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The impact of transaction costs on state-contingent claims mispricing

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A B S T R A C T

We analyze the impact that transaction costs have on asset mispricing in state-contingent claims markets. In particular, we examine betting markets, in which, it has been argued, transaction costs cause the favorite-longshot bias, a pricing anomaly analogous to the volatility smile in options markets. By using a heterogeneous agents model, we prove that transaction costs alone cannot cause mispricing. Also, we run agent-based simulations to character- ize the response of market prices to increments in transaction costs. We find that transaction costs have a significant impact on market inefficiency, by amplifying existing mispricing both directly, influencing market prices, and indirectly, inducing a non-linear response from the agents.

1. Introduction

Sports betting markets are a good proxy for financial markets and have been extensively used to analyze market efficiency. In particular, many num- ber of studies have examined the favorite-longshot bias (FLB), an empirical regularity whereby betting on favorites yields higher expected returns than betting on longshots. This anomaly is of noteworthy importance, as it has been found in most state-contingent claims markets, such as prediction mar- kets (Wolfers and Zitzewitz, 2004) and options markets (Hodges et al., 2003). It has also been observed in other contexts (Vaughan Williams et al., 2016).

One of the several theories proposed to explain the FLB argues that transaction costs cause the bias. Hurley and McDonough (1996) suggest that, in a parimutuel market with short-selling constraints, positive trans- action costs cause the FLB. However, recent findings demonstrate the need for significant adjustments to their model. In fact, despite the possibility of short-selling in exchange markets, the FLB still exists (Smith et al., 2006). However, both transaction costs and the level of the FLB are significantly lower in such markets, suggesting correlation between the two.

We show how a model in which traders have heterogeneous behaviors can explain all these observations. To achieve this, we extend the model devel- oped by Restocchi et al. (2016) by incorporating transaction costs. We prove that, in a market with a book-balancing bookmaker playing against heteroge- neous agents, transaction costs cannot cause the FLB. Then, we investigate price formation by using agent-based simulations. We reproduce three dif- ferent levels of FLB, including its neg-

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ative form, and analyze prices under different values of transaction costs. Our results suggest that transaction costs amplify the mispricing generated by the agents' sub-optimal behavior, and that they are positively correlated with the absolute level of the FLB (i.e. with market inefficiency). This finding suggests that, in contrast to the arguments of Hurley and McDonough (1996) and Vaughan Williams and Paton (1998), transaction costs are not correlated with the direction of the FLB.

2. Model and analysis

We consider the model introduced by Restocchi et al. (2016), in which agents belonging to five different behavioral classes bet on a two-outcome event in a fixed-odds market. Four of the five types of agents bet according to their utility functions, which are derived from prospect theory, and represent risk loving, risk averse, misperceiving, and informed bettors. The fifth class represents noise bettors, who randomly bet on either outcome A or B. Given the outcome $i \in \{A, B\}$, we denote with p_i its probability to happen, with π_i the associated price of an Arrow-Debreu contract set by the bookmaker, and with V_i the fraction of money bet on such outcome (i.e. we assume that the total money bet, V, is $V = V_A + V_B = 1$). Then, the expected profit for the bookmaker is:

$$\mathbb{E}(P) = V - \frac{p_A}{\pi_A} V_A - \frac{p_B}{\pi_A} V_B \tag{1}$$

Then, the profit in the single game is defined in the following way:

$$P = \begin{cases} 1 - \dfrac{V_A}{\pi_A} & \text{if A occurs} \\ 1 - \dfrac{V_B}{\pi_B} & \text{if B occurs} \end{cases} \tag{2}$$

Restocchi et al. (2016) take into account two possible pricing strategies that the bookmaker can employ, namely a profit maximization and a risk mini- mization strategy. Their results, obtained by using both historical data and simulations, suggest that the average bookmaker is more likely to minimize the risk (cf. maximize the profit). This behavior is similar to that of market makers in option pricing, as suggested in the relevant literature. Given the assumption that bookmakers seeks risk minimization, their optimal pricing strategy is to set both potential payoffs to be equal, i.e. $1 - \frac{V_A}{\pi_A} = 1 - \frac{V_B}{\pi_B} = \lambda$ By substituting this expression in Eq. (2), we obtain the expression of the prices:

$$\begin{cases} \pi_A = \frac{V_A}{1-\lambda} \\ \pi_B = \frac{V_B}{1-\lambda} \end{cases} \tag{3}$$

The profit λ is linked to transaction costs by the following relation:

$$TC = \pi_A + \pi_B - 1 = \frac{1}{1-\lambda} - 1 \tag{4}$$

Now, we formulate the following proposition:

Proposition 1. *Transaction costs are not a sufficient condition to cause the FLB.*

In a two-outcome market the FLB exists if and only if the expected return of a bet on A is higher than that of a bet on B. Hence:

$$\frac{p_A}{p_B} > \frac{\pi_A}{\pi_B} \Leftrightarrow p_A > p_B \tag{5}$$

By substituting Eq. (3) in Eq. (5), we obtain the following condition for the FLB to exist:

$$\frac{p_A}{p_B} > \frac{V_A}{1-\lambda} \frac{1-\lambda}{V_B} \tag{6}$$

The terms including the bookmaker's profit λ cancel each other out. Hence, assuming a risk-minimizing bookmaker, the FLB (or its reverse counterpart) cannot be caused by transaction costs.

Hypothesis 1. *Transaction costs amplify the level of the FLB and, as a consequence, market inefficiency.*

To test this hypothesis, we run agent-based simulations using the market compositions (i.e. distribution of agents) obtained by Restocchi et al. (2016) for three markets with very diverse levels of the FLB, and compute market prices for transaction costs in the range 0%–50% by steps of 1%. The resulting price curves are presented in Fig. 1 for the market compositions found for the tennis, the under-over 2.5 goals in football, and the baseball market, which display a weak, strong, and weak negative FLB, respectively.

To analyze in more detail the relation between transaction costs and mispricing, we estimate the parameters of the following equation by using an OLS regression for transaction costs, with the level of the FLB as the dependent variable:

$$LFLB_i = \alpha + \beta TC_i + \epsilon_i \tag{7}$$