Leadbetter, Matthew (2020) *Doping in Sport: A Behavioural Economics Perspective.* Doctor of Philosophy (PhD) thesis, University of Kent,.

UNIVERSITY OF KENT

DOCTORAL THESIS

Doping in Sport: A Behavioural Economics Perspective

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

in the

School of Economics
Faculty of Social Sciences

Declaration of Authorship

I, Matthew LEADBETTER, declare that this thesis titled, "Doping in Sport: A Behavioural Economics Perspective" and the work presented in it are my own. I confirm that:

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- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
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Abstract

Faculty of Social Sciences

School of Economics

Doctor of Philosophy

Doping in Sport: A Behavioural Economics Perspective

by Matthew LEADBETTER

This thesis primarily aims to provide a solid theoretical understanding behind the incentive structures, decision making and rationality of athletes who decide to utilize doping decisions within a competitive sporting contest. This thesis analyzes the rationality behind eliciting a doping decision, outline a two-stage model of doping in sport in which athletes choose how much to dope and then how much effort to exert, with payoffs determined by an all-pay auction. We also show that a winner-takes-all prize structure leads to maximum effort (when effort can be monitored) but also maximum cheating when it cannot and to explore the complimentary idea that people behave more dishonestly in a sporting environment than they do in other environments through theoretical and experimental analysis.

Acknowledgements

First and Foremost, I would like to acknowledge and thank my Supervisors Prof. Edward Cartwright and Dr. Anna Cartwright for their work in helping me in this project. This body of work would have not been possible if it were not for their tireless effort, dedication and willingness to go above and beyond in providing helpful assistance.

I would also like to thank the University of Kent and all of their staff for allowing me the opportunity of completing this Doctorate, it has been a pleasure to work here for the past few years during the preparation of this thesis.

I would also like my Parents, Sharon and Michael Leadbetter for their unending support.

Contents

Dedicated to my Nain And Taid, Gwen and George Kerr

Chapter 1

Introduction

Economic theory generally considers competition and competitive environments as desirable. Competition helps improve the functioning of markets, it fosters innovation, it guarantees efficiency by forcing firms to produce at lowest possible costs, it encourages highest effort among employees within a firm and it reduces possibilities of discriminatory behaviour of employers as to do so would lead to economic potential being unfulfilled. However, this drive for efficiency tends to pit economic agents against each other in contests where agents compete against one another to secure economic rents and this competitive environment may drive agents into enacting illicit behaviour in order to secure higher rents.

Gilpatric (2011) states that every contest is characterized by rules (sometimes implicit) that define the difference between acceptable and unacceptable behavior. Executives within a firm compete for promotion based on their performance, but accounting fraud, violation of government regulations, or simply unprofessional or unethical business conduct unacceptable to the firm may be undertaken by agents in order to gain an illicit advantage over their competitors and, as such, wherever competition motivates a desirable activity or productive effort it may also motivate undesirable, and possibly even prohibited, behaviour.

This incentive to circumvent the rules is prevalent and rewarding in a wide variety of markets, within the labour market cheating could entail the willingness of employee to bribe customers or supervisors to increase their position in a hierarchical management structure (Krakel, 2007), within education, individuals colluding in order to increase their ability within academic tests (McCabe et al, 2001) and within competitive industries, cheating could entail the effort of individuals within firms sabotaging competitors to gain from the negative outcome (Harbring et al, 2007).

Broadly speaking, we define cheating as any form of breaking the implicit or explicit rules of a contest. As such, cheating could feasibly be considered as a criminal action. The rationality is that the primary objective of cheating is to avoid punishment from a referee for enacting an illicit choice in order enhance the payoff received from a contest.

Becker (1968) states that crime could be viewed as a rational act that is chosen by an individual depending on the benefits and costs involved. Those who choose to enact illegal actions based upon the cost-benefit analysis may be regarded as "rational cheaters". Previous economic research has investigated cheating in education and confirmed that people with low grade point average (GPA) cheat more than students with high GPA (Kerkvliet and Sigmund, 1999; Bunn et al., 1992) primarily because they have more to gain from doing so. It has been demonstrated that cheating behaviour within this environment can be reduced by increasing the costs of being caught (Kerkvliet and Sigmund, 1999).

One of the most visible examples of where this competitive environment leads to significant levels of cheating is within the sporting industry. In the sporting world over recent years, cheating has been an extremely contentious and lucrative issue. Szymanski (2003) indicates that the structure of sport is inherently unstable. Players perform and agree to abide by tournament rules and regulations to compete for a prize measured in status and money. Due to this payoff there is an incentive for players to illicitly increase their competitiveness in order to either be accepted into competing within a sport or to increase their capability in order to win a competition. In the context of sport, cheating may take many forms, for example match fixing or sabotage.

With issues such as match fixing within the Italian Serie A, spot fixing within the Indian premier league's cricket system and research and development theft within the Formula 1 industry, there is an indication that these incentives are not only prevalent within the market but that attempts to combat cheating within the industry of competitive sports seems improperly regulated and ineffective. The ubiquitous nature of these problems across several different sporting competitions does seem to indicate that there is still an incentive for competitors to cheat across all sectors of the industry despite the best attempts of anti-doping authorities. As such, theory suggests that if the opportunity for cheating arises for competitors in a sporting industry, it will be exploited by players and could lead to a situation that would represent market failure within the industry.

According to Preston and Szymanski (2005) 'Doping has probably been the biggest single problem relating to 'cheating' for sports administrators'. Doping involves the illicit solicitation of non-therapeutic uses of legal substances, illegal substances and drugs to artificially increase their capability to compete within a competitive environment and allow for an "unfair" advantage over other competitors within the same industry. (Dilger, frick and Tolsdorf, 2007)

Since the 1930's, progressive advances in synthetic drugs has led to a direct link between the consumption of performance enhancing substances and increased levels of success within the sporting market of the doper. Due to the extreme success of such methods, advances within the doping industry have been significant and the range of prospective substances and therapies available to prospective cheaters has enhanced dramatically. Dopers now have the chance to employ highly advanced substances (such as Stimulants, Diuretics and masking agents) and/or highly advanced biochemical enhancements (such as the increase in oxygen transfer through blood doping or chemical and physical manipulation through gene therapy). Doping in sport can be appropriated as a proxy for cheating as to better understand the decisions of individuals adopting illicit activity within markets.

