the manager's own philosophy. The following fund manager's statement can be considered as representative:

> With the help of my spreadsheets, I produce an image of the company in my head: whether the firm grows, how it grows - in "doubles digits" or "single digits", organically or otherwise. For me, such pictures are important to determine the trend. This is my way of thinking. (Fund manager, European emerging markets, Frankfurt/Main)

In the interviews, the portfolio managers often refer to a picture of the market or of a company as a puzzle, which develops during the course of applying the heuristic rules and tools. The heterogeneity of the approaches in handling complexity leads necessarily to the diversity of these puzzles' pictures and thus to the diversity of the expectations and decisions that are based on them.

However, it seems that diversity of individual approaches is desirable for investment companies. Beunza/Stark (2004: 395) demonstrated in their paper that in the case of arbitrage traders, the trading room is organized in the way that diversity of calculations is maintained; uniformity is not welcomed. Interviews with portfolio managers show as well that different approaches are used within the same banking house or asset management company. Two portfolio managers, who are active in the same investment company but at different branch offices in Zurich and in Frankfurt, reported on two completely different investment processes. In Zurich, the process is strongly formalized, it is a team- and model-based investment process; in Frankfurt, each portfolio manager is completely free in designing his own investment strategy. Some investment companies knowingly allow the heterogeneity of the approaches. For example, the portfolio manager of Jupiter's Global Managed Fund, who has nine other managers in his team, stated: "I encourage each of the managers to do their own thing, to run their fund in the way they want to run it" (Kelleher 2007: 11).

Now we have a picture of portfolio managers who reduce complexity non-uniformly. They use available elements of their framing devices and combine them differently. The tightness of the free space is highly determined by the organizational rules, but such free space always exists.

This picture is applicable because the asset management industry is still a highly individual business. It relies on the experts, the individual portfolio managers, who supposedly earn over years a better profit than the market average or the competition. The investment companies rely on the individuals, "the gold fingers" (Döhle/Hetzer/Palan 2002: 154-164). At the same time, however, the weaknesses of those key players are becoming ever more apparent to the industry: Lacking discipline, possessing limited capacities in data processing, and depending on emotion jeopardize the performance of the active fund managers. The solution is expected from the consistent application of the computerized strategies.

5.2 Formal Models

An alternative method to deal with the complexity in the market is the use of formalized, computer-assisted models. The associations between the factors of influence and their effects are determined with the help of statistical procedures. Computers analyze past data and determine which factors, under what type of conditions, were significant for the outperformance of certain securities. These analyses then serve to predict what factors will be significant in the future. As in the case of heuristics, the number of factors to be considered is deliberately limited, and the associations between those factors are ascertained. The computerized strategies of the complexity reduction are, however, not based on

human experience, but rather on the statistic analyses.

Quantitative models are elements of the portfolio managers' frames. They are often relatively similar to each other. A portfolio manager (quantitative asset allocation, Zurich) described the formalized tools that are used in her bank as follows:

> We have valuation… What we naturally also have, is momentum, we have sentiment and cyclical forces.[8] It is exactly alike in every other asset management shop.

One of the reasons for the models' similarity is the fact that the experts, who program and use quantitative tools, are trained at the universities in the same mathematical methods. In addition, the successful strategies are rather quickly imitated (Gangahar 2007: 7). Quantitative portfolio managers observe each other's products and adopt and modify some of them. One quantitative expert, introducing tools developed in his division, used the word "steal" several times: "We stole this model from this and this bank," and it seems to be a common practice.

Given this tendency, the question arises about whether the application of the computer models can reduce the market complexity to such an extent that the markets could no longer be maintained. Here we are addressing the problem of "computer herding": If the investors judge the market with the same or similar formal models, i.e., reduce the complexity in the same way, they will also have the same or similar expectations and make the same decisions. This means that all of them would favor the same side of the market. In other words, they would want only to buy at the same time or only to sell at the same time. This would cause the other side of the market to thin out and threaten the market's existence.

