En Garde!
Tournament Asymmetry and Disincentive Effects in International Fencing Competitions

by

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Abstract

In this paper I test the predictions of tournament theory using panel data from international fencing competitions. The theory predicts that for a given level of prize spread, agents' effort incentives are reduced due to the asymmetry. Using two measures of prize spread, I estimate the impact of these measures on performance for five separate skill-sorted cohorts using OLS and the Heckman selection model. I find evidence of ordinal disincentive effects for fencers of a lower skill level, which is consistent with the predictions of the theory.

I. Introduction

Tournament theory has important implications for the construction of optimal compensation schemes. Tournament theory examines how agents behave when they are rewarded based on ordinal rather than cardinal performance. In other words, the defining factor for receiving compensation is an agent's output relative to his or her peer group, not the agent's output in absolute terms.

Corporate hierarchies are naturally structured to fit the tournament model: employees compete against each other for promotions and more prestigious job titles. In these settings, it is often very difficult and costly to monitor employee output in absolute terms, but relatively simple and inexpensive to monitor employee output in relative terms. As such, the employee who outperforms her peer group is advanced and reaps the benefits, while the others have to wait for the next round of advancement. The analysis of a corporate hierarchy thus becomes inverted: the high salary and extensive benefits available to company vice-presidents is not a reward for that vice-president's output in his current position, but a reward for outperforming his peers while he was an assistant vice-president. Empirical studies can show how various reward schemes affect incentive levels for performance and thus can help managers construct compensation schemes to entice employees to produce an economically efficient level of output by naturally pitting them against their peers.

In this paper I test the predictions of tournament theory using panel data from international fencing competitions. Specifically, I examine the assumption of asymmetric tournaments. According to the model, when agents vary nontrivially in skill, effort levels decline due to disincentive effects, especially for the weaker agents. Using econometric analysis I find evidence supporting the theoretical predictions of the tournament model. For a fixed level of rewards,

weaker fencers have lower levels of effort incentives than stronger fencers. These ordinal

disincentive effects are reflected in lower finishing positions.

Most of the empirical literature regarding tournament theory uses sporting events as a natural

experiment.   I extend this analysis to international fencing competitions. Fencing tournaments are

a good setting for study for several reasons. First, similar to other sports, data on these events is

readily available, freely accessible, and (for the most part) complete. Second, the competitors vary

greatly in skill, and tournament organizers make no effort to equalize the field through

handicapping. In fact, the opposite is true –more skilled fencers benefit by having the privilege of

competing against the weaker fencers first, making tournaments easier for the stronger fencers and

more difficult for the weaker fencers. This ensures that tournaments are highly asymmetric and I

can safely believe any incentive effects I find are a reflection of this asymmetry.

The rest of this paper is organized as follows: Section II reviews the relevant literature and

relates it to my own project, Section III provides an overview of fencing and its competition

structure, Section IV covers the theory of the tournament model, Section V introduces and explains

the data, Section VI discusses the methodology and results of the empirical specifications, and

Section VII concludes with closing remarks and recommendations for future research.

II. Literature Review

Lazear and Rosen (1981) developed the first model of tournament theory. They showed that a

pay scheme based on relative rather than absolute output yields the same efficient allocation of

resources as a traditional pay scheme which pays according to MPL, provided the workers are risk-

neutral. If they are risk-averse, then it is possible for the employees to prefer the rank-order pay

scheme (this depends on the shape of their utility functions).

Another theoretical paper reexamines one of the traditional assumptions of tournament theory which states more skilled agents prefer low-risk (that is, low-variance) strategies in order to preserve their favorable position whereas less skilled agents prefer high-risk (high-variance) strategies hoping that these strategies can offset their skill deficit. Krakel and Sliwka (2004) consider an asymmetric tournament (players have different inherent abilities, and thus, different inherent likelihoods of success) which is conducted in two stages. In the first stage, each player chooses his level of risk; in the second, each player chooses his level of effort. The authors show that risk taking influences work incentives as well as the likelihood of winning. Because of this, a dynamic range of subgame perfect equilibria are possible; more skilled players might choose more risky strategies, and less skilled players may choose less risky strategies. These equilibria also depend on the prize spread, the shape of the cost function, and the magnitude of the difference in ability.

A series of empirical studies test the predictions of tournament theory. Ehrenberg and Bognanno (1990) analyze data from the 1984 men's PGA tour in order to confirm the theory that tournaments have incentive effects. The authors' econometric analysis uses a golfer's score as the measure of output and a proxy for effort level. The crucial independent variable is the prize level since this theoretically captures incentive effects; other variables are included to control for the individual golfer's skill, his opponents' skill, and the difficulty of the course. The authors find considerable evidence suggesting higher prizes lead to lower scores, other things being equal. The authors also show that tournaments with greater prizes affect entry by attracting more-skilled players. As Ehrenberg and Bognanno discuss, their analysis does not consider risk levels associated with individual strategies (i.e., conservatively hitting down the middle of the fairway or risking a shot over a water hazard) but nevertheless are confident that the data conclusively supports golfers

respond to financial incentives. This paper will apply a similar empirical methodology to control for the entry decision and differences in skill level under a different sport - fencing.

Becker and Huselid (1992) measure and include risk as a control variable in their empirical study. They suggest that golf may not be an ideal data source because golfers, due to the sequential nature of the sport, cannot directly influence each others' actions.   For their own analysis, Becker and Huselid look at auto racing, a sport where the strategies of the competitors have direct effects on each others' actions.   The authors analyze two professional circuits: the National Association for Stock Car Auto Racing (NASCAR) and the International Motor Sports Association (IMSA). For given races, the authors collect data on adjusted finishing position, spread of the prize money, percentage of the purse going to the top finishers, the number of caution flags (which are penalties against racers), race length, and average speed. The authors run multiple specifications for each auto racing circuit with adjusted finish as the dependent variable; the variation in the specifications arises in the finishing place length of the spread variables. The authors find that variations in prize money spread between high and low finishes has a significant impact on performance. Also, the authors show that risky behavior, as measured by the number of caution flags, increases when the spread exceeds the sample mean by more than one standard deviation. The specification chosen by Becker and Huselid is the starting point for the specifications presented in this paper. Specifically I use an incentive variable and a position variable which are constructed in a manner very similar to theirs.

