Dynamics of Price Formation in Financial Markets

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Introduction and Outline

1.1 Introduction

Financial markets have long been recognized to have an informational role. The importance of this function of financial markets is profound given the information asymmetries common to agents in any economy. Prices may aggregate and disclose information, enhancing the optimality of allocation decisions. If this aggregation ability is perfect, as is contended by the early neoclassical work, informational differences between agents are dissolved completely, resulting in an optimal allocation of resources. Though evidently desirable because of the implications for welfare, this idealistic view has changed dramatically over the last two decades. In fact, the seminal work of Grossman and Stiglitz [1980] has brought about a consensus within financial economics that the informational efficiency of financial markets needs to be imperfect in order to disclose private (costly) information. This understanding has shed a different light on many issues within the theory of financial markets with far-reaching implications. If the informativeness of prices is limited, the details of market structure - such as investor preferences and trading mechanisms - impact the degree of informational efficiency and, hence, partly determine the functioning and added value of financial markets in general. It implies the presence of information frictions between differently informed agents, which affects risk premia and market robustness. Not surprisingly, it has engendered a strand of literature, both theoretical and empirical, that studies price formation under asymmetric information. This line of study has two main objectives. On the one hand, it aims to uncover alternative explanations for phenomena reported by the empirical literature regarding for instance time series properties of market statistics. On the other hand, it aims to arrive at normative statements regarding market mechanisms and regulatory issues. Although the surge in interest and publications in this area has been quite explosive, the field is still fresh and there are many questions still open. It is to this strand of literature where we seek to contribute. Specifically, we focus on the dynamics of price formation in financial markets under asymmetric information. Although our approach is theoretical, we connect to a broad range of issues, varying from the implications of market growth under costly information to the explicit derivation of technical trading rules.

Our principal objective is to gain an understanding of the intertemporal behavior of prices under information asymmetry. Roughly, our focus can be divided into two parts. One focus concerns the issue of information friction in markets in which agents can only re-trade the asset to cash profits. We provide a generic framework of such markets with agents who are differentially informed and exchange multiple assets across different generations. We consider how information asymmetry impacts market statistics and performances measures of financial markets. Additionally, we study the consequences of market growth given a fixed cost for the acquisition of superior information.

The other focus concerns so-called charting or technical analysis. The usage of technical trading rules in practice is widespread. Whether such activity indeed has added value is doubted by many. The question whether past prices can be used to predict (future) price realizations to some extent has been and still is the cause of debate among financial economists. Overwhelming empirical effort has been seen in this area, although the resulting evidence is still somewhat mixed. In spite of this, relatively little effort has been put in a theoretical motivation why prices should or should not be predictable. In this thesis we seek to close this gap. We provide a rationale for the usage of technical analysis, and explicitly derive trading rules rational chartists would use given a generic specification of the excess liquidity supply process. Moreover, we try to contribute on this descriptive level of financial markets with the consideration of the time series properties of stock returns. Having established a rationale for charting, we address a natural follow-up question: How does the parasitical presence of chartists impact a financial market and the welfare of its participants?

In short, this thesis aims to contribute to the theory of price formation under information asymmetry. Against this background, our results have relevance on different levels. On a descriptive level of financial markets, we derive time series properties of stock returns and the associated optimal trading strategies for chartists. Additionally, we demonstrate how market growth under costly information may be to the detriment of liquidity investors, and how the development of a market determines its sensitivity to information friction. On a normative level, we show that unrestricted entry of chartists to financial markets may lead to market breakdowns. Finally, on a theoretical level, we extend the rational expectations paradigm to re-trade economies, in the form of a generic multi-asset model and a single-asset model that allows for a higher order autoregressive specification of the supply process.

1.2 Approach and Background

For this study, we adopt the so-called competitive noisy rational expectations approach. This popular paradigm within financial economics builds on the innovative work of Grossman and Stiglitz[1980] and Hellwig[1980], and formalizes the information feedback between prices and investors. Within this framework, a central role is played by the notion of information asymmetry or information dispersion. Information asymmetry typically occurs if some investors have an information advantage. Usually, the impact of these informed investors has a dual character. Their presence introduces an adverse selection problem for less well-informed investors. Informed investors, however, also enhance the informational efficiency of prices, allowing uninformed investors to predict fundamentals with more precision. Beliefs, probabilities and conjectures of agents are keywords in such differentially informed markets. The rational expectations approach provides a natural manner with which to handle the problem of how individual beliefs are formed. It demands that agents' subjective beliefs about the distribution of future outcomes and the structure of the market coincide with the actual probabilities of outcomes and the market structure. Hence, it also implies that agents rationally use the information signal revealed by prices to enhance the quality of their investment decision. The noisy rational expectations approach is distinguished by its assumption of a source of uncertainty that renders the market incomplete. This assumption resolves the Grossman-Stiglitz paradox, and is usually incorporated through the introduction of so-called liquidity traders. The latter derive their trading motives from private liquidity shocks or hedging needs. Finally, the competitive variant of the rational expectations approach - which we adopt - assumes that individual agents act as price takers, which may be motivated by assuming they are infinitesimally small compared to the market as a whole. The competitive noisy rational expectations approach is standard within this strand of literature, and contains the basic ingredients that are necessary to make a financial market work. It allows one to extract implications for the informativeness of prices and its impact on market statistics. Moreover, this type of setup exhibits a certain mathematical elegance and also a reasonable success rate when it comes to the ability to solve for equilibria. Combined with the fact that it captures the essentials of the trading process, this setup has been adopted by many researchers over the years, and is the primary modeling tool in this thesis.

