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# Liquidity provision in a limit order book without adverse selection☆

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ABSTRACT

In this paper, we develop a dynamic model of a limit order market populated with liquidity traders who have only private values. We characterize and analyze the equilibrium order placement strategies of traders and the conditional execution probabilities of limit orders as a function of traders' liquidity demand and the state of the limit order book. We solve for the equilibrium of the model numerically, and analyze its properties by performing comparative dynamics analysis. Our analysis shows that changes in the steady state of the limit order book and optimal order placement strategies reflect corresponding changes in the trade-off between order execution risk and the size of potential trading gains. The equilibrium order flow depends on the current state of the limit order book since a trader's optimal trading strategy is largely affected by the time and price priorities of the existing limit orders in the book. We demonstrate how changes in the dispersion of traders' private values affect optimal trading strategies and conditional execution probabilities of limit orders. Our main result is that the dispersion in private values across traders has a significant impact on the stationary state of the equilibrium limit order book and the average bid–ask spread. A wider distribution of private values leads to more order placement at prices away from the consensus value, and therefore, to a larger bid–ask spread. Further, our numerical simulations show that extending the life span of limit orders reduces the average bid–ask spread observed in equilibrium. Finally, we find

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that the equilibrium percentage of market order submissions is also increasing in the dispersion in liquidity traders' private values.


## 1. Introduction

In a limit order market, buyers and sellers can submit an order of one of two types. A market order executes immediately the best price posted by previous limit orders. A limit order specifies a particular price for the order and specifies a promise to trade at that price. The limit order book is a list of all unexecuted limit orders. Traders provide liquidity by submitting limit orders and consume liquidity by submitting market orders. Many financial assets are traded in limit order books. There are many stock exchanges around the world where trading takes place completely (e.g., Euronext, Stockholm, Helsinki, Hong Kong, Shanghai, Tokyo, Toronto and various Electronic Communication Networks) or partially through electronic limit order books (NYSE, Nasdaq, London). Despite this prevalence of limit order markets, the theoretical literature on limit order markets is very small. Understanding the dynamic choice between limit orders and market orders is important because rational agents can optimally use different trading strategies depending on the state of the limit order book and their subjective beliefs about the value of financial assets that are traded in these markets. These different strategies, in turn, can generate significant effects on price impact, trading volume, bid–ask spreads, and the volatility of market prices.

The objective of this paper is to develop a new model of dynamic optimal order placement in a limit order market in order to better understand the economic trade-offs underlying the choice between limit orders and market orders by incorporating the dynamic nature of limit order markets. In our simple setting with symmetrically informed traders each of which has a private valuation of an asset, we focus on the trade-off between the price of an order and its execution probability that is essential to the analysis of traders' choice between limit and market orders. This basic trade-off between order price and execution probability can be summarized as follows. A trader can always obtain a larger probability of execution at the cost of a less favorable execution price away from the bid–ask spread, which can be interpreted as an implicit cost for demanding liquidity. By definition, a market order is a "limit order" with execution probability one and therefore has no execution risk at all. The motivation for trade results from agents' differences in their private valuations of the asset, which causes the agents to have differences in their incentives to provide or consume liquidity. Traders with more extreme private values are more impatient than traders with moderate private valuations that are close to the mean of the probability distribution of private values. In our model, there is no independently moving common value component and the average private value of traders is constant. Therefore, we abstract from the risk of being picked off (winner's curse).[1] Thus, we focus on the trade-off between price and execution probability in a limit order market and its effect on liquidity provision in an environment without adverse selection. After modeling the arrival of traders (sellers or buyers) in the market, we characterize and analyze the equilibrium order placement strategies of traders in terms of the state of the limit order book and the execution probabilities of limit orders. We solve for the equilibrium of our model numerically using several parameter specifications and theoretically investigate its properties by performing comparative dynamics analysis. In our model, limit orders last for a finite number of periods, and they cannot be modified or canceled after submission. We devise and implement a numerical algorithm of successive approximations to solve for the stationary Markov equilibrium of the model. The algorithm is based on mapping the liquidity demand/supply of traders into their subjective order execution probabilities. Imposing a monotonicity restriction as in Hollifield, Miller, Sândas, and Slive (2006), we then invert this mapping to derive the liquidity demand/supply of the traders with respect to the execution probabilities of orders at different prices. Using this approach

[1] Since a limit order involves a commitment to a price, it is exposed to unfavorable changes in the common value of the asset. This adverse selection risk is called the winner's curse risk or picking-off risk.