One of the most relevant recent examples of the use of performance enhancing drugs was the actions of Lance Armstrong, former seven time Tour de France winner and figurehead of competitive road cycling, disgraced by recent revelations surrounding his involvement in doping practices. Furthermore, additional successful professional road cyclists such as Tour de France winners Tyler Hamilton and Floyd Landis, Giro D'Italia winner Ivan Basso and winner of all three major tours Alberto Contador have all been convicted of anti-doping violations in the pursuit of success. However, these high profile cases only represent the most visible aspect of doping within the sport of road cycling. In fact, over 65 different positive cases of doping within the industry have been reported since 2007, only three winners of the last fifteen Tour de France competitions have not been banned for utilizing performance enhancing drugs and the highest finish for a rider never implicated in doping controversies between the years of 1998-2006 was fourth.

In addition to the actions of competitive road cyclists, systemic state sponsored doping regimes have been uncovered within the Russian Olympic team prior to the 2016 Rio Olympics. According to the McLaren Report (2016) between 2011 and 2015, Russia's Ministry of Sport, the Centre of Sports Preparation of the National Teams of Russia, the Federal Security Service (FSB) and the WADA-accredited laboratory in Moscow had conspired to operate for the protection of doped Russian athletes by providing a state-directed fail-safe which allowed for a "disappearing positive methodology" to remove positive tests from being observed in a conservative estimate of 643 positive cases across multiple sporting disciplines. The method included removing sealed, tamper-proof urine tests and removing the substances within to be replaced with non-contaminated substances without breaking the seal on the tamper proof security bottles. So, despite increases in funding available for anti-doping authorities, increases in the complexity of monitoring of athletes and additional punitive measures for athletes that violate doping rules, the utilisation of illicit substances and therapies has remained a common phenomenon in the sporting world.

Since the introduction of the World Anti Doping Agency (WADA) in 1999, there has been an effort to harmonize policies across all sports in order to allow for a standardized procedure for monitoring and testing of individuals. Yet, this action to harmonizing policies to create a uniform policy, as to counter-act the use of performance enhancing substances and their impact upon competition. However, this approach may not be entirely effective. Waddington & Smith (2009) note that the patterns of drug use varies considerably from sport to sport, dependent upon the characteristics required of an athlete to be successful in that particular market. A single anti-doping policy may not be sufficient to eliminate the use of performance enhancing substances, but rather a number of policies, based upon a sport-by-sport approach may be more effective.

By the end of the 1990's there was perception of a lack of co-ordinated research policy, especially with regard to new analytic methods and little had been done to promote anti-doping activities on an international level (Catlin et al, 2008). This had led to a significant advantage for competitors who attempted to use doping techniques. Individual competitors could take advantage of arbitrage within a single sporting market due to the vast differences in testing standards throughout the world. There was a belief that if there was an ability to the harmonize the vastly divergent rules and regulations regarding anti-doping testing and legislation and implementing a uniform code of conduct, monitoring and punishment across all sporting markets then there would be an increase in the effectiveness of anti-doping efforts.

Whilst much vaunted Anti-Doping Administration & Management System (ADAMS) system and 'Whereabouts' testing procedure has lead to a dramatic increase in the capability of anti-doping agencies to monitor their athletes and the introduction of a characterization of cheaters that distinguishes between those who are "unintentional cheaters", those who fall foul of doping rules through the actions of other agents and "real cheaters" who receive far harsher punitive measures, the approach undertaken by anti-doping authorities still seems to be an adversarial one and this type of adversarial approach towards athletes may not lead to a complete eradication of doping from sporting contests. There may well still be a incentive for agents to utilize doping procedures, techniques and substances if there is no element of self-policing within the industry and a change in norms of competition.

1.1 Outline

Houlohan (2002) states that even though massive investment into research and development and detection of performance enhancing drugs has been undertaken as a preventative measure relatively little is known as to how competitors start taking drugs, the circumstances that arise for an athlete to start taking drugs or how drug use varies by sport, gender, age or region and, as such, doping remains in almost every competitive field. In recent years influential sportsmen and women in American football, baseball, tennis, association football and Athletics have been implicated in doping scandals in one form or another.

Lippi (2008) notes that the major challenge of anti-doping policies is the application of robust testing that can account for the vast array of extreme biochemical and metabolic heterogeneity of substances used for the purpose of artificial enhancement. If the testing procedures of regulators are outpaced by the introduction of new, enhanced substances and methods of introducing foreign substances then the "integrity" of sporting competition is at risk (Azzazy, Mansour & Christenson, 2005). Therefore if there is no adequate ability for the regulator to monitor all sets of possible actions that are available to the competitors within the industry then, given the conclusions of Daumann (2003), competitors will take any possible method of artificial enhancement.

If the relatively hard-line approach undertaken by Anti-doping authorities has not lead to the eradication of doping within the sporting industry, then we need to understand why not. In order to do that, we need to provide a comprehensive expected utility model that incorporates the benefits and costs of undertaking doping techniques and also attempting to understand if the effect competition has upon the level of doping within the sporting industry.

Doping in sport is relatively unique in the sense that it seems to benefit neither spectators of the sport, consumers of the sport or the agents involved in the long-term. Tax evasion, for instance, is a conflict between those who can gain from under-reporting their income and those who benefit from increased government spending. Similarly, cyber-crime is a conflict between those who can gain from having your credit-card details and those who want to minimize fraud. In both these examples there is a relatively clear distinction between winners and losers. Doping in sport, however, provides a scenario where nobody seems to gain.

According to Waddington and Smith (2009) spectators and sponsors don't like doping due to its ability to distort "natural" competition and reduce the value of the competition as a whole. The sporting authorities don't like doping as it leads to a mis-allocation of resources and cases where those who "should" win do not. Pharmaceutical companies have little to gain from doping as the incorrect (or in cases, correct) application of their substances and therapies lead towards negative health effects for those competing and, perhaps most importantly of all, athletes consistently say they would prefer no doping scenarios.

This is not to deny that some people do gain from doping, such as black-market smugglers that infiltrate supply networks and sell illicit substances to individuals who wish to benefit from illegally enhanced capabilities. But, the gainers seem so few that they cannot possibly offer a plausible explanation for why the use of drugs is as widespread as it seems. Not only, therefore, is doping a problem it seems to be a paradoxical one.

With this in mind, in order to reduce the incidence of cheating and doping, we first have to understand the individual decision making of each rational athlete when deciding to go against the laws of sport by using a doping substance or technique. We need to outline the different sporting contexts in which a doping decision can be analyzed, in terms of expected utility and strategic behaviour, in order to understand what potential mechanisms can be levied against individuals who are incentivized to use a doping decision.