The models we utilize are multi-period models. As such we relate to the work of, inter alia, Brown and Jennings[1989], Grundy and McNichols[1989], Wang[1993] and Brennan and Cao[1996]. Our approach is distinguished in that it builds on the idea that financial markets contain an overlapping generation feature. The motivation for this feature is that

most financial assets, such as shares in company stock, have a lifetime that exceeds the time horizon of the common investor. In fact, the time horizon of the average investor is likely to be much shorter than the time until liquidation of the asset. This applies most directly to those market participants who play a crucial role in the determination of prices: market makers and professional traders. Additionally, we focus our attention on steady state economies. This allows us to extract characteristics of markets unconditionally. Multi-period models that assume a liquidation date by definition introduce a time-dependency in the properties of the price-formation process. In particular, it implies that as time progresses, the uncertainty in the economy is resolved. Absence of uncertainty resolution, however, accords better with reality, given the continuous stream of random and exogenous innovations to which any economy is subject. With the application of the rational expectations paradigm to steady-state, overlapping generations economies, we try to acknowledge these aspects of financial markets.

The information aggregation process in financial markets is a complex one, and as the reader will observe, the rational expectations approach carries this burden of complexity. The rational expectations concept is strict in the way it assumes agents to behave. Agents are rational utility maximizers, perfectly knowing the information-price relation, and perfectly conditioning their forecasts on information signals. One may object to the sterile environment and argue that the complexity of financial markets cannot be described by formulas. The key, however, is that the mathematical framework developed over the years for describing the flow and feedback of information through prices allows one to think more precisely and with more focus about the delicate issue of information in financial markets.

1.3 Outline and Main Results

The models developed in this thesis have a common ground: all can be characterized as steady-state overlapping generations economies. To be able to contrast our approach with other contributions in this area, we have incorporated a survey, contained in Chapter 2. It provides the background within which our efforts should be viewed. The main focus is on the competitive rational expectations approach, and, in particular, its multi-period extensions. We describe this concept starting with the innovative work of Grossman, and concluding with the multi-period noisy rational expectations models that have been developed over the past recent years. Additionally, this survey proposes a static model that incorporates both the Diamond and Verrecchia[1982] and the Hellwig[1980] limiting economy. Moreover, we characterize a generic method of solution for multi-period rational expectations models. We conclude by explaining and contrasting our approach with the models described.

In Chapter 3, we derive the equilibrium conditions for a multi-asset multi-period noisy rational expectations model in which the assets traded are infinitely long lived. The generality of the model is emphasized by the fact that it incorporates both Admati's [1985] multi-asset model, and Grundy and McNichols[1989] multi-period model as special cases. The framework is unique in the heterogeneity of its agents. Not only are they heterogeneously informed and endowed, but agents also differ in the length of their time horizon. The generality of the framework does not, however, allow for easy elaboration on the characteristics of the economy. In spite of this, its characteristics are found to be quite intuitive. For instance, we show how the rationality of agents makes prices unbiased predictors of the fundamental value, even if its liquidation period is infinitely far in the future. Additionally, we can interpret the key parameters and relate them such notions as the informativeness of a price system and the risk tolerance of a market. We discuss several special cases of this framework. The main ambition of this chapter, however, is to contribute on a (rational expectations wise) theoretical level, and to provide a generic basis for single-asset special cases that are studied in Chapters 4 and 5.

In Chapter 4, we consider how information friction in re-trade economies affects market statistics. Usually, insider trading has a dual character. On the one hand, the presence of better informed agents introduces an adverse selection effect that increases the costs of liquidity. On the other hand, informed investors increase the absolute information quality of prices regarding fundamentals. If an asset is re-traded, however, information quality only has relevance in its ability to predict future prices and not in its transparency concerning fundamentals. It creates a dominant role for information dispersion as opposed to absolute information quality. This is exemplified by the fact that homogeneously informed markets, be they perfectly informed or uninformed, have identical values for measures of market performance, such as market depth and price volatility. We demonstrate an uni-modal dependency of such market statistics as volume, volatility and market depth on the fraction of informed investors. Volume and volatility increase in the degree of information friction, while market depth is decreasing in this quantity. The critical fraction of informed agents, where the extreme points of these dependencies are realized, is shown to decrease as markets develop. Price variance and volume are seen to be more resistant to changes in information friction in well-developed markets. Interestingly, this result is not seen for market depth. Its sensitivity is higher if markets are more developed. The implication is that in better-developed markets, insider regulations may be relatively more beneficial to liquidity traders.