For example, the implementation of similar stop-loss strategies for the computer-controlled portfolio insurances was one of the factors that caused the stock market crisis in 1987 (see Authers 2007: 9). In August 2007, the unfavorable developments of some qualitatively managed hedge funds caused similar turbulences in the market. A global quantitative equity fund of Goldman Sachs lost 30 per cent of its value within one week because the computers could not foresee some market movements and as a result implemented a wrong strategy. Many other computer-managed investment funds experienced the same fate and caused the drastic price fall in the market (Tett/Gangahar 2007: 7).

With this in mind, we must raise the question of whether complexity is reduced in the field of the quantitative portfolio management nearly uniformly, within the very tight frames.

Currently, we cannot assert that. Since each investment company and each portfolio manager still develop their own models, the models are not absolutely identical. The diversity is also caused by the fact that all preliminary modeling decisions are made by humans. During the process of "crafting" the models,[9] the experts determine individually which data sources are utilized, which data are collected and processed, as well as how individual parameters are modeled.

In addition, many portfolio managers are still convinced of the fact that numerous important parameters are not quantifiable. The fund advisor Nils Bartram from Hauck & Aufhäuser commented: "There are soft factors, which are very important for the future share

[8] Valuation, momentum, and sentiment are techniques to assess securities and markets. Valuation helps to estimate the market value of an asset and to decide if it is expensive or cheap. Momentum refers to the dynamics of price movements. Sentiment indicators gauge investor attitudes toward the market. Cyclical forces refer to the influence of the general business cycle.

[9] Several interviewees termed the process of modeling as "crafting" the models.

development, which you cannot press into any Excel tables" (Hussla 2007: 26). The qualitative factors (the management quality, the value of a brand, corporate governance, etc.) are taken into consideration only in the form of subjective estimations. This subjectivity causes inaccuracy. A portfolio manager (European emerging markets, Zurich) describes the problems of the application of a formal valuation model:

> Our funds performed badly in the last year because input data for the models are mere subjective estimations. During the last year, we assessed the growth of the Chinese market too low; accordingly we estimated the oil price at around 33 USD (we are maintaining this forecast still[10]). That led to the fact that the macro data, which were fed into the model, were wrong; everything was wrong then. Garbage in - garbage out. That is our central problem with models.

The leeway, which exists when "feeding" the models, leads to heterogeneous statements and decisions and prevents a radical complexity reduction in the market.

Flexibility often exists also during the implementation of the computer-based strategies. The extent of the flexibility depends particularly on the policy of the investment companies; i.e., an institution decides again how tight frames are. Some insist on the radical implementation of the strategies handled by the computers because only in this way can the advantages of the qualitative investment be completely exhausted.

However, some investment companies allow the last decision to be made by humans. They permit the fund managers to bring in their experiences and their feelings for the market and to implement the models' recommendations or not Portfolio managers term this procedure a "qualitative overlay." One of them (tactical asset allocation, Zurich) describes it as follows:

> In the end, the whole is, to be honest, a qualitative decision. We decide how serious we take the valuation signal, for example. It is an overlay when we say "OK, the yen is, according to the purchasing-power parity model, strongly undervalued, but the macroeconomic parameters don't look good…it is unlikely, that the Bank of Japan increase the interest rates, and so on." For this reason we don't take a strong position in yen. It is a typical decision. Very qualitative.

The interviews confirm that creative intuition, interpretations, story telling, metaphors, and fantasies principally supplement formal methods of handling and thus maintaining the complexity in the markets. The portfolio managers still do not trust the formal methods entirely and use them only as supporting tools for their decisions. In general, the flexibility in implementing the models' strategies is considered as a central condition of their application. Here is an example:

> It is important to know, what is going on in a company. If a model recommends buying a cheap company, I must know why it is cheap. For example, Surgut[11] is cheap, it has been cheap for a long time, but the reason for this is known: its management. Prosperity fund (a large shareholder) plans a management change within the company. If that finally happens, if the previous managers are fired and a new team is hired, the Surgut will double, and it will be a good deal. Until then it remains uninteresting, no matter how cheap it is. (Fund manager, European emerging markets, Frankfurt/Main)

The head of the "Quantitative Strategies and Risk Research" department in a big investment house in Frankfurt/Main described three generally possible handling of model outcomes:

> We have three basic approaches… First of all, we have a strong research supply for all fund managers; they can access this research freely and without restrictions, but they are not obliged (that's an important point!). Then there is overlay advisory. For example, we have a signal… equity market or bond market short-long (we keep it simple), then we have a portfolio manager who has a broad bond fund and who says,

[10] March 2007.