In Chapter 2 we outline a generalized model of cheating in sport and focus on specific strategic and behavioural aspects of the model in order to understand why individuals may rationally decide to enact a doping decision, despite the inherent costs involved, in order for us to have an understanding of what must be addressed from a policy perspective.

In addition to understanding the benefits and costs of rational agents enacting a doping decision within sport, we must also look at the relatively unique framework of sporting competition.

When observing sporting competition, the "rational cheater model" would suggest that the higher the level of competition (i.e. the higher the benefit/payoff derived for having an outcome 'better' than other economic agents) the more cheating we should observe and as such the usage of a cheating mechanism should be seen as more of a continuum rather than a discrete element and by construction. Furthermore, these mechanisms can say nothing about the interplay between doping decisions and effort portrayed by athletes.

Frank and Cook (1995) argue that people in higher positions of certain fields are disproportionately rewarded, which heightens the level of competition and generates a "winner-take-all" outcome where many people compete for prizes without a realistic chance of obtaining them and may decide to enact illicit decisions in order to enhance their chances of gaining these positions. So whilst cheating is legal and ethical quandary, it may also lead to the mis-allocation of resources to individuals whom, through mere effort alone, would not hold the capability to attain such rents and its successful application is a direct incentive for individuals to subvert the rules and regulations of a market.

Whilst There has been literature that focuses upon strategic interaction and a growing body of literature that uses game theory to analyze doping in sport, However, the focus seems to be placed upon looking at doping and effort mechanisms in combination through contest theory (e.g. Krakel 2007, Gilpatric 2011, Ryvkin 2013, Mohan and Hazari 2016).

Whilst Contest theory can allow us to observe outcomes within an all-pay framework it does tend to have specific functional forms (e.g. Krakel 2007, Gilpatric 2011) or strong assumptions such as homogeneity (Ryvkin 2013) are necessary to obtain results, which does present a challenge to obtain a flexible approach that can yield general insight for policy design.

To provide the tractability lacking in current literature, within chapter 3 we consider a two stage game in which players first choose how much to dope and then choose how much effort to exert in training. The combination of ability, doping and effort determine a player's score. Players with the highest score win prizes (where we allow that there may be more than one prize) and because the doping and effort costs are sunk and those with the highest scores win we have an all pay auction. This will help complement the current literature surrounding contest theory and provide a point from which policy may be drawn.

1.1.1 Competition and framing

Haugen (2004) categorizes the issue of performance enhancing substances as a two player game where there are homogeneous players competing for a prize. Within the construct of the game there is a dichotomous choice of doping which, if enacted, leads to a fixed increase in the capability of the player. Analysis of the two player game indicates that the structure of the game is similar to that of a prisoner's dilemma. Players within the game apply their ability to dope based upon the significant benefits of doping and the player's belief surrounding the doping decisions of the opposing player. Competitors within this game are Pareto optimal in a situation whereby neither player takes performance enhancing substances. However, due to information asymmetry between players regarding doping decisions and payoff comparisons, both players take the additional benefit but also bear the costs of doping. These costs include future discounted health costs, costs of procurement, the costs of norm infringement and the expected probability of being caught weighted by the expected cost of punishment.

In the models that follow the interpretation of doping suggested by Haugen (2004) a competitor will utilize any form of illicit advantage if there is an overall expected utility gain from doing so. Unless there is a direct economic incentive to not cheat, competitors will. This economic disincentive may come in the form of a cost attributed to eliciting the action of cheating or a reward for not implementing any form of cheating strategy. The methods of deterrence that are currently being utilized can be considered consistent with what would be expected from analyzing a standard economic model of cheating.

In order to correct this element of market failure, there is a general acceptance that the presence of a strict exogenous regulatory body is required. The role of the regulator within these models is to decrease the overall level of expected utility gain of individuals within the market by actively disincentivizing the usage of illicit techniques. Theoretically, an increase in the level of punishment leads to an additional cost placed upon the individual competing within the market and can be considered as a direct disincentive for competitors and leads to a decrease in expected utility for individuals utilizing illicit substances and therapies within the industry. Additionally, an increase in the level or effectiveness of monitoring within the industry increases the probability of an individual who utilizes illicit substances or therapies within the industry being caught and punished for their actions and therefore leads to a similar effect upon expected utility.

Regulatory bodies within this framework must therefore undertake strong methods of deterrence such as increases in the monitoring of competitors behaviour and introductions of harsh punishment mechanisms in an attempt to reduce the expected utility gain to the point where individuals would be unwilling to dope in order to sustain a no-doping equilibrium in the long-term. As such, there has been a significant increase in the application of policing and regulation within the sporting world based upon a "punitive law and order approach" that seeks to uncover and punish individuals that enact cheating and doping decisions within a competitive sporting environment. Under this approach, regulators have increased their use of extensive and intrusive techniques in order to detect doping and cheating within the industry and then used strict punishments that eliminate individuals who use doping procedures from competition for extended periods of time (Waddington Smith, 2009).

Because of this, the response to the rapid escalation of individuals utilizing illicit materials by Anti-doping agencies within sport has taken an extremely adversarial approach. Generally, after major doping crisis' there is an increase in the punishment and monitoring mechanisms in an attempt to decrease the level of doping within the industry. The most recent example of which is the formation of the World Anti-Doping Agency (WADA) in 1999. WADA was created as a direct response to the uncovering of large scale doping within the Tour de France, attempted to harmonize the separate rules and regulations surrounding doping around the world under one unified organization, increase the level of monitoring of individuals competing in sport and effectively punish competitors who were caught using performance enhancing techniques. Since its formulation WADA has employed more advanced doping techniques and instigated better coordinated testing procedures than preceding organizations.

Nagin (2002) investigated cheating behavior in a firm and found that while reductions in monitoring (i.e. measures that track employee's location and activity) have increased shirking from some employees, other employee's do not respond according to the "rational cheater model" and continue to work at the same level as under the previous monitoring regime. Another area in which "cheating" has been investigated is tax evasion. Franzoni (2000) points out that whilst the empirical research in this area is inconclusive, expected punishment appears to negatively affect the level of tax evasion in a country.

Whilst the incentive to cheat is built into a competitive reward structure, behavioural and psychological motives may lead towards increased cheating under competitive environments because competition emphasises the importance of personal success. As a result, Individuals may find themselves less bound to adhere to standards and social norms of fairness and use cheating in order to increase their own payoffs.