In Chapter 5, we use a single asset special case of the framework developed in Chapter 3 to consider how the characteristics of markets change under market growth. We contrast two

types of markets, one where agents are exogenously endowed with superior information, and one where agents can acquire this information advantage at a certain cost. When considering market growth, in the first type of market, the simple implication is that market depth increases given the increased competition between agents. In markets where superior, yet costly, information can be acquired, the impact of a growing number of traders is found to have two effects. On the one hand, it increases the competition between agents, which positively impacts the depth of the market. On the other hand, the increased competition decreases the relative benefits of becoming informed, which in turn increases the degree of information friction in the market. The latter effect diminishes market depth. The cumulative impact of the two effects is that with costly information acquisition relative market depth reduces as the number of traders increases. This implies that the significant increase in market size that could be observed on many exchanges over the past years, may lead to the undesirable result of lower market depth which will be to the detriment of liquidity investors.

On a more technical note, in Chapter 5, we also explore a unique feature of the model that is developed. The market is heterogeneously composed of investors with different time horizons. As such, a market is represented in which different generations actively exchange the assets, and where in each period a new generation is born that replaces another generation that has arrived at its consumption horizon. Using simulations, we consider how the length of time horizons of investors affects their trading behavior. Generally, investors are shown to trade more aggressively with increasing time till consumption. The reason is that the possibility of intermediate trade allows for dynamic diversification and hence for larger positions in the early stages of an investors' trading career. This also implies that if agents act myopically, generally they will trade less aggressively.

In Chapter 6, we propose a stationary noisy rational expectations economy in which the aggregation of noise and information in prices motivates the presence of pure technical analysts. We derive a closed form solution for a quite generic class of economies. In fact, liquidity supply is allowed to follow an autoregressive process of arbitrary dimensions. We demonstrate the equilibrium conditions if agents have time horizons that extend over multiple periods in the spirit of Chapters 3 and 5. Subsequently, we explore in more detail the myopic investor equilibrium. Specifically, we derive the trading rules technical analysts use, and their related characteristics. It is argued that even though chartists try to trade against liquidity traders that have a transitory impact on supplies, they may still behave as trend-followers. Additionally, we derive formulae for volatility and correlations between lagged price changes. To exemplify our findings, we study an application of the framework. In this special case, we allow the liquidity supply to be a second-order autoregressive process. Specifically, we consider

a market in which the supply level is highly persistent, and its innovations are positively correlated. It is shown that under these circumstances, the equilibrium exhibits features that are found in empirical studies of financial markets. For instance, chartists are shown to apply a trend-following exponential moving average rule, one of the most popular rules observed in practice. Also, short-term autocorrelations are positive, while longer-term autocorrelations may be negative. An interesting observation can be made: though technical analysts exploit correlation patterns in returns, an increase in their presence makes correlation patterns more profound. This result stems from the fact that technical analysts trade less competitively. A relatively larger presence of their kind decreases the average competitiveness of the market, which in turn leads to higher risk premia, price volatility and significant correlation patterns.

We conclude this chapter with an elaboration on the implications of our findings for the efficient market hypothesis. The conventional interpretation of this hypothesis cannot be directly applied to our model. In fact, whether our model violates the efficient market hypothesis depends on the definition used. However, the technical analysis applied in this model is simply a means to optimally weight each public signal (in the form of price realizations). In fact, technical analysis is necessary for each agent, irrespective of his type -chartist or fundamentalist- in order to optimally determine his demand.

In Chapter 7, we use the generic model of Chapter 6 to study how the presence of technical analysts impacts market statistics and utilities of rational agents. This study is motivated by the intriguing observation that chartists owe their existence entirely to the information based trading activities of other agents. Chartists display a parasitical type of behavior, free-riding on the information collection efforts of others. Having established a rationale for their existence, a natural question is to what extent chartists affect market statistics, and in particular, the welfare of other agents. It is shown that contrary to what one may expect, both fundamentalists and chartists benefit from a large presence of technical analysts. The reason is that the reduced competitiveness in their presence gives all traders the possibility to extract larger rents from liquidity traders. However, there is a limit to the fraction of technical analysts for equilibrium to be viable. As such, a unique type of market breakdown can occur: the financial market may fail because informed agents refuse to trade if a market is too uninformed on average. This is in contrast to the usual association with market breakdowns under information asymmetry, where uninformed refuse to trade if the market is too dominantly impacted by a presence of insiders.