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A note on sufficient conditions for no arbitrage

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Abstract

It is shown that the absence of call spread, butterfly spread and calendar spread arbitrages is sufficient to exclude all static arbitrages from a set of option price quotes across strikes and maturities on a single underlier.

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1. Introduction

The absence of arbitrage opportunities is a fundamental principle underlying the modern theory of financial asset pricing. In particular, this concept is intrinsic to the statement of the first fundamental theorem due to Harrison and Kreps (1979), Harrison and Pliska (1981), and Delbaen and Schachermayer (1994). These authors establish conditions and exact definitions under which the absence of arbitrage opportunities is equivalent to the existence of an equivalent martingale measure.

In a continuous time setting, it can actually be quite difficult to confidently establish whether or not the given prices of a given set of assets are arbitrage-free. The reason is that

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the definition of an arbitrage opportunity depends critically on the nature of the information set which can be used in developing trading strategies in the specified assets. Likewise, the associated continuous time martingales are defined through conditional expectations which rely on the same informational basis. Typically, this informational basis includes the entire path of past underlying asset prices at a minimum. Hence, to certify that a given set of asset prices are arbitrage-free in continuous time, the structure of the possible price paths must be specified a priori. For example, one must specify whether the possible price paths are purely continuous, pure jump, or a combination of the two. One must also specify whether the possible price paths display finite or infinite variation over time. Since one can only observe past prices in practice and then only discretely, it is difficult to have any confidence in any particular structure which is imposed on future paths. Nonetheless, a certification that a given set of asset prices is arbitrage-free in the traditional sense does require this specification of the nature of the possible price paths.

One way out of this difficulty is to alter the technical definition of an arbitrage opportunity. By reducing the size of the information set upon which trading strategies can rely, it becomes easier to certify that a given set of asset prices are free of these restricted arbitrage opportunities. A concrete example of such a restricted set of trading strategies is given in Carr, G eman, Madan and Yor (2003) (henceforth CGMY). These authors introduce the phrase “static arbitrage” to describe a much simpler concept of an arbitrage opportunity. Parsing this phrase, the arbitrage part refers as usual to a costless trading strategy which at some future time provides a positive profit with positive probability, but has no possibility of a loss. The static part of the phrase signifies that the position taken in the underlying stock at a particular time can only depend on the time and on the contemporaneous stock price. Positions cannot depend on past prices or their path properties. CGMY establish the equivalence of no static arbitrage with the existence of a Markov martingale in some information filtration. This martingale is used to price the assets just at the initial time by discounting the expected cash flow under this process. Assuming that the initial market prices of a given set of European calls are free of static arbitrage, Madan and Yor (2002) go beyond the CGMY existence result by providing several concrete constructions of Markov martingales which are consistent with these prices.

The CGMY results suggest a related problem which is of considerable practical interest. This problem is to determine whether or not a given rectangular grid of European option prices quoted across several strikes and maturities is in fact free of static arbitrage. Many specific arbitrages are known due to the seminal results of Merton (1973) and others, but it is still unclear at this relatively late date whether the elimination of these known arbitrages is sufficient to exclude all static arbitrages. The limited but useful contribution of this short note is to establish the structure of a finite set of tests that do in fact imply that all of the option quotes are free of static arbitrage. If the given option quotes pass our set of tests, then no further tests need to be conducted in order to certify that the quotes are free of static arbitrage.

A critical step in the formation of our tests requires the extraction of risk-neutral probability measures at each maturity from quoted option prices. This fundamental idea is essentially due to Breeden and Litzenberger (1978). The extraction of these measures is followed by establishing sufficient conditions for these measures to be increasing in the convex order as described in Shaked and Shantikumar (1994). We next appeal to Kellerer

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