Eber (2008) indicates that "the only real hope for ending the practise of doping lies in the norms of fair competition between the athletes". Recent advances in behavioural economics suggest the adversarial approach may not be best for regulating the market. Instead it points towards a more cooperative approach which recognises a wider set of incentives and influences on behaviour than the standard mode. The current methods of attempting to limit the usage of drugs in sport will not completely eradicate the usage of more sophisticated doping techniques in the long run and may, in fact have the inverse effect. As such, there should be a shift in the actions of anti-doping agencies away from punitive measures towards more co-operative measures, such as harm reduction and a greater level of self-regulation within the industry.

Therefore, in order to fully understand why doping decisions are enacted within a competitive sporting framework in order to reduce the incidence of them from a policy perspective, we must understand if there are behavioural effects that may be influencing the level or incidence of doping.

Experimental literature suggests that most people are lie averse (Rosenbaum, Billinger and Stieglitz 2014 and Capraro 2018). A key question we must to address in our work is how an individuals willingness to cheat is influenced by strategic incentives. In Chapter 4 we explore the effects that incentives in a contest may have on agents willingness to cheat and whether or not a reduction in monitoring leads to an increased level of cheating, as we would expect from expected utility modelling.

Additionally, we need to find whether there are individual or attitudinal differences that lead to athletes becoming more willing to engage in dishonest behaviour and whether cultural and situational influences from the sporting environment lead to individuals deciding to cheat more than under "normal" competition.

Most analysis of anti-social and dishonest behaviour in sport has focused on heterogeneity between athletes or their environment (e.g. coaches or type of sport). Our objective in Chapter 5 is to explore the complimentary idea that people behave more dishonestly in a sporting environment than they do in other environments due to its competitive nature. We argue that there are various mechanisms an 'honest person' can use to justify dishonest behaviour in sport.

This approach should give us a relatively full understanding over the strategic elements that go into an individuals choice to elicit a doping decision, allow us to give a more generalized version model of doping in sport that can help form policy that dissuading individuals from eliciting the doping decision whilst being complementary to current literature, demonstrate whether or not payoff structures and monitoring have any effect upon reducing the overall levels of cheating and whether or not simply being within a sporting environment has a significant impact on whether an individual will decide to cheat and to what extent.

Chapter 2

Doping as a discrete choice

2.1 Individual decision making

The underlying question we have to consider in this thesis is why an athlete would dope, and why they would not. Only if we answer this question can we unpick the reasons why we have a doping problem and what would help alleviate it. So, why would someone dope?

In a series of interviews and focus group discussions with athletes, coaches, and others involved in sport, Mazanov and Huybers (2010) identified the ten choice factors summarized in Table 2.1. In a follow up study (Huybers and Mazanov 2012), they estimated the relative strength of each choice factor by asking a large number of sportspeople hypothetical choice questions about an athlete called Kim[1]. The factors that showed up most strongly were 'quick fix' performance enhancements (because of injury or fast track to the top), financial gain, health effects, the probability of being caught and the financial and non-financial consequences of being caught. Interestingly, sources of influence and information were less important, although the recommendation of a coach or senior athlete had some effect.

[1]Survey respondents were given a series of hypothetical scenarios and asked in which scenario they thought that Kim was most likely to dope.

TABLE 2.1: Themes, choice factors and descriptions for drug use. Source, Manazov and Huybers (2010)

Variable	Description
1. Expected Performance Outcome	The objective of using the drug e.g. to improve performance or overcome injury
2. Money Amount	The expected Financial gain from improved performance
3. Money Contingency	Contingency in the contract withdrawing financial gain in case of Doping
About the Drug	
4. Source of Influence	Member of sports network, such as coach Sports doctor, competitor or role model
5. Source of Information	Information about doping e.g. From Pharmaceutical company, Medical Journal or blog
6. Health side effect	Expected effect on health
The deterrence system	
7. Detection	Likelihood of successful detection
8. Prosecution leading to ban	Likelihood of successful prosecution
Consequences if Prosecuted	
9. Financial consequences	Fine and loss of money
10. Non-financial consequences	Other consequences such as public humiliation

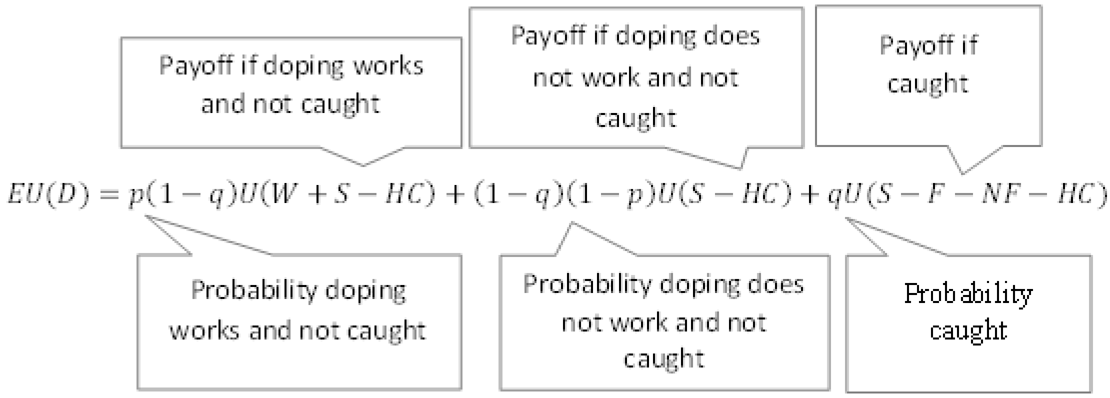
However, these hypothetical choice experiments and surveys can only tell us so much. There is much disagreement, for example, about the willingness of athletes to trade health for performance enhancement. Goldman, found that 50 percent of surveyed athletes would be willing to take a substance that guaranteed sporting success even if it led to certain death within five years (Goldman, Bush and Klatz 1984). This suggests an extreme willingness to trade health for glory.

The Goldman dilemma has, however, been questioned, and many consider the 50 percent figure a gross over-estimate (Woolf, Mazanov and Connor 2016). Different surveys also give very different results regarding athletes assessment and understanding of health risks (e.g. Stelan and Boeckmann 2006 and Lentillon-Kaestner, Hagger and Hardcastle 2012). It is difficult to unpick what something like expected 'performance improvement' actually means. For instance, Goulet et al. (2010) found that pressure to lose or gain weight was strongly influential in the decision to dope.