[11] Surgutneftegaz is one of the major listed oil and gas companies in Russia.

"The model which signals short-long is a good model." He receives then an e-mail from us whenever we have a new signal and implements it 1:1. The next stage is that we work with model portfolios. It is usually the case when we have an investment process where we say, "The first step is the quantitative approach," for example screening over many equities… we prepare the list of hundred most interesting equities and allocate the model portfolio. In the first stage of the investment process there is this input, in the second stage the fund manager checks, "Does the whole thing fit?" … he adjusts the whole thing, makes an explicit overlay… We distinguish it internally: it is a model portfolio if concrete weightings are assigned; it is a pure research if it is just a list, a ranking.

The interview shows that there are three ways to handle the results of quantitative departments within one investment company. The free space of portfolio managers depends on the product that they manage and on the company's strategy. But if there are no clear instructions to use a model, the personal opinion about models ("the model is a good model") is crucial. In other words, models are a part of frames, but they do not always have to be used.

The existence of the qualitative overlay suggests that skepticism about the usefulness of formal models often prevails. Generally, it is argued: "There are many useful areas for investment judgment where quantitative models never become practicable. In 1996, what did investors say would be the impact on Hong Kong stock values when that British colony reverts to mainland China in 1997? There are simply not enough cases of very similar type to do a least-square regression of returns versus possible governing factors. One may do better by forming a subjective judgment, reasoning from cases that are similar enough to offer analogy, but that are not similar enough to use for statistical analysis" (Wilcox 1997: 66). In other words, there are always new factors added, which are not considered in any model and which must be programmed afterwards. In the interviews, the subprime crisis was mentioned as such a factor. A portfolio manager (tactical asset allocation, Zurich) reported that she just started to integrate this new factor into her models in December 2007, when the crisis was already in full swing. She described the inclusion of the new factor as a creative process, which her competitors perhaps arrange similarly, but differently, so that their models generate a different output.

Models prove to be highly imperfect instruments for handling complexity because they are not capable of capturing all relevant factors and determining causal relations between them. Models cannot supply clear forecasts because they cannot sufficiently take into consideration the dynamics of the relevant factors, particularly their changes as well as the emergence of new factors. An interview partner (bond portfolio manager, Zurich) reported on his experience with an interest rate model:

Years ago I also created some models: regression and factor models and so on. Those functioned very well for some time, for about two years, but then there were shocks. For example, the Asia crisis, the Emerging Markets crisis and LTCM[12], also the Russian default[13]. In any case, everything went completely wrong. The model said six percent, and the interest rate was four percent. Previously the difference had been in the range of 20-30 basis points; thus, it had been correct. Nevertheless, all of a sudden, nothing could be done with it. In the original format that I had conceptualized, the model was no longer useful. The dominant factor in the market became "the escape into the quality"; the bonds rose, the equity fell due to this one particular factor. And this factor was not included into the model. If I had taken in my model the variable "Emerging Markets Spreads," then it would have functioned very well. However, that was originally not included.

[12] LTCM: A large hedge fund that put the global financial system at risk as a result of its collapse in 1998.

[13] Russian default: Financial crisis in Russia, which led to the suspension of debt payment of the Russian state in 1998

The relations between the market-relevant factors cannot clearly be determined for a sufficiently long period. As William Strazzullo, the Chief Market Strategist at Bell Curve Trading, put it: "When they [models] work, it's good, but over time relationships [between the factors included in the model] inevitably break down" (Gangahar 2007: 7). Complexity is reduced by the application of the models only temporarily and rather seemingly.

