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The efficiency of top agents: An analysis through service strategy in tennis

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ABSTRACT

We consider the question whether top tennis players in a top tournament (Wimbledon) employ an optimal (efficient) service strategy. While we show that top players do not, in general, follow an optimal strategy, our principal result is that the estimated inefficiencies are not large: the inefficiency regarding winning a point on service is on average 1.1% for men and 2.0% for women, implying that – by adopting an efficient service strategy – players can (on average) increase the probability of winning a match by 2.4%-points for men and 3.2%-points for women. While the inefficiencies may seem small, the financial consequences for the efficient player at Wimbledon can be substantial: the expected paycheck could rise by 18.7% for men and even by 32.8% for women. We use these findings to shed some light on the question of whether economic agents are successful optimizers.

1. Introduction

Most economists believe that agents maximize something and that they are successful in doing so. Stigler (1976) provides a typical and outspoken example of such a view in his critique of Leibenstein's (1966) notion of X-efficiency. Any inefficiency claimed by Leibenstein or others is – according to Stigler – nothing but a failure to measure all relevant inputs, or to correctly specify what is being maximized. For example, John Capozzi's well-known business maxim:

> *Only make a great deal if you have no intention of ever doing business with that person again… otherwise make a good deal,*

would not – if followed – indicate inefficiency. It might indicate that the agent does not maximize short-term profit, but he or she would still maximize long-term profit or, more vaguely, 'utility'. Førsund et al. (1980, p. 21) point out that such a view is essentially an act of faith, as it can be neither proved nor disproved.

Perhaps, however, we *can* prove or disprove the hypothesis that agents are successful maximizers. For this we would need a situation where (a) it is unambiguous what it is that the agent wishes to maximize, and (b) clean and complete data are available. Under these conditions any apparent suboptimality must be true suboptimality. Such a situation can only be found in a very structured environment. One possibility for creating such an environment is through a laboratory experiment. This has the advantage of maximum control, but it also has disadvantages: in laboratory experiments, reported violations of optimality are often belittled by claiming that the incentives were insufficient or that the violations will be eliminated by learning or by market competition. Although Tversky and Kahneman (1986) agree that these factors are relevant, they question whether accounting for them would ensure fully optimal choices. In the end, this is an empirical issue.

Our environment is a field experiment: the service strategy of tennis players at Wimbledon. This is a real-life setting where high prizes can be won, competition is fierce, and the players (our agents) are highly trained and very experienced. They want to win matches on the professional tour, especially at the 'grand slam' tournaments of which Wimbledon is arguably the most important. It seems reasonable to assume that these agents wish to maximize the probability of winning a match. In addition, our data are clean. The tennis environment is therefore ideal to study the efficiency of human behavior, also because tennis has an unusual and archaic rule which does not exist in other comparable sports (table tennis, badminton, volleyball), namely that the server has two chances to

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bring the ball into play (first service, second service) rather than one. Even with one service the question needs to be answered how difficult this service should be: too easy and the server loses the point in the subsequent rally, too difficult and the service will be a fault much of the time. Choosing the right balance is obviously important. In the current situation the server has two services, and this has two consequences. First, to determine the optimal strategy of choosing the strengths of the two services is more difficult than in the one-service case. Second, the existence of two services doubles the amount of information we possess about a player's strategy against a specific opponent.

Based on a simple model we can calculate the players' optimal strategy and we can compare this with their actual strategy. The discrepancy (ratio) between the two defines their efficiency. We shall show that tennis players are not entirely successful in maximizing their objective function. This is not surprising, because 100% efficiency is humanly unattainable given the continuity of the decision problem. Our main interest, however, is not a discrete test for (in)efficiency, but rather an estimate of the continuous measure of how close top players are to full efficiency. Since we also have a good measure of the quality differences among the players (position on world ranking), we can examine how the players' inefficiencies depend on their quality and competition within a match. This will shed some light on Tversky and Kahneman's (1986) question whether incentives, experience, and competition ensure fully optimal choices.

We emphasize that our interest is not in *relative* efficiency (how well does one agent perform relative to another agent, in particular relative to the most successful agent), but rather in *absolute* efficiency (how well do agents perform compared to the optimum achievable). Thus we shall not assume that top agents lie on the efficiency frontier. Instead we want to measure how far they are removed from the frontier. We also note that we do not measure the efficiency of *average* agents, but of *top* agents. We want to know whether top tennis players are efficient and, if not, how much room for improving their efficiency exists. Several methods have been proposed to allow for inefficiencies of firms, in particular stochastic frontier analysis; see the surveys by Førsund et al. (1980) and Schmidt (1985/86), the monograph by Kumbhakar and Lovell (2000), and a Bayesian perspective by Koop et al. (1997). Nonparametric tests of optimizing behavior of consumers as well as firms have been introduced by Varian (1982, 1985). The main emphasis of these studies is, however, the measurement of efficiency (productivity) of an average agent, while our interest is on the efficiency of a top agent. The latter should also help us to better understand the relevance of high levels of experience and ability for efficiency.