What clearly comes through, however, in all of the studies done on the psychology of doping this is that there are a number of significant factors that influence the doping decision (Anshel 1991, Overbye, Knudsen, and Pfister 2013, Ntoumanis et al. 2014). Even if we stick to the factors that consistently come out as very important there is still a complex trade-off between financial and non financial gains from performance enhancement versus health risks and the likelihood of being caught. Moreover, there is also very strong evidence that an individual's willingness to dope will depend on that individual's gender, personality and moral values (Goulet et al. 2010, Ntoumanis et al. 2014). For instance, women seem less likely to dope than men (e.g. Pitsch and Emrich 2011)

The starting point for economic and game theoretic analysis of the doping decision is that choice can be modelled as a rational weighing up of costs and

FIGURE 2.1: An equation for the expected utility from doping



benefits (Maennig 2002, see also Strelan and Boeckmann 2003). To illustrate, we might end up with an equation like that in Figure 2.1. Here we attempt to capture the incentive to dope of an athlete, who we will call Marion, by expressing her payoff as a function of some basic primitives. More specifically, the expected utility from doping. $EU(D)$ is expressed as a weighted sum of three possible outcomes:

i) Doping works, i.e. the performance gain is as expected, and the athlete is not caught. In this case their payoff depends on a base salary, S, gain from performance enhancement,W, and health costs, HC

(ii) Doping does not work and she is not caught. In this case their payoff depends only on the base salary, S and health costs, HC

(iii) The Player is caught doping. Then their payoff depends on a financial fine, F, and non-financial punishments NF. These three outcomes are weighted by the probability of them happening which depends on the probability doping works, p, and the probability of being caught, q.

Clearly, the equation in Figure 2.1 is, at best, only a highly stylized representation of the incentives an athlete may face. For instance, it may be that the payoff if caught depends on whether doping was successful; the probability of being caught may depend on the extent of doping; the health costs associated with doping may be stochastic; the success of doping may not be a simple binary outcome but vary from successful, winning gold, to highly successful, winning gold with a world record time; and so on. Indeed, there is an almost limitless set of possibilities. Even so, an economic perspective says that we can gain invaluable insight from studying simple models of choice. In this regard it is worth highlighting that a guiding principle of economic methodology is that a model should be judged on the quality of its predictions and insight and not on the realism of its assumptions.

If choices are consistent then they can be modelled as if rational, the overwhelming evidence from a variety of contexts, including doping in sport (Huybers and Mazanov 2012), is that people's choices are consistent most of the time (e.g. Andreoni and Miller 2002). And as Strelan and Boeckmann (2003) note, the decision to dope is unlikely to be made on a whim. Performance enhancement from steroids, EPO, human growth hormone, and so on requires systematic use of a long period of time. Moreover, the potential consequences of being caught doping are typically life changing. It would be surprising, therefore, if an athlete were to dope without consciously weighing up the costs and benefits to some extent.

2.1.1 Role of Strategic Interaction

The previous section has framed sport in terms of an individual athlete making a decision to dope. If our interest was in recreational sport, such as an individual training to improve fitness, then we could stop there. Professional sport is, however, by its very nature, a competitive process.

Whilst breaking records might be valued to some extent by an individual, the true value and utility from competition is derived from being ahead of others. Athletes do not compete within a void, but rather in a competitive environment against other agents within a system that extends beyond each individual agents control.

Consider, for instance, the arguments Lance Armstrong gave to justify his doping, that it was impossible to compete without doping due to the doping actions of his competitors, that the action of doping was systemic, endemic and a natural aspect of competitive road cycling norms and that a competitive Tour de France race would be "impossible" without the additional oxygen benefits of using either Erythropoietin (EPO), Blood transfusions mid-race or any other element that increases Oxygen transfer rates from red blood cells to muscles. Now we might discount Armstrong's comments to some extent as ex-post rationalization however it is clear that the behaviour of others is inextricably linked with attitudes to doping. For instance, we might have the athlete who dopes in order to keep a level playing field with other dopers or we might have the athlete who dopes in order to get ahead. A third characterization of player would be an athlete who do not dope but fear that they will lose out to dopers. Beliefs about the actions of others are therefore not only likely to influence doping decisions but other aspects of strategy as well.

Many of the primitives in figure 2.1 depend on the actions of others, such as the probability of detection. One primitive, namely the probability that doping will be performance enhancing, p, almost certainly will depend on the actions of others. This needs to be taken into account as after all an athlete has very little control over what others do and so she can essentially take p as given. One difficulty with this approach is the underlying assumption that people must act on their beliefs and not necessarily objective reality.

Under an expected utility framework, rational agents will solicit any illicit action that yields a positive economic outcome, based upon the benefit gained by the utilization of illegal techniques and substances weighted by the risk of being caught and punished by regulatory bodies overseeing the competition and correspondingly, any action that will lead to an economic deficit would not be solicited by a rational economic agent.

2.2 The prisoner's dilemma

If an athlete knowingly takes performance enhancing drugs then he clearly has some reason for doing so and within most Game theoretical models we assume that this is due to the expected utility derived from making such a decision. Despite athletes, sponsors, fans and pharmaceutical companies receiving a higher payoff overall in a competitive environment with no doping, athletes may decide to dope in order to maximize their own individual payoff.

The insight that doping will emerge even if no one wants is of fundamental importance because it shows that doping is a social problem. Doping is not (solely) a consequence of individual athletes being 'immoral' or 'cheats', but, instead, a consequence of the basic incentive structures within sport. Given the fundamental importance of this insight we shall spend some time building the argument.

Consider a 2x2 game amongst two players competing to win an event, each of them independently has the opportunity to enact a doping decision in order to improve their chance of success. To keep things simple let us suppose these are the only two athletes capable of winning the competition. Furthermore, suppose that doping is a discrete choice. If we use this assumption, then there are the four possible outcomes depicted in Table 2.2. we have assumed that if both athletes do the same thing then they have an equal chance of winning. While, if one athlete dopes when the other does not then victory is

TABLE 2.2: Outcomes in a Two Player Doping game

		Player 2	
		No Dope	Dope
	No Dope	Equal Chance	P2 Wins
Player 1			
	Dope	P1 Wins	Equal Chance

TABLE 2.3: Payoffs in a Two Player Doping game

		Player 2	
		No Dope	Dope
	No Dope	$\frac{W}{2}, \frac{W}{2}$	0,W-c
Player 1			
	Dope	$W - c, 0$	$\frac{W}{2} - c, \frac{W}{2} - c$

guaranteed for the doper. Note that this means doping increases the chance of winning by 50 percentage points.

Assume that there is a payoff value attributed to each of the four possible outcomes. So, let W denote the prize for winning, which might include the monetary prize, increased sponsorship etc. and let c define the cost of doping, which could include health costs, the probability of being caught for enacting a doping decision and the financial penalties associated if caught. We then obtain the game depicted in Table 2.3[2]. For example, if Player 1 dopes and Player 2 does not then Player 1 is sure of winning the Prize, W, but pays a cost, c, and has net payoff $W - c$. Similarly, if both dope then both have a 50 percent chance of the prize W and both pay cost c so have net payoff $= \frac{W}{2} - c$

[2]Strictly speaking this is not a complete description of the game because it ignores the role of 'nature' in deciding who wins if both do the same thing. This, though, does not change equilibrium predictions.