Empirical studies exist also in other settings beyond professional sports. Knoeber and Thurman (1994), using data from the broiler chicken production industry and analyzing both linear (marginal product of labor) and tournament evaluation schemes, attempt to test the three main

predictions of tournament theory: changes in prize structures which do not affect the prize spread (relative prize distribution) will not have an impact on performance; more able players will chose low-variance strategies; and handicapping, which effectively closes the skill gap between players in an asymmetric tournament, can rectify disincentive effects. The authors find that the performance of producers does not change if the baseline prize changes while keeping the relative reward structure constant. They also find a negative relationship between producer ability and producer variability. Finally, by examining the differences between the linear and tournament reward scheme they find evidence of handicapping which increases effort effects. These conclusions support the predictions made by tournament theory. The discovery of these results in an industrial setting is very encouraging since it is the first empirical study which confirms the utility of the tournament model outside the narrow realm of sports.

It is important to note that Knoeber and Thurman cannot directly test the effects of asymmetry since regulators have handicapped the industry. The effects of this handicapping are already present in the data, making it impossible to directly analyze production in the broiler chicken industry in absence of handicapping. My paper seeks to fill in the gap in the empirical literature by examining an asymmetric tournament where the organizers implicitly encourage heterogeneity.

More recently, empirical studies has focused on the level of individual strategy. The resulting literature mostly deals with efficient levels of risk and is overwhelmingly empirical. These studies use professional sports as a source of nonexperimental data. For example, Klaasen and Magnus (2009) use the example of service strategy in tennis to answer whether economic agents are truly successful optimizers. They first present a theoretical model relating the probability of a

fair service x to the conditional probability of winning a point given a fair service $y(x)$. Using data from Wimbledon, the authors observe the frequency of successful services on the first and second attempts $x1$ and $x2$ and their corresponding frequencies of resulting in winning the point on either attempt (measured by $y1$ and $y2$). Using this data, the authors estimate probabilities for the above using a generalized method of moments. The authors conclude that inefficiency in service strategy exists, being on average 1.1% for men and 2.0% for women. If these inefficiencies are corrected, the authors contend that the new optimal strategy could potentially result in salary increases of 18.7% and 32.8% for men and women, respectively.

In another empirical study, Lee (2004) uses the television show World Poker Tour as a natural experiment to examine whether agents respond optimally to prize incentives for given risk levels in a tournament setting. Because riskier strategies in poker inherently are the result of more betting, the author uses the absolute value of the variation of an individual's chip count over the course of a given tournament as a measure for risk taking. The author regresses risk taking on the marginal increase in prize money by advancing one rank, the marginal decrease in prize money by decreasing one rank, chip count variance between the nearest leader and follower, and a vector for various control variables. It is important to note that all prize structures in World Poker Tour tournaments are convex, so the gain by increasing one rank is not equal to the loss by decreasing one rank. The author concludes that expectation of gains and losses does influence the amount of risk taking by a player. When holding other explanatory variables constant, larger expected gains or smaller expected losses increase incentives for risk-taking. Also, a player's response to expected gains and losses are highly asymmetric –a player responds much more strongly to expected losses than to expected gains. While this evidence may initially appear to weaken Krakel and Sliwka's theory, it is important to note that there is insufficient information as to the card players' skill level

an cost functions (except perhaps in the limited sense of using opportunity cost as an *ex-post*

measure in case a given strategy leads to failure). Ultimately Lee's work illustrates a specific

subgame perfect equilibrium which supports the traditional tournament model conclusion without

directly refuting Krakel and Sliwka.

III. An Overview of Fencing

In this section I describe modern competitive fencing, paying particular attention to epee

competitions. I also describe the structure of the international tournaments which serve as the

basis for my data.

<u>Modern Fencing</u>

Modern competitive fencing is called Olympic fencing to distinguish it from other versions of

the sport which place more emphasis on the recreation of historic swordplay than athletic

competition. Olympic fencing is scored by touches. Since actions happen to quickly, an electric box

wired to the fencer's weapon is used to determine if he or she has landed a valid touch. Each

individual match is called a bout and is fenced to a predetermined number of touches subject to a

time limit.

There are three weapons with which a fencer can compete: foil, saber, and epee. The foil

is the oldest of the fencing weapons. The blade has a rectangular cross section and is very flexible.

A foilist is allowed to score only by landing the tip of the blade on his or her opponent's torso, both

front and back. In addition, foil fencing is governed by a convention called right-of-way, which

states that the fencer who first initiates an offensive action is awarded the touch in the event of a

simultaneous hit. In other words, if fencer A attacks fencer B, fencer B must stop fencer A's attack by deflecting the blade or retreating out of distance before initiating an attack and attempting to score.

Saber is also governed by the convention of right-of-way but is fenced quite differently. The blade is slightly shorter than the foil, and the guard wraps around to the hilt to protect the hand. All of the body above the waist is valid target area. Saber fencers are permitted to score with either the tip or the edge of the blade, meaning slashing is permitted. Saber bouts are extraordinarily quick, often over in a matter of minutes, and it is arguably the most physically taxing of the three weapons. Because the modern electric saber is so light, it is much easier to attack than defend, leading competitors to develop overly aggressive offensive actions which, if employed in an actual duel, would be sure to get the fencer killed. This makes saber the weapon which least resembles actual swordplay.

The last weapon, epee, is modeled after the rapier, which was the civilian's dueling sword during the Renaissance. Many have described the weapon as a larger version of the foil. The blade is thick, not very flexible, and has a sturdy triangular cross-section. The bell-shaped guard is large enough to protect the entire hand, which is vital since the entire body is valid target in epee fencing. Also, epee is not governed by right-of-way; each fencer can attack whenever they feel like it, and in the event of a simultaneous touch, both fencers are awarded a point. The freedom afforded to the fencers makes it difficult to obtain a touch without one's opponent also scoring; because of this, epee matches tend to resemble a game of cat and mouse, with each fencer attempting to deceive the other with feints and short pseudo-attacks.

This paper examines epee fencing exclusively. As mentioned above, epee is the least restrictive of the three weapons –fencers can hit anywhere, at any time, so long as they hit with the

tip of the blade. New epee fencers are often astounded with this degree of freedom, thinking the

possibilities for dynamic actions and complicated offensive attacks are limitless. However, after a

few bouts the fundamental law of epee fencing becomes glaringly obvious –just because you *can* hit

anywhere does not mean you *should* hit anywhere. Ironically enough, in being free to direct any

sort of attack to any place on the opponent's body, epee fencers learn that only a select few moves

should be used on a select few target areas. This is a result of the lack of right-of-way in epee

fencing –complicated attacks require more time to set up, meaning an opponent can simply initiate

their own attack during one's initial preparation. At its very core, epee fencing is a race, and the

first one to make a hit wins.