Handling the models is an additional complexity factor in the financial market and represents a fundamental problem for all model users. A uniform model determining the different market parameters does not exist. A portfolio manager (quantitative asset allocation, Zurich) reported that she runs several models simultaneously, in order to compute parameters such as momentum or sentiment; each of the models, estimating the same parameter, can produce different recommendations. As a result, the problem of the model combination develops: How does one deal with the different recommendations of the models that determine the same parameters? Today's market players consider this as a central problem:

> This is something where investment managers really differ. Because the tools are always the same: a little of DCF[14] or, my God, do I take the equilibrium interest rate or the latest short term … oh, that is trivial: we look at it, we know the outcome. The question is: How does the model combination work? And this is what makes the shops different (quantitative asset allocation, Zurich).

Model combination is a problem, which develops the market complexity in the process of the quantitative handling. Portfolio managers, who use formal computer-assisted methods, must judge how they include the quantitative parameters in their decision-making processes, while those parameters are differently determined by computers. Hence, they are confronted with another complex problem, which again can be solved either with the help of heuristics (subjective judgment) or with formal methods of model combination (model mixing, model synthesis, model switching, etc.). In other words, the market participants treat the problem of the model combination, like all other market problems, in different ways. This guarantees the heterogeneity of expectations and decisions in the market and at the same time produces additional complexity. Financial market complexity remains "man-made."

In addition, the models themselves must be considered as a complexity factor. They become a factor of influence because their interaction, as already suggested, affects the market. Problems like "computer herding" and "model combination" give evidence that the application of models increases the complexity in the markets rather than drastically decreasing it. With MacKenzie (2006), it can be assumed here that financial models are not "recording equipment" (cameras), but also "engines," which became an independent and substantial part of the economic processes. Thus, if models evaluate markets and compute the investment strategies, they have to include themselves as a factor of influence in their calculations. However, this is what they cannot do, meaning that they cannot record and capture the total complexity of the markets. Their use provokes the diversity of decisions and results in an increase of the market complexity.

6 Conclusion

In this paper, it has been shown that, though the practice of portfolio managers is tightly framed by law, financial institutions, education, and technological tools, there is room for portfolio managers to use those frames independently and non-uniformly. We

[14] DCF refers to the Discounted Cash Flow model: Valuation tool based on estimated future cash Flows.

demonstrated the flexible use of those rooms by discussing both ways of the complexity reduction at the individual level: heuristics and formal models.

The application of heuristics, i.e., the individual rules and tools of data processing, leads to the diversity of the investors' approaches. Investors either choose which elements of the frame (analysts' reports, management meetings, communication with colleagues) they effectively use, or they create their own tools like individual spreadsheets or scoring models within the given frames. Heuristics vary very strongly.

Though complicated formal tools, which are based on the mathematical models, show a tendency to standardization, we also find here significant flexibility in their usage. Models are not uniformly conceptualized and "fed"; their results are often subject to interpretation and discussion ("qualitative overlay"). The existence of room for maneuvering in utilizing formal models is considered by market participants as a necessary condition for the use of models at all. Formal tools also produce problems, for example, model combination, which requires individual creative solutions within existing frames.

In other words, there are heterogeneous ways of complexity reduction within frames. Financial market complexity is thus not a result of the interplay of identical actors with straightforward frames that are uniformly used. This finding is important because it draws attention to the question of the complexity emergence. It could be suggested that the discovered diversity contributes to the emergence and maintenance of market complexity at the macro level. Financial market complexity is caused not just by reciprocity of actors who are primitive and comprehensible in their way (like Brownian particles). There is also complexity at the micro level that has to be taken into consideration. Attention should be paid to the question of how complexity in the financial markets is generated, as each individual participant tries to reduce it.

There are already inquiries of this kind in the economic theory of complexity. Arthur et al. (1996) showed, for example, by means of computer simulations, that if we assume heterogeneous financial market participants and their interdependence and let them adopt their beliefs quickly, then "the market self-organizes into a complex regime" (Arthur et al, 1996: 4). Bubbles and crashes occur, and prices show complex statistical features. This mechanism should be explored more closely from the sociological point of view.

Interviews are obviously an insufficient tool to deal with this problem. Participant observations and further methods of empirical research are required. But this coupling between heterogeneity of individual ways of handling complexity and the emergence of complexity at the macro level should be considered as the next step of research.

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