To analyze the game in Table 2.3 we need to look at the incentives of Player 1 and Player 2.

Consider Player 1. Suppose that Player 1 believes Player 2 will not dope, Player 1 has the decision to either Dope (and receive payoff $\frac{W}{2}$) or decide against doping (and receive the payoff $W - c$). Player 1 does better to Dope if and only if;

$$W - c > \frac{W}{2} \tag{2.1}$$

This simplifies to

$$W > 2c \tag{2.2}$$

In other words, the prize has to be twice the costs of doping, suppose next that Player 1 believes that Player 2 will Dope. Player 1 can decide to either Not Dope (and receive payoff of 0) or Dope (and receive payoff of $\frac{W}{2} - c$). Again Player 1 does better to dope if and only if $W > 2c$. Given the symmetry in the game the incentives for Player 1 and Player 2 are identical. So Player 2 should also decide to dope if and only if $W > 2c$.

The most interesting case for consideration is where $W > 2c$ and so the prize for winning is relatively large. If this is the case then irrespective of what Player 2 does, Player 1 should enact a doping decision and the same is the case for Player 2.

Both players therefore have a dominant strategy in Doping and suggest a full doping outcome as the Nash equilibrium in the game.

If both players decide to enact a doping decision then they both receive the payoff $\frac{W}{2} - c$. If neither player decides to dope then they receive the payoff

$\frac{W}{2}$. The latter outcome is preferred by rational agents because they avoid the health costs associated with doping and that the action of doping would create a dead-weight loss. However, due to the strategic interaction between the two players, both athletes are incentivized to dope.

The fact athletes dope does not, therefore, imply that they 'want' to dope. We have to look at their strategic incentives. Even though both athletes, in this game, would prefer they abstain from doping, that it is not an equilibrium outcome because the gains from doping are simply too high to ignore. This trade-off between group and individual incentives gives rise to a social dilemma.

However, it is important to recognize when analyzing this simplistic variation of the performance enhancing drug game (Haugen, 2004) we are making questionable assumptions.

It might be, for instance, that the chances of a positive drug test are less if both dope. Or, the punishment for doping might be less for an athlete that does not win. If so, the cost of doping would be less when both dope than if just one dopes. In this game we assume that both athletes are risk neutral and that may not be a plausible assumption to make.

2.2.1 Tragedy of the Commons

In the previous section we considered a game with only two athletes. This is a very useful simplifying assumption but obviously leaves open the crucial question of what happens if we have many athletes competing for the one prize. Suppose that there are $N > 2$ athletes that are capable of competing to win the prize, W. the assumptions that all athletes are of the same ability and must make a binary, dope or not dope, decision will remain the same.

TABLE 2.4: Payoffs in a Many Player Game

		Other	
		$d = 0$	$d > 0$
Player 1's Decision	Dope	$W - c$	$\frac{W}{d+1} - c$
	Not Dope	$\frac{W}{n}$	0

The mechanics are not dissimilar from that of the standard game, the athlete with a strong preference for current period benefits will disregard the health costs to use illicit techniques and if all players dope then there is no change in advantages from the base game. Additionally, Haugen (et al, 2013) replicated the conditions of the performance enhancing drugs game proposed by Haugen (2004) across n-players.

The payoff to an athlete will depend on the number (or proportion) of other athletes who dope as summarized in Table 2.5. If Player 1 Dopes, they pay a cost, c, and is in with a chance of winning the prize. The chance of winning will depend upon how many others decide to enact a doping decision.

For example, in the previous section we stated that there was other player, Player 2, and if Player 2 decided to enact a doping decision, $d = 1$, then Player 1 had a 50% chance of winning. The more athletes dope the higher the level of Doping (d) the less chance Player 1 has to win the Prize. If Player 1 does not dope then the only chance to win is if nobody else in the game dopes.

Let us start the analysis by asking if it can be an equilibrium for no athlete to dope. Setting $d = 0$, Player 1 will have an incentive to dope if

$$W - c > \frac{W}{n} \tag{2.3}$$

This can be re-written as

$$W(\frac{n-1}{n}) > c \tag{2.4}$$

The key thing to note is that the more athletes there are, the larger n is, then the more likely this condition will be satisfied. If n is sufficiently large, then the condition reduces to merely saying that the prize for winning should be bigger than the cost of doping. Thus, the more athletes there are, the harder it is to sustain doping free sport. The intuition for this result is simple enough in that more athletes make it less likely an athlete will win and so the potential gain from doping is higher.

Consider next if it can be an equilibrium for all athletes to dope. Setting $d = n - 1$ we can see that Player 1 will have an incentive to dope only if

$$\frac{W}{n} > c \tag{2.5}$$

This is a much tougher condition to satisfy. So, the more athletes there are the less likely we will end up with every athlete doping. Again, the intuition for this result is that more doping athletes make it less likely doping will pay off.

So far, we have seen that the more athletes there are the less likely it is an equilibrium for no one to dope or for everyone to dope. The likely outcome, therefore, is that some dope and some do not. To be more precise we can find the level of d where Player 1 is indifferent between doping and not.

$$\frac{W}{d+1} = c \tag{2.6}$$

This can be re-written as

$$d^{\star} = \frac{W}{c} - 1 \tag{2.7}$$

The interesting thing to note about this condition is that it does not depend on the number of athletes. Instead, the predicted number of dopers depends solely on the relative trade-off between the prize and cost of doping. The proceeding discussion shows that there are natural limits to doping. In particular, we should not expect every athlete to dope. Moreover, the bigger the prize and the lower the cost of doping the more are predicted to dope.

However a social dilemma still remains. Suppose that we end up with the equilibrium level of doping, $d^{\star}$, which defines the optimal level of doping in the game given the parameters. Anyone who refuses to dope at this level has an expected payoff of zero as they hold no expectation of winning the prize and anyone who decides to dope has an expected payoff of zero. In this case, all of the potential gains from winning are eroded away by the costs of doping. This is not a coincidence but an inevitable consequence of the incentives athletes face to compete.

If all athletes chose to not dope then each athlete would have expected payoff $\frac{W}{n} > 0$. This, similar to the previous sections analysis of a simple Prisoners dilemma in a 2 player game, would indicate that there is a better outcome than a $d^{\star}$ level of doping. So, again we have a social dilemma in the sense that the equilibrium outcome is worse for everyone than can be achieved if doping is eliminated. If athletes could somehow commit to not doping then it would be in their interests to do so.