Fencing Tournament Format

All official fencing competitions are tournaments, and all of these tournaments have the

same general structure. Before competition begins, fencers are grouped into pools of between four

to seven competitors. These pools serve as the preliminary rounds of the tournament. Each fencer

in a pool fences another fencer in a three minute, five-touch bout. After each bout, the final score

and other statistics (how many times a fencer hit, how many times a fencer received a hit, etc.), and

after each fencer has completed fencing all others in his pool, these scores are tabulated to give an

overall score. The purpose of this scoring in the preliminary pool matches is seeding –after pools,

each fencer is assigned a ranking based on how well he performed. After each fencer receives his

ranking, the second round of the tournament –direct elimination –begins.

Direct elimination is conducted in a typical tournament-bracket style competition: the

highest-ranked fencer first fences the lowest-ranked fencer, the second-highest fencers the second-

lowest, etc. If the number of fencers in a tournament does not equal a power of two (which it

frequently does not) the field is adjusted accordingly by giving the highest-ranked fencers "byes" which are free passes to the next round. Matches are now fenced to 15 and last for three 3-minute periods. The winner advances to the next round and the loser is eliminated from the tournament. There is no fence-off for third place; both fencers eliminated in the semifinals tie for the bronze medal.[1]

IV. Theory of the Tournament Model[2]

In this section I summarize the relevant properties of the tournament model. First, tournament theory models, which explain wage differentials in terms of relative rather than absolute performance, do a very good job of explaining scenarios such as athletic events or competition for positions within a corporation. Second, reward schemes based on relative performance have very strong incentive effects. In particular, the prize spread from one position to the next greatly influences the level of effort exhibited by the players. Third, the degree to which a tournament system is noisy is the degree to which individuals are rewarded (or punished) for reasons other than their relative performance. Noise tends to decrease effort incentives. The tournament organizers (an athletic coordinator, a corporate board of directors, etc.) can counteract this effect by increasing prize spreads. Fourth, when individuals differ significantly in skill their effort incentives fall since in all likelihood the more skilled will receive the largest prizes regardless of effort levels. Effort incentives for both groups can be increased by handicapping the skilled individuals, but care

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[1] The exception to this format is the Olympic Games. At the Olympics, there is no preliminary pool round; fencers are ranked based on previous performance during the same year and immediately begin direct elimination. Also, there is a fence-off for third place in the Olympics.

[2] The explanation of tournament theory in this section is only a summary of the theory's main characteristics. Readers interested in learning more should consult Edward P. Lazear's *Personnel Economics for Managers*, chapter nine.

must be taken that the disincentives to the skilled are not so high that they avoid the tournament altogether.

Explanations and Examples

Traditional economic theory explains income differentials in terms of a worker's marginal productivity. If Alice and Bob both hold manufacturing positions at Widget Corp's factory, and Alice can make twice as many widgets per hour as Bob, the theory predicts that Alice should command twice Bob's salary. Any other salary level for either Alice or Bob would present an opportunity for Widget Corp to make additional profits. Given their productivities, it is only this difference –Alice earning twice as much as Bob –which preserves their employer's indifference and makes Alice and Bob equally attractive.

This theory suggests that very small differences in income are due to very small differences in performance, and very large differences in income are due to very large differences in performance. However, this is not always the case. Consider a typical NBA Finals series against two teams which are nearly equally matched. The winner of the series is the first team to win four out of the seven games. There have been many instances where the opposing sides have battled and, due to their very similar levels of talent, forced a game seven winner-take-all scenario. The team which wins (often by a slim margin) takes the NBA championship, which is often accompanied by increased endorsement deals for the star athletes and significant bonuses for each member of the team. Meanwhile, the losers get nothing except for the consolation prize of a minor divisional title. Here is a case where the performance of one team only narrowly outstripped the performance of the other, yet the differential in "income" –money, prestige, etc. –was great. In addition, these rewards are independent of the magnitude of the teams' victories or defeats. If the winning team

had won four games in a row and ended the series quickly, the prizes they received would not be any more substantial. Clearly, absolute performance is not the only (or even the most significant) determinant of income in such scenarios. Such scenarios are evidence of the tournament model in practice.

As mentioned in the introduction, tournament theory can also be applied to corporate settings. As an example, let us revisit our analysis of Widget Corp. The CEO and board of directors want to maximize the corporation's profits, and a key component of this is to ensure that its workers are putting forth a level of effort consistent with their true levels of productivity. The managers first turn their attention to Widget Corp's marketing department. Provided that workers in the marketing department are salaried (not paid by the hour or by unit of output), they have an incentive, once employed, to shirk and not put forth their highest effort levels. Working hard creates disutility, and by offering a lower level of effort the workers increase their utility surplus. Obviously there is a lower bound to effort shirking –none of the employees would wish to withhold effort past a certain point due to the risk of being fired.

What upper management truly desires is a low-cost method of getting their employees to put forth the level of effort which maximizes profits.[3] As it turns out, the corporate employment structure, hierarchical by nature, is a highly effective method of inducing employees to put forth the optimum level of effort. First, corporate employment structures have a fixed number of positions. The corporate ladder continues downwards with increasingly large numbers of positions as the

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[3] It is important to note that there is a limit to the profitability of employee effort. Higher effort levels which produce higher output levels require more pay, but due to diminishing marginal productivity this is not always desirable.

ladder descends. Associated with each of these positions is a predetermined prize: the salary

afforded to that position.

It is clear by now that corporate hierarchy rewards those who are relatively more

productive. In this sense, tournament theory can be applied to employment situations involving the

corporate ladder since the main criterion for the application of the theory –the use of relative

performance in determining rewards –has been met. Intuitively the reader may have already

guessed that the most important aspect influencing employee effort, and the one which upper

management has the most control over, is the reward structure associated with each advance in

position, i.e. salary levels. This highlights the importance of this paper's empirical study: by

gathering data and examining incentive effects researchers provide valuable information to

corporate executives.

When considering promotions as motivators, it is important to remember that it is the

difference in salary a higher position commands which induces employees to put forth the optimum

level of effort. The actions of employees competing for scarce promotions and raises are influenced

by the magnitude of this difference: Alice and Bob, both making $60,000 per year currently, are

more likely to put forth more effort and compete more rigorously for a promotion which yields

$100,000 per year than they would if the position offered only $80,000 per year. Similar analysis

applies to competitors in fencing tournaments. Fencers competing in a bout are going to be much

more careful and put forth much more effort in the single-elimination gold medal match than they

would in the pools stage where the marginal consequences of an additional win or loss are

relatively small in magnitude.