Sports statistics (and sports economics) has developed from an anecdotal field where one collects statistics (so many double faults, so many aces), to an almost-respectable discipline. An important reason for this development is that sport statistics can help answer behavioral questions. Moreover, sports data are readily available and they are measured much more precisely than most economic data. This has led to studies on racial discrimination (Gwartney and Haworth, 1974; Kahn and Sherer, 1988; Nardinelli and Simon, 1990; Stone and Warren, 1999; Szymanski, 2000; Kanazawa and Funk, 2001; Goff et al., 2002), efficiency of the betting market (Zuber et al., 1985; Sauer et al., 1988; Golec and Tamarkin, 1991; Dixon and Coles, 1997; Gray and Gray, 1997), comparison of betting markets and financial markets (Levitt, 2004), the effect of labor strikes on consumer demand (Schmidt and Berri, 2004), preferences under risk (Julien and Salanié, 2000), mixed strategy equilibria (Walker and Wooders, 2000, 2001; Chiappori et al., 2002; Palacios-Huerta and Volij, 2008), incentive effects (Ehrenberg and Bognanno, 1990), rationality (Gandar et al., 1988), optimal labor contracts (Lazear and Rosen, 1981), control of externalities (Carlton et al., 2004), favoritism (Garicano et al., 2005), maximizing behavior of firms (Romer, 2006; Adams, 2006), and so on.

The studies most closely related to our paper are Walker and Wooders (2001), Chiappori et al. (2002), Palacios-Huerta and Volij (2008), Romer (2006), and Adams (2006). Walker and Wooders examine whether tennis players aim their first service to the receiver's left or right (only two options), in such a way that the probability of winning a point is equal for the two directions, as the theory of mixed-strategy equilibrium implies. Their results provide some evidence that the behavior of top players conforms closely to this theory, which contrasts to the conclusions in many experiments. Our set-up and analysis differs from theirs in three important respects. First, since the probability of winning a point depends not only on the direction of the first service (especially when the first service is a fault), but also on spin, speed, and many other factors, we concentrate on a broader concept, namely the probability of serving in, and we consider both the first and second service. Our analysis should therefore have higher power. Second, since our analysis is continuous rather than discrete, we not only test for efficiency, but also (and in particular) estimate the *magnitude* of the inefficiency. Third, both Walker and Wooders and we are interested in the relevance of a player's quality for optimal play. Using a different data set, involving inexperienced card players, Walker and Wooders reject the theory, and they take this as evidence that play by high-quality players conforms more closely to the theory than play by novices. In our analysis, we can test the relevance of a player's quality for optimality within a single data set.

Chiappori et al. (2002) also test mixed-strategy play, but now for penalty kicks in soccer rather than for tennis. Their results are also consistent with optimality, thus confirming the conclusions of Walker and Wooders (2001). Palacios-Huerta and Volij (2008) bring professional soccer players to the laboratory to play card games, and find that they play close to optimality, in sharp contrast to college students.

Romer (2006) studies profit maximization of firms by focusing on coaches and their teams in professional (American) football. More specifically, he tests for optimality of the coach's decision on 'fourth down' between kicking and 'going for it'. In contrast to Walker and Wooders (2001), Chiappori et al. (2002), and Palacios-Huerta and Volij (2008), he overwhelmingly rejects optimality. Even though Romer studies teams and allows for interactions between agents, whereas we study individual behavior, our tennis data may help answer some of his questions. Romer gives two possible explanations for his rejection and the overconservative behavior of coaches. First, the coach's objective function may be more complicated than Romer assumes; second, coaches are not able to correctly maximize. Unfortunately, says Romer, there is little evidence which of the two explanations causes the suboptimal behavior. In tennis, however, there are two services, and the maximization for the second service is easier than for first service. We shall see that this fact can be exploited to shed some light on the true cause of suboptimal behavior.

Adams (2006) questions Romer's results, in particular the assumption that success rates on third down equal those on fourth down, and concludes that coaches may in fact make optimal decisions.

The literature thus reports mixed evidence on optimality. Our contribution is to provide some new and cleaner insights to help resolve this ambiguity, and also to estimate the level of efficiency, rather than testing for perfect efficiency, which is the focus in the existing literature.

The organization of this paper is as follows. In Section 2 we present the theoretical model, based on the relationship between the probability that a service is in (x) and the conditional