This particular dilemma is an example of the tragedy of the commons in which a 'common resource' is over-exploited (Bird and Wagner 1997). In this instance the common resource is performance enhancing drugs. Each athlete has an incentive to use that resource even though its use imposes a negative externality on other athletes.

However, the nature of a 'many athlete' setting does warrant some discussion. We have assumed that only the winner gains. In reality, we expect that finishing second is better than finishing third, and so on. This will, however, depend on the sport in question. In athletics, for instance, winning the 100m at the Olympics counts for a lot more than winning at the Diamond League meeting in Zurich, or similar; the focus, therefore, is on one 'big' event. In most sports, however, there are multiple opportunities to gain and this can smooth the distribution to some extent. With regard to this type of analysis, The consequences of multiple prizes were explored by Haugen, Nepusz and Petroczi (2013).

Essentially, if the relative gains from winning diminish the further down the pack an athlete is then the analysis of this section holds true. We just need to find the cut-off marginal gain that is sufficient to induce doping.

2.2.2 Asymmetric Ability

Until now we have assumed that all athletes have the same ability. Clearly, we need to consider a more realistic setting where abilities differ. In order to illustrate this asymmetry in ability we return to a 2-player setting.

If p denotes the probability of Player 1 winning then $1 - p$ denotes the probability of Player 2 winning. Therefore the expected payoff of player 1 if neither player is doping equals pW and that of player 2 is equal to $(1 - p)W$. For simplicity let us assume that if both dope then the probability of Player 1 winning is still p.

If neither athlete dopes then Player 1 has a probability p of winning the Prize, W. Implicitly we assumed previously that $p = 0.5$. If we allow for Player 1 to

TABLE 2.5: Payoffs in a Asymmetric 2-player Game

		Player 2	
		Not Dope $d = 0$	Dope $d > 0$
Player 1	Not Dope	pW, $(1-p)W$	$(p-\delta_2)W$, $(1-p+\delta_2)W-c$
	Dope	$(p+\delta_1)W-c$, $(1-p-\delta_1)W$	$pW-c$, $(1-p)W-c$

have more ability in the competition than Player 2 then $p > 0.5$ and if Player 2 is more able in the competition than Player 1 then $p < 0.5$.

If one athlete dopes and the other does not, given that the athletes are of different ability, it is almost inevitable that the consequences of doping will differ. Consider first the case where Player 1 decides to dope and Player 2 does not.

Let δ_1 denote the amount by which the probability of Player 1 winning increases. In which case Player 1 will win with a probability $p + \delta_1$ and Player 2 wins with a Probability $1 - p - \delta_1$. In this case, the expected payoff for Player 1 is $(p + \delta_1)W - c$ and that of Player 2 is $(1 - p - \delta_1)W$

Consider next the case where Player 2 dopes and Player 1 does not. Let δ_2 denote the amount by which the probability of Player 2 winning increases. In this case Player 1 will win with a probability $p - \delta_2$ and Player 2 wins with a Probability $1 - p + \delta_2$. Table 2.5 summarizes the relevant payoffs[3]

The game depicted in Table 2.4 is clearly more complex. First, we must check to see if the main findings hold true and if it is still a Nash equilibrium for both Players to Dope. If Player 2 dopes then it is in Player 1's best interest to dope when

$$pW - c > (p - \delta_2)W \tag{2.8}$$

[3]Note that we implicitly assumed previously that $\delta_1 = \delta_2 = 0.5$

this can be re-arranged as

$$\delta_2 W > c \tag{2.9}$$

Similarly for Player 2, if Player 1 dopes then it is in the best interest of Player 2 to dope when

$$(1-p)W - c > (1-p-\delta_1)W \tag{2.10}$$

.

This re-arranges to

$$\delta_1 W > c \tag{2.11}$$

Therefore it is a Nash equilibrium for both athletes to dope if

$$\delta_1 W, \delta_2 W > c \tag{2.12}$$

To gain further insight assume that Player 2 does not Dope. In this case it is in Player 1's best interest to dope if $(p+\delta_1)W > pW$. This is equivalent to $\delta_1 W > c$.

Similarly if player 1 does not Dope then it is in Player 2's interest to Dope if $(1-p+\delta_2)W - c > (1-p)W$ which reduces to $\delta_1 W > c$.

Therefore if condition 2.12 it satisfied then the unique Nash equilibrium of the game is for both players to Dope. Clearly, as with the previous examples, both players would be better off if they did not dope and we obtain the same social dilemma of doping if the gains from doping are sufficiently high.

However, the preceding discussion has not really touched on the issue of asymmetric ability. Let's consider a situation whereby Player 1 is a lot better than Player 2. For instance, assume that $p = 0.9$ and as such there is a 90%

chance of player 1 winning in a "fair" contest with no doping involved. Crucially, Player 1 cannot benefit much by unilaterally doping, we know that at most Player 1 can, at best, improve their chance of wining by a maximum of 10%, $\delta_1 < 10\%$. However, Player 2 has a lot to gain through the elicitation of a doping regime. If, for example, the doping decision leads to a 50% chance of winning, as opposed to the 10% in a fair contest, then there is a possible 40% improvement, $\delta_2 = 0.4$.

In general, asymmetric ability is likely to lead to a big discrepancy between δ_1 and δ_2. In particular if Player 1 is significantly better than Player 2 then we may end up with the situation

$$\delta_2 W > c > \delta_1 W \tag{2.13}$$

Indicating that Player 2 can unilaterally benefit from doping whilst Player 1 does not.

In this setting there does not exist a Pure Strategy Nash Equilibrium. To appreciate this point we just need to consider the four possible outcomes. If Player 1 does not dope then, because $\delta_2 W > c$, Player 2 will have an incentive to dope. So it is not a Nash Equilibrium for either player to dope. However, if Player 2 does dope then layer 1 has an incentive to dope as $\delta_2 W > c$. In this case, Player 1 has an incentive to dope in order to 'Wipe out' the competitive advantage that Player 2 would gain from Doping. Therefore, it is not a Nash Equilibrium for Player 2 to dope and Player 1 not to. Continuing this logic it is not possible for either player to dope nor is it a Nash equilibrium for Player 1 to dope and Player 2 to not.