While the above insights are important, several key questions still need to be addressed. Returning to the corporate example, what are the benefits and costs associated between pay structures where lower level pay starts low and scales upward rapidly with promotions, versus relatively high-paying entry positions combined with moderate pay increases as employees climb the ladder? Employees who find nose-to-the-grindstone effort levels and constant competition distasteful would prefer the second option; those who get a thrill out of a competitive environment, the first. Contrastingly, corporate management wants to induce effort levels to be high, but not so high that they scare off their mid-level producers, who have an important place in the organization. At the same time, they want to make sure they do not attract only those workers with little ambition or passion. They also want to induce an optimum level of effort for as low a cost as possible. However, before upper managers can decide on an optimal rewards scheme, there is one last important factor which needs to be considered.

The Effects of Chance

Chance –that is, good or bad events which are exogenous to the model –can significantly impact effort levels in the salary hierarchy. These events distort effort levels away from the levels predicted by the tournament theory model (Lazear 1998).

As a general rule, the more noise in the system, the lower the level of effort exhibited by employees. To see why, imagine the CEO of Widget Corp intervenes in the promotion competition between Alice and Bob. The CEO decrees the recipient of the promotion will be decided by a coin flip. Alice and Bob now have no ability to influence their chances of being promoted. The probability of getting the better job is completely removed from their effort level and thus they have no incentive whatsoever to work on their presentations.

The entirety of tournament theory depends on these workers capitalizing on their ability to outperform their peers. In the above case, infinite noise has been introduced; that is, the results have been completely removed from the effort levels of the employees. In cases like these, workers will simply give up because they see that success or failure has been completely removed from their effort.

The above case is an example of noise completely destroying effort incentives ("infinite noise"). Of course, the amount of noise present in the competitive structure can take on other values. Intermediate levels of noise are not only possible, but are in fact the most likely scenario in the real world. Regardless, the administrators of the tournament (managers) must find a way to counteract the effects of noise so that the players in the tournament (employees) still have an incentive to actively compete with each other. This can be done by increasing the prize spread. If Alice and Bob are made the heads of to two different proposal teams, the noise associated with introducing additional players may cause Alice and Bob to reduce their effort levels. By increasing the prize spread, most likely by increasing the salary of the position for which Alice and Bob are competing, upper management can counteract the effort-reducing effects of noise.

Epee fencing is undoubtedly the "noisiest" of the fencing events. Variability is large simply because luck plays a significant role due to the lack of protection from right-of-way rules. Combined with asymmetry, this is another feature which planners might find relevant. Executives working in inherently risky businesses will likely find the results presented in this paper of even more significance than executives in "quieter" industries.

Heterogeneous Agents

When we first examined the effects of prize differentials on effort levels, we implicitly assumed homogeneity. We will now adjust the model to reflect the asymmetry which we observe in fencing competitions.

As one might intuitively predict, a greater degree of heterogeneity among agents produces disincentives. The less productive agents know that they are unlikely to catch their more productive peers even with considerable effort, so they shirk. On the other end of the spectrum, the more productive agents know they are in little danger of being usurped by their less productive colleagues, so they also shirk. The end result is high-productivity agents keeping their favorable position, often leading to promotion, with the low-productivity workers left behind, all without significant effort levels from either party. This effect increases the greater the capability differences between the agents.

The chief motivation for this paper lies in the unlikelihood that tournament organizers will always deal with agents of uniform quality. Hopefully the results I present can be used to highlight the inefficiencies created by disincentive effects and to lay the groundwork for effective policy countermeasures.

V. Data

The data for this project comes directly from www.nahouw.net, the premier database for tournament fencers of international caliber. For each tournament sponsored by the FIE (the

International Fencing Federation, the body which governs modern, Olympic-style fencing) data is recorded on the competitors, their performance, and their relative rankings.

This project's data is taken from the 2007-2008 fencing season, which begins with the Kish Island, Iran World Cup in January and culminates in the Summer Olympic Games in August. (The Olympic Games only partially affect the structure of the tournament fencing season. Typically the World Championship Tournament is held in late summer/early fall, but in Olympic years the Olympic Games are used in lieu of the usual tournament championship.) The dataset contains cross-sectional data at the individual competitor level spanning across the 17 FIE tournaments held over the 2007-2008 season yielding a panel data set.

The initial dataset contained 1948 observations. However, many of these observations were outliers in the form of low-ranked fencers competing in a single tournament and remaining absent the rest of the season. This is due to the FIE zoning requirements, which stipulate the number of competitors each country can send to a sanctioned tournament. Typically the FIE allows a country to send between three and six fencers depending on the size of the tournament. However, the host country is given special dispensation and is afforded the privilege of entering significantly more competitors. The result of this policy is that the host nation enters not only its usual elite fencers but also several others who are not competitive at the international level. This is done for several reasons, such as "breaking in" up-and-coming fencers or giving fencers who are local-level champions the satisfaction of being able to claim they fenced in international competition. As one would expect, these extra fencers finish towards the bottom of the field; coupled with their extremely low world ranking, this creates the aforementioned outliers. For example, the World Cup event held in Buenos Aires had a total of 21 Argentine fencers out of a field

of 46 and all but two finished in 25th place or lower. In comparison, the country which sent the

second most competitors was the United States, with only four fencers enrolled, all of whom

finished higher than 20th place.

In order to more accurately capture the true incentive and control variable effects amongst

regular competitive fencers, the sample size was restricted to those fencers which, at any time

during the 2007-2008 season, were ranked within the top 100. The reasons for this are twofold.

First, the fencers past this threshold compete at least semi-regularly, with entry frequency

increasing sharply as world ranking drops. Second, the points totals of the fencers ranked lower

than 100 tends to become trivial very quickly, which is a reflection of true competitiveness (skill)

and willingness to compete (entries). The resulting dataset has a total of 763 observations and

their summary statistics are listed in Table I.

The measure of performance and effort is *FINISHik*, which is defined as the finishing position

of the *ith* fencer in the *kth* tournament. Although it may initially appear that the finishing position is

a measure of absolute performance, this is not the case. Finishing position is partly a function of

skill but it is also heavily determined by the relative strengths of the fencers. When a fencer wins a

tournament, we make no claims as to his *absolute* skill level, only his *relatively* higher skill as

compared to his competitors. (Obviously, at the international level all fencers are very talented, but

skill levels vary still vary significantly.) *FINISHik* is the dependent variable in the main specification

and its variations.

The maximum value of *FINISHik* indicates that the lowest finishing position filled by a top

100-ranked fencer was 184th place. The large standard deviation relative to the sample mean is

quite normal for epee tournaments and illustrates its noisy nature.

