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The optimal pricing of a market maker in a heterogeneous agent economy

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ABSTRACT

This paper extends some classical models, built upon the representative-agent and Walrasian market-clearing mechanism, into one characterized by a market-maker trading mechanism with investors having heterogeneous beliefs regarding the likely future payoff of a risky security. We show the optimal determination of the bid and ask prices and resultant trading volume. The endogenously-determined spread and volume are increasing with the degree of the heterogeneity of investors' beliefs. We analyze the market marker's risk exposure based on his inventory, under the condition in which he is fully informed of the investors' beliefs, and under the condition in which he is not.

1. Introduction

The representative agent paradigm which fails to take into consideration investors' heterogeneous beliefs and hence the market's buy and sell orders simultaneously is not suitable for the study of the *market-maker trading mechanism* in which the bid and ask prices are simultaneously set by the market marker. One essential element of this market mechanism is the interaction between the market maker and a group of heterogeneous investors. Recently, heterogeneous-agent modeling has played an

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increasingly important role in the literature on asset pricing, including the market-maker trading mechanism.[1] Heterogeneous-agent modeling (HAM) should be suitable for studying the nature of the market-maker trading mechanism in which the bid and ask prices need to be determined by effectively mapping a set of investors, with heterogeneous beliefs, into buyers and sellers. The existence of the bid and ask prices and the difference between the two, known as the spared, is, in effect, a common practice to make this mapping feasible. Nonetheless, most existing applications of HAM to the market-maker trading mechanism only consider one price, instead of considering both the bid and ask prices.

Outside HAM, there is a large body of literature addressing the bid and ask pricing, although with some stringent assumptions. For example, Garman (1976) and Amihud and Mendelson (1980) assume that the arrival of buy and sell orders in the market follow exogenously-given independent Poisson processes; Copeland and Galai (1983) introduce the exogenous probability density functions of market price and investors' orders; some seminal papers, such as Kyle (1985), Glosten and Milgrom (1985), Easley and O'Hara (1987), and Easley and O'Hara (1992), regard the investors' demand as an exogenous independent variable; Shen and Starr (2002) even specify that the evolution of price is exogenous. These assumptions help keep the tractability of the model, but in reality the size and the frequencies of the buy and the sell orders and the bid and ask prices are not mutually independent. Neither is any of them exogenous to the other; they mutually affect each other and are determined endogenously together. HAM directly works on the heterogeneous structure of the investors and directly bridges the investors' trading behavior and the market maker's bid and ask price formation with little reliance on the above assumptions.

With the above research background, this paper attempts to study the optimal pricing behavior of the market maker and hence the determination of the bid and ask prices in a heterogeneous agent economy. Before getting into the technical details of this heterogeneous-agent model of the market-maker trading mechanism, we provide a sketch of the model with its theoretical underpinnings and insights.

We propose an extended version of the Grossman–Stiglitz model (Grossman and Stiglitz, 1980), in which there are two types of investors and one market maker trading simultaneously. The equilibrium means that *supply equals demand*. This setting is different from that of the classical *sequential trade model* used by Glosten and Milgrom (1985), etc., in which investors arrive one by one randomly. The two types of investors differ in their beliefs regarding the future payoff of a risky asset, which makes them have different positions in the market. As we shall see later, the one holding the long position is the buyer, and the one holding the short position is the seller. Given these two types of investors, the market maker determines a bid price and an ask price, and quotes the former to buy from the seller and quotes the latter to sell to the buyer.

Comerton-Forde et al. (2010) use an 11-year panel of daily NYSE market-maker inventory and revenues to show that after the market maker holds large positions, the effective spreads widen, which implies that the market maker widens the spread to reduce his inventory and to limit his risk exposure. This finding challenges the market maker's *zero-profit* assumption introduced by Glosten and Milgrom (1985), who point out that if the inventory carrying capacity of the market maker is large enough, the market maker earns zero profit. But it needs to be asked why the market maker is willing to hold excessive inventory. As an enterprise, the market maker makes profits from trading with investors rather than investing in the risky security like an investor. His goal is to minimize risk and to maximize profit. In this vein and for simplicity, we further assume that the market maker's targeted inventory equals 0, i.e., a zero-inventory target, which implies zero risk exposure. With this assumption, our research question can be formally presented as a constrained optimization problem: the market maker is assumed to maximize his profit by bearing zero risk. We call the solution to this problem the optimal bid and ask prices.

We obtain the solution of the optimal bid and ask prices. This article finds that, if the market maker has perfect information regarding all investors' beliefs, the zero-inventory target can be achieved, and the derived optimal bid and ask prices, volume, and market maker's profit are all positively related to the degree of the heterogeneity in the beliefs of investors about the likely future value of the security.

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[1] See, e.g., Chiarella et al. (2006), Zhu et al. (2009), He and Zheng (2010), and Chiarella et al. (2011).