In the absence of a pure strategy Nash equilibrium we can look for a mixed strategy Nash equilibria In equilibrium Player 1 needs to randomize their doping decisions in such a way that Player 2 is indifferent to between doping and Not doping. Let q_1 denote the probability of Player 1 doping we need.

$$(1-p)W(1-q_1)+(1-p-\delta_1)Wq_1 = (1-p+\delta_2)W(1-q_1)+(1-p)Wq_1 - c \tag{2.14}$$

This simplifies to

$$q_1 = \frac{\delta_2 - \frac{c}{W}}{\delta_2 - \delta_1} \tag{2.15}$$

Analogous reasoning tells us that in equilibrium, Player 2 will decide to dope with probability

$$q_2 = \frac{\frac{c}{W} - \delta_1}{\delta_2 - \delta_1} \tag{2.16}$$

One interesting thing to take from this analysis is that the equilibrium probabilities do not depend on relative ability, as measured by p. All that matters is the amount that each athlete can gain from doping, δ_1 and δ_2. This is generally going to be true. In particular, an athlete's incentive to dope will depend on what that athlete, and competitors, can gain from doping. It is only indirectly going to depend on relatively ability per se.

In equilibrium, the expected payoff to Player 1 if they do not dope is

$$pW(1-q_2)+(p-\delta_2)Wq_2 = pW - \delta_2 Wq_2 < pW \tag{2.17}$$

Recall that in Equilibrium Player 1 is indifferent between doping and not doping. We therefore know that Player 1's expected Payoff is less than if Player 1 and Player 2 did not dope. Similarly in terms of Player 2, their expected Payoff if they did not decide to dope is

$$(1-p)W(1-q_1)+(1-p-\delta_1)Wq_1 = (1-p)W - \delta_1 Wq_1 < (1-p)W \tag{2.18}$$

In this case, Player 2 would also be worse off than if both players had decided not to dope. Thus, even though this game is far removed from the prisoners Dilemma from which we began analysis, the same basic result remains, both players would be better off if doping did not exist.

2.2.3 Layers of Doping

In the proceeding discussions we have seen that some athletes may dope while others do not. But, is it the dopers that always win? The simple answer is no. To get a first insight on this issue let us look again at the asymmetric ability game of Table 2.5 . What we are going to look at is the probability that Player 2 dopes, Player 1 does not dope, and yet Player 1 still wins. This is easiest to look at with a specific example and so suppose that $p = 0.9$, $\delta_1 = 0.05$, $\delta_2 = 0.4$ and $\frac{c}{W} = 0.35$

Note that Player 1 has a 90% chance of winning a fair contest, p=0.9. And, more importantly, still has a 50% chance of winning an unfair contest, $\delta_2 = 0.5$. With this in mind let us look at the equilibrium outcome The equilibrium probability that Player 2 dopes (using equation 2.13) is

$$q_2 = \frac{0.35 - 0.05}{0.4 - 0.05} = \frac{6}{7} \tag{2.19}$$

The Probability that Player 1 does not dope (from equation 2.11) is:

$$1 - q_1 = 1 - \frac{0.4 - 0.35}{0.4 - 0.05} = 1 - \frac{1}{7} = \frac{6}{7} \tag{2.20}$$

So the probability that Player 2 dopes and Player 1 dopes is approximately 0.74. Recall if this happens there is a 50% chance that Player 1 wins. The probability that Player 2 dopes, Player 1 does not Dope and Player 1 still wins is therefore around 37%

The preceding example shows that doping and winning need not go in tandem. The reason for this is that doping is driven by relative and not absolute gain. Player 2 has an incentive to dope because it dramatically increases his chances of winning. He is, though, still unlikely to win. This example illustrates the more general principle that doping decisions are about relative gain and loss and not winning per se. This is a crucial point and so we shall provide another example to illustrate the point.

Consider again a situation where there are a number of exceptional athletes and a number of average athletes. This time, however, suppose that an average athlete cannot beat an exceptional athlete even if the average athlete dopes (and the exceptional athlete does not). Is there any incentive for the average athlete to dope? If the only prize up for grabs is a gold medal then an average athlete does indeed have no incentive to dope. But, in the world of professional sport the gold medal is unlikely to be the only prize on offer.

If there are m Olympic places and $n_B < m$ exceptional athletes then exceptional athletes are guaranteed being on the Olympic team and can just focus on the gold medal. Applying the logic of Section 2.1.2 we would expect $d_B^\star = \frac{W}{c} - 1$ to dope, where W is the relative gain from winning the gold medal. Average athletes are in a competition for the $n_B - m$ remaining Olympic places. Suppose that there are n_L average athletes and the relative gain from getting a place on the team is Z. Then we can extend the analysis of Section 2.1.2 to cover this case. The only thing we need to change is that now more than one athlete can win the prize.

The relative payoffs for doping versus not doping are summarized in Table 2.5. If the number of average athletes who dope is less than the number of places up for grabs then all dopers get a place and non-dopers have a chance. If the number of average athletes who dope is more than the number of places up for grabs then only dopers have a chance of a place. In equilibrium, Player

TABLE 2.6: Payoffs in a many athlete game for Olympic Places

		Number of Average athletes that dope	
		$d_2 < n_B - m - 1$	$d_2 > n_B - m - 1$
P2	Not Dope	$Z - c$	$Z\frac{n_B - m}{d_2 + 1}$
	Dope	$Z - \frac{n_B - m - \delta_2}{n_2 - \delta_2}$	0

2 is indifferent between doping and not doping at:

$$Z\frac{n_B - m}{d_2 + 1} = c \tag{2.21}$$

Which can be re-written as

$$d_2^\star = \frac{Z(n_B - m)}{c} - 1 \tag{2.22}$$

Note that it is entirely plausible the number of average athletes who dope could exceed the number of exceptional athletes who dope. In particular, we only need that $Z(n_B - m) > W$ meaning that the total gain from athletes getting a place on the team exceeds the prize from winning.

We see again that it is not only winners with an incentive to dope. Indeed, in this example there may be little incentive for exceptional athletes to dope because they are guaranteed a comfortable living, have little chance of winning the gold, and stand to gain little from doping.

Average athletes, by contrast, may have a strong incentive to dope because doping might be their only way of securing a future as a professional athlete. This example reiterates the point that the potential gains from doping are what we need to consider when attempting to devise policy to reduce the level of doping within the market and that the gains from doping may be larger the further down the pack we go. One thing to appreciate at this stage is the potential for 'layers of doping' where doping occurs at critical ability thresholds, whether that be winning the gold or making a place on the Olympic team.

2.3 Norms of Fair Play

The focus of this chapter will now start to shift from one of understanding the incentives to dope to that of trying to reduce doping. Naturally, this will lead us to look at the