PSPREADk is the variable which captures incentives for better performance. It is defined as the average difference in points awarded to the top eight competitors minus the average points awarded to the rest of the field. The points awarded for each finishing position are fixed before the tournament even begins and are awarded based on relative performance, analogous to wages for positions within a corporation being fixed before that position is filled by an employee. The variation in this variable comes from two sources. The first, the official FIE point structure, occurs even before taking entries into account.

The FIE decides how many points are awarded to each position; in one structure, the first place finisher is awarded 64 points and each subsequent finisher receives points scaled down by a power of two; the other points structure decreases similarly, but the first place position is awarded the lesser amount of 32 points. The second is decided by the number of entrants. The greater the number of entrants, the lower the average points awarded to the field finishing below the top eight, thereby increasing the value of *PSPREADk.* The range of the data is approximately three standard deviations, which is encouraging because it suggests sufficient variation in the data to arrive at meaningful results.

The cutoff point of eight is selected due to the nature of epee fencing. Due to the rules governing its scoring, epee is the fencing event in which chance is most likely to play a significant role. Similar to American football, it is not unusual "on any given Sunday" for a low-ranked fencer to upset a top favorite. What makes an epee fencer skillful is not a few first or second place finishes, but consistent finishes in the top eight. Indeed, if a fencer entered every tournament and finished eighth place in each, it would be very probable that this fencer would end the season as the World Cup Points Champion, simply due to the variability associated with the sport. This is why

Table 1: Summary Statistics*

Variable Name	Description	Mean	S.D.	Min	Max
FINISHik	Finishing position of fencer *i* in tournament *k*	44.058	38.528	1	184
PSPREADk	Avg. points for a top eight finish minus avg. points for rest of field	28.856	9.482	14.767	43.728
HHIk	Herfindahl-Hirschman Index of the *kth* tournament	6340.187	1916.782	2169.263	9082.475
STARTRANKik	Rank of fencer *i* at beginning of tournament *k*	42.076	27.548	1	100
ENTRIESik	Number of competitors in tournament *k*	143.232	51.226	26	205
AGEi	Age of the *ith* fencer at the Olympic Games	27.967	4.590	21	45
MEANRANKk	Mean of *STARTRANKik* in the *kth* tournament	42.076	4.807	27.571	48.269
*TOPENTRYk***	Number of top 16 competitors in tournament *k*	10.471	5.535	1	16

*Statistics rounded to three significant figures
**Tournament-level data with only 17 observations. All other variables have 763 observations

in epee fencing, when one speaks of the "finals," they are not referring to the gold medal match,

but the series of bouts that begin in the round of eight tournament bracket.

The expected sign of the coefficient of *PSPREADk* is not immediately obvious.   Since

PSPREADk captures incentives for higher finishes, we might expect a negative coefficient (a higher

PSPREADk leads to a lower i.e. "smaller-numbered" finishing position, which is actually indicative of

better performance). However, these fencing tournaments are highly asymmetric. Fencers vary

greatly in skill and tournament organizers make no effort to handicap these better fencers. It is

possible that *PSPREADk* might exhibit a positive coefficient, which would imply the highly

imbalanced nature of fencing tournaments actually creates disincentive effects. This would only be

true if it is shown that tournaments with greater prizes attract more capable fencers. I will

elaborate on this in the methodology section; for now, we must acknowledge that the sign for the

coefficient of *PSPREADk* has theoretical justification in both the negative and positive cases.

An alternative incentive measure is *HHIk*, the Herfindahl-Hirschman Index of the kth

tournament. I use this as an alternative to *PSPREADk* in several specifications as a check on

PSPREADk. This statistic, a measure of market concentration, is typically used by economists

studying industrial organization and the theory of the firm. However, it is also applicable to

tournament theory as a measure of determining the magnitude of the prizes rewarded to the top

finishers. The points awarded to a specific finishing position are calculated as a percentage of the

total points available, multiplied by 100, and then squared. Each of these are added together to

arrive at the HHI.   A high HHI means that the majority of the points are awarded to the top

finishers and there is little benefit for those finishing in relatively lower positions. A lower HHI

indicates that prizes are more spread out and available to lower-finishing fencers.   The resulting

number is a measure of prize concentration, with an upper bound of 10,000. The data shows that

HHIk's maximum value is close to this upper bound, but its minimum is significantly lower and its

mean suggests tournaments of moderate concentration on average.

HHIk is most useful as a measure of a fencer's *a priori* expectation of tournament strength. I

will further elaborate on this in the methodology section. Since the tournaments in question are

asymmetric, there is theory supporting both positive and negative coefficients for the HHI.

STARTRANKik, defined as the starting rank of the *ith* fencer in the *kth* tournament, is the

first of the control variables. It may be possible that this variable has some incentive effects as well

–for example, fencers with a better (lower in numerical value) starting rank may have less of an

incentive to put forth their best effort due to their already comfortable position, or they may in fact

try harder (leading to finishing positions with smaller numerical values) in order to further solidify

their elite standing. Incentives aside, however, it is likely starting rank accurately captures a

fencer's skill over the course of a season. As such, we expect a positive coefficient: the higher the

starting rank of the *ith* fencer in the *kth* tournament (due to lack of effort, skill, or both), the higher

his finishing position.

ENTRIESk, another control variable, is defined as the number of competitors entered in the

kth tournament. The average tournament in the 2007-2008 fencing season had approximately 143

competitors, which is much closer to its maximum value than its minimum value. This degree of

variation is typical for international fencing competitions

Like *STARTRANKik*, it is possible there are some incentive effects associated with entry,

specifically that the decision to compete in the *kth* tournament may depend on the potential prize

(*PSPREADik*) available in that tournament. This will be discussed further in the results section. In

regards to its affect on $FINISH_{ik}$, the theoretical prediction is a positive coefficient because more entries reduces the probability of any given fencer finishing in a high position, since there are more fencers competing for a predetermined number of better finishing positions.

Another control variable is AGE_i, the age of the ith fencer at the time of the Olympic Games. This variable is particularly interesting due to the nature of epee fencing. The mean of AGE_i, 27.5 years, may be high for professional athletics as a whole but it is perfectly normal for epee fencers. Epee fencers peak very late in terms of the career of elite athletes, and it is not uncommon to see top fencers remaining competitive in their late thirties. I included AGE_i as a squared variable; theory predicts a negative coefficient, and it is possible that we may only observe the ascending half of the negatively-sloped parabola due to the aforementioned explanation.

The final control variable is a measure of the strength of the competition in a given tournament. $MEANRANK_k$ is the average starting rank of the fencers in the kth tournament. The expected coefficient is negative; higher average ranks imply a less competitive field, leading to better finishing positions for the ith fencer.

Also included are a series of position variables generated by interacting $PSPREAD_k$ with dummies for fencers whose starting ranks fall within each of the eight-brackets (ranks one through eight for the first group, ranks nine through 16 for the second, 17 to 32 in the third, etc.) . I included these terms order to discern whether the prize spread has differing incentive effects for for fencers of differing skill levels, which is entirely possible due to the asymmetric nature of the tournaments. If there are differing incentive effects, the magnitude of the coefficients should be smaller for more skilled fencers (either more negative or less positive, pointing to lower finishing positions and hence relatively greater effort incentives).

The final variable, *TOPENTRYk*, is not a control variable in the main specification but a variable in a separate specification and correlation test. It is defined as the number of fencers with a world ranking in the top 16 who enter the *kth* tournament. The reason I chose the top 16 for this variable stems from the noisy nature of epee fencing. Although top honors are reserved for the top eight finishers, the degree of mobility through these top ranks is highest from the top 16; that is, we frequently see fencers from the top 16 break into the top eight, and fencers from the top eight fall to the top 16. I felt defining the "elite" field as only the top eight too restrictive for this particular variable and including those other fencers who have a high probability of finishing in and being ranked in the top eight positions would yield more meaningful results. Since this variable is tournament-level rather than competitor-level, there are only 17 observations. I generated this variable in order to test whether a tournament with a larger *PSPREADik* (a greater purse available to the higher finishers) attracts tougher competitors. The outcomes of the regression specification and correlation test (with PSPREADik) are presented in the results section.

VI. Methodology and Results

Using the data described in the previous section, I estimate the following equation for the finishing position of the *i*th fencer in the *k*th tournament:

$$FINISH_{ik} = \beta 0 + \beta 1 PSPREAD_k + \beta 2 STARTRANK_{ik} + \beta 3 ENTRIES_k + \varepsilon_{ik}$$

Table 2 presents the results of several OLS specifications. For each of these six specifications, the subsequent explanatory variables were added piecemeal as a sensitivity check. In the first of these (columns 1-3), all the control variables are present and *PSPREADk* is used as the

incentive variable. The coefficients of *STARTRANKik* and *ENTRIESk* are positive, as predicted –the

lower a fencer's ranking, the lower he tends to finish, and the more fencers entered in a given

tournament, the harder it is to finish in a favorable position. *AGEi* and *AGEi2* are negative and

positive, respectively. This too is expected since epee fencers start competing at a young age but

reach peak performance much later than most professional athletes. The positive coefficient of

AGEi2 suggests that at a certain point, the marginal detrimental effects of an aging body outweigh

the marginal positive effects of additional experience, which is true of any sport. *MEANRANKk* also

has a negative coefficient, suggesting that weaker fields lead to higher finishing positions for a given

fencer, which is again in agreement with theoretical predictions. All of these variables are

significant at the one percent level, except for *MEANRANKk*, which is significant at the five percent

level.

Interestingly, the coefficient of the incentive variable *PSPREADk* is positive and significant at

the one percent level. This suggests that a higher reward spread leads to worse performances.

Remember that tournament theory predicts higher reward spreads tend to increase effort in

performance in symmetric tournaments but may reduce effort and performance in asymmetric

tournaments. The coefficient of *PSPREADk* provides initial evidence that effort incentives are in fact

dulled by asymmetric tournaments.

The OLS specifications in column 4 includes *PSPREADk* and several pairwise variables which

vere generated by interacting *PSPREADk* with rank dummies to capture differing incentive effects

for fencers of different skill levels. The other explanatory variables have declined in significance,

but all are still significant at the five percent level. Of the incentive variables, *PSPREADk* and

SIXTEENi are insignificant, but *THIRTYTWOi*, *SIXTYFOURi*, and *RESTi* are positive and significant. All

of these coefficients are positive, and the general trend in their magnitude suggests incentives for

higher effort levels and thus better performance are reduced for fencers of lower skill levels. This is in-line with the results of the third specification, but is more informative since it captures the differing incentive effects for different competitors.

The next specification uses *HHIk* instead of *PSPREADk* as the incentive variable. The other explanatory variables' coefficients and standard errors have not changed significantly and *HHIk* is not significant at any acceptable level. This changes slightly after generating interaction terms for different groups of fencers by interacting rank dummies with *HHIk*. The results of these regressions are presented in the final two columns. Ultimately, the results suggest that *HHIk* is an inadequate measure of capturing incentives.

The final OLS specification replaces *HHIk* with the pairwise variables interacted with *PSPREADk* to capture differing incentive effects for fencers of different skill levels. The other explanatory variables have declined in significance, but all are still significant at the five percent level. Of the incentive variables, *EIGHTi* and *SIXTEENi* are insignificant, but *THIRTYTWOi*, *SIXTYFOURi*, and *RESTi* are positive and significant. All of these coefficients are positive, and the general trend in their magnitude suggests incentives for higher effort levels and thus better performance are reduced for fencers of lower skill levels. This is in-line with the results of the third specification, but is more informative since it captures the differing incentive effects for different competitors.

Table 2
Results of OLS Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
PSPREADk	0.521**	0.543**	0.457**	0.056		
	(0.122)	(0.122)	(0.128)	(0.194)		
STARTRANKik	0.551**	0.536**	0.545**	0.338**	0.545**	0.385**
	(0.042)	(0.042)	(0.042)	(0.099)	(0.042)	(0.102)
ENTRIESk	0.252**	0.255**	0.321**	0.320**	0.370**	0.376**
	(0.023)	(0.023)	(0.038)	(0.038)	(0.036)	(0.036)
AGEi		-7.410**	-7.508**	-5.130*	-6.980**	-4.772*
		(2.136)	(2.131)	(2.152)	(2.195)	(2.210)
AGE2i		0.115**	0.117**	0.079*	0.109**	0.074*
		(0.034)	(0.034)	(0.034)	(0.035)	(0.035)
MEANRANKik			-0.854*	-0.912*	-1.313**	-1.428**
			(0.404)	(0.399)	(0.386)	(0.381)
HHIk					0.000	-0.001
					(0.001)	(0.001)
HHI16k						-0.000
						(0.001)
HHI32k						0.001
						(0.001)
HHI64k						0.003**
						(0.001)
HHIrestk						0.002
						(0.001)
SIXTEENi				-0.005		
				(0.012)		
THIRTYTWOi				0.317*		
				(0.147)		
SIXTYFOURi				0.669**		
				(0.182)		
RESTi				0.555*		
				(0.267)		
Observations	763	763	763	763	763	763
R-squared	0.33	0.35	0.35	0.37	0.34	0.36

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

The coefficients have the expected sign, and they suggest that asymmetric tournaments

create disincentive effects. However, this only holds if tournaments with higher prize spreads

attract more capable fencers. Fortunately, we can use the data to test this premise. By looking at

tournament-level data rather than competitor-level data, we can conduct two simple tests to see whether tournaments with higher prize spreads attract more capable fencers. First, we can correlate *PSPREADk* with the variable *TOPENTRYk*. Second, we can regress *TOPENTRYk* on *PSPREADk*.

The data shows that the correlation coefficient of *PSPREADk* and *TOPENTRYk* is 0.694. The correlation is high, but not definitively so. The regression results are more convincing, however:

Table 3
Tournament Strength Check

	OLS
PSPREADk	0.373**
	(0.100)
Observations	17
R-squared	0.48

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

These results, significant at the one percent level, suggest that increasing the point spread by approximately three points draws one additional elite fencer into the field. Considering observations for *PSPREADk* come in increments separated by much more than three points, we can conclude that the above results are applicable. Tournaments which promise higher rewards do attract stronger fencers, lending weight to the results of the main OLS specifications.

Selection

There is one other aspect of the data which has not yet been discussed –the panels are highly imbalanced. Only a small number of competitors attend all the tournaments, and several attend only one or two. After rectangularizing the dataset, I discovered that 45.5% of observations

were missing. In other words, adjusting the dataset such that each fencer was listed for each tournament whether they attended or not shows the "average" fencer missed nearly half the tournaments!

This is concerning for two main reasons. First, the highly imbalanced nature of the panels made the fixed effects model infeasible – the vast majority of the competitor dummies were dropped by the software package when I attempted to run the regression. However, I believe this is somewhat mitigated by breaking the incentive variable into components based on a fencer's ranking (see the results of the final OLS specification).

The second problem is more concerning. A fencer's decision to enter a tournament or not is not random. The fencer makes his decision to enter based on a number of different factors; because of this, the OLS results are most likely subject to selection bias. To account for these factors, I used the Heckman selection model.

The Heckman selection model is a two-step process including an OLS regression and a probit regression. It is the probit regression which serves as the selection component. In this case, we can use information based on whether a fencer enters a tournament or not to improve the estimates of the explanatory variables in the OLS model.

For fencer *i* in tournament *k,* the probit regression has the following form:

$$PROF_{ik} = \alpha 1 PROHH_{lk} + \alpha 2 PROSTARTRANK_{ik} + \alpha 3 HOMECOUNTRY_i + \mu_{ik}$$

where *PROF* is a dummy variable for entry, *PROHHI* and *PROSTARTRANK* are the same as their OLS counterparts except for the missing observations, which are now filled in, *HOMECOUNTRY* is a dummy variable for whether the *kth* tournament is located in the *ith* fencer's home country, and μ

is a standardized normal error term. The results of the probit regression, along with the

explanatory variables' marginal effects, are reported below.

Table 4
Probit Results

	(1) Probit	(2) Marginals
PROHHIk	0.000**	0.000**
	(0.000)	(0.000)
PROSTARTRANKik	-0.010**	-0.004**
	(0.001)	(0.001)
Observations	1316	1316

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

The defining feature of the Heckman selection model is the presence of excluded

restrictions. These are explanatory variables present in the probit model but not in the OLS model.

Without these variables which exclusively explain entry, the Heckman results would simplify to an

OLS regression. The two excluded restriction are *HOMECOUNTRYi* and *HHIk.* The first is a dummy

variable equal to one if a tournament is held in the *i*th fencer's home country. The second is used

as an *a priori* estimate of tournament strength. Since *PSPREADk* is not defined or known until after

all entries are compiled, *HHIk* is an effective term to capture expectation while avoiding

endogenous selection.

The results of the full Heckman selection model follow. Two models were tested: the first

uses *PSPREADk* as an incentive measure, and the second again uses *HHIk* as a check.

Table 5
Results of the Heckman Selection Model: PSPREAD

	(1) Point Spread	(2) Point Spread (probit)	(3) Point Spread by Rank	(4) Point Spread by Rank (probit)
PSPREADk	0.458**		0.086	
	(0.171)		(0.250)	
STARTRANKik	0.506**		0.335*	
	(0.055)		(0.133)	
ENTRIESk	0.343**		0.336**	
	(0.051)		(0.050)	
AGEi	-7.221*		-4.652	
	(2.894)		(2.862)	
AGE2i	0.117*		0.077+	
	(0.047)		(0.046)	
MEANRANKik	-0.969+		-0.938+	
	(0.531)		(0.515)	
PROHHIk		0.00025**		0.00025**
		(0.000)		(0.000)
PROSTARTRANKik		-0.010**		-0.010**
		(0.002)		(0.001)
PROHOMECOUNTRYi		7.180		7.178
		(13,124.789)		(11,078.312)
SIXTEENi			-0.005	
			(0.015)	
THIRTYTWOi			0.202	
			(0.200)	
SIXTYFOURi			0.762**	
			(0.240)	
RESTi			0.376	
			(0.354)	
Observations	1019	1019	1019	1019

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 6
Results of the Heckman Selection Model: HHI

	(1) HHI	(2) HHI (probit)	(3) HHI by Rank	(4) HHI by Rank (probit)
HHIk	-0.000		-0.001	
	(0.001)		(0.002)	
STARTRANKik	0.514**		0.364*	
	(0.056)		(0.143)	
ENTRIESk	0.396**		0.397**	
	(0.048)		(0.046)	
AGEi	-6.842*		-5.339+	
	(2.934)		(2.871)	
AGE2i	0.112*		0.089+	
	(0.048)		(0.046)	
MEANRANKik	-1.469**		-1.576**	
	(0.502)		(0.482)	
PROHHIk		0.00025**		0.00025**
		(0.000)		(0.000)
PROSTARTRANKik		-0.010*		-0.010**
		(0.002)		(0.001)
PROHOMECOUNTRYi		7.181		7.178
		(14,503.508)		(12,321.334)
HHI16k			-0.000	
			(0.001)	
HHI32k			0.000	
			(0.001)	
HHI64k			0.003**	
			(0.001)	
HHIRESTk			0.001	
			(0.002)	
Observations	1019	1019	1019	1019

Standard errors in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%

Again, the results of the specification containing *PSPREADk* and its associated interaction terms are more robust and have greater explanatory power than the specifications containing *HHIk* and its associated interaction terms.

The coefficients of the explanatory variables are in-line with theoretical predictions and previous results. Several of these variables have declined in significance even though they carry the same sign as in previous specifications. Of these, *STARTRANKik* is just shy of the one percent level, and *AGEi* is just shy of the ten percent level. Looking at the incentive interaction terms we see the same result as before: the relative magnitudes and significance of the interaction coefficients suggest disincentive effects for weaker fencers (or, alternatively, greater incentive effects for more talented fencers).

Examining the probit portion of the model, we see that fencers with less favorable rankings at the start of a tournament are less likely to enter. The intuition behind this result is similar to that underscoring the incentive interaction terms in the OLS model: less skilled fencers are deterred from entering more tournaments. This makes sense because fencers are very likely to be aware of the highly asymmetric nature of their competitions and, since effort creates disutility, are unlikely to compete given the low likelihood of receiving a prize (points) large enough in magnitude to justify the disutility of effort.

Still focusing on the probit model, we find a positive coefficient for *HHIk* and a large t-score. This suggests that a fencer's decision to enter a tournament is influenced by, and positively related to, the concentration of points available in a given tournament –the more the top finishers benefit at the expense of the rest of the field, the more likely a fencer is to enter. This is surprising

considering our analysis of *HHIk* and the relative magnitudes and significance of the incentive interaction terms in the OLS portion of the model.

Discussion

For the Heckman selection model, the probit analysis is likely subject to omitted variable bias, which may explain the unexpected coefficient sign of *HHIk*. In addition to the variables already present in the probit regression, competitive fencers also base their entry decision on an expectation of the level of competition. While it seems this would justify including *MEANRANKik* in the entry model, this is not possible due to the nature of the model –in estimating which fencers enter, we cannot use a statistic measuring characteristics of those fencers do end up entering. This also precludes *STARTRANKik* and *PSPREADk* (the latter because it is dependent on entry based on the way the variable is constructed). Not including these variables is necessary to avoid endogenous selection problems.

VII. Conclusion

In this paper I have provided empirical evidence supporting the theory of asymmetric tournaments. Specifically, I show that, other factors being equal, higher point spreads lead to worse performances for a given fencer. I also show that the effects of the prize spread are different for fencers of differing skill levels –while the null hypothesis cannot be rejected for stronger fencers, there is significant evidence suggesting weaker fencers face disincentive effects in the face of higher reward spreads.

Because entry into fencing tournaments may be subject to selection bias, I corrected the results in the OLS specifications using the Heckman selection model. Although the other explanatory

variables became less robust, the coefficients and signs for the incentive variables did not vary greatly from the OLS results and are still in line with the predictions of the theoretical model.

These results are of particular interest since the empirical literature on asymmetric tournaments is sparse. Knoeber and Thurman (1994) consider asymmetric tournaments in their paper, but in their study the tournament organizers handicap less able players to eliminate the presumed disincentive effects. To my knowledge my work is the first study which illustrates the ordinal disincentive effects in a tournament not subject to handicapping.

Although the above estimations are not perfect, they nevertheless support the hypothesis that asymmetric tournaments produce disincentive effects; furthermore, the evidence suggests that these incentive effects are different for competitors of differing skill levels, a conclusion consistent with the theory of the tournament model. To my knowledge, no other empirical study has confirmed the presence of disincentive effects in tournament settings. These results are highly significant and merit further research.

The most obvious improvement would be to increase the sample size. This paper examined data from a complete fencing season; it is not unreasonable to assume more robust results could be obtained from data sets spanning several seasons. There are difficulties with this method as well (newly participating fencers replacing retiring fencers, differing tournaments, rules changes, etc.), and there is no guarantee that an expanded data set will also correct the problem of significantly imbalanced panels. Nevertheless, running a similar study with a more comprehensive dataset at the very least would serve as a check against the results presented here.

Instead of simply expanding the dataset over the course of several fencing seasons, it could also be expanded to include female fencers. I did not do this for my project because too much of the requisite data was missing. Data concerning the performance and achievement of female

feners is not as meticulously kept as it is for men. Fortunately this problem is being rectified (in

international fencing events, at least); data from the latest fencing season, just compiled a few days

prior to the writing of this paper, catalogued identical and complete results for male and female

epee fencers.

A further improvement method would involve adding the risk variable, *RISKik*, to the

specification. *RISKik* would be defined as the number of risky strategies used by the *ith* fencer in

the *kth* tournament. As stated before, I was unable to acquire satisfactory data for this variable. I

present and describe it here only because of its theoretical importance and my commitment to

include it to the faculty during my proposal presentation. Ideally, the risk variable would be

included in the main specification in the same manner as Becker and Huselid (1992) even though

the definition of risk in their specification differs greatly from the one presented here. Becker and

Huselid define risk as the number of caution flags in a given race, which is a reflection of unsafe

driving which may cause harm or, albeit rarely, fatalities. Risk in this paper's specification is defined

as any fencing technique which is dangerous to execute from a competitive standpoint. That is, a

technique is risky if it has the potential to fail and allow the opponent to easily score a point, not if

it has the potential to injure.   Theory has no clear prediction as to the sign of *RISKik*'s sign. It is

possible that fencers may use fewer risky strategies as they advance, counting on their standard

techniques to propel them to the highest ranks, or they may use more as they advance, hoping to

catch opponents off-guard. Intuitively we would expect stronger fencers to use fewer risky

techniques so as to preserve their likely favorable finish and weaker fencers to use more risky

strategies since they have little to lose seeing as their probability of placing highly in a given

tournament is low, but Krakel and Sliwka (2002) prove a possible theoretical refutation to this

claim.

The primary challenge is that the only way to reliably acquire this data would be to watch footage from every single match of every tournament in the data set. Even if a researcher could acquire this data there is still the problem of subjectivity in asserting the level of risk associated with a given fencing technique. One suggestion would to be to record the number of times a given fencer executes an unprovoked advance-lunge or *fleche* attack. Others would advocate a rotational technical analysis based on the tactical wheel presented earlier in this paper.

A final improvement would require an adjustment to the dependent variable, *FINISHik*. In other studies researchers have adjusted a variable describing relative finishing position to arrive at an objective scale; for example, Becker and Huselid (1992) modify the finishing position of the drivers by multiplying the finish variable by a term for race speed. Without adjusting *FINISHik*, we cannot say definitively whether the weaker fencers are actually have disincentives for performance or whether their incentives are simply weaker than those of stronger fencers. As stated before, in the context of fencing tournaments these are flip sides of the same coin. As such, the results still agree with the theoretical predictions, but they would be more convincing if it were possible to isolate either condition. For simplicity's sake, I have referred to the phenomenon in this paper as "disincentive effects" but readers should be aware of the ordinal, rather than cardinal, value of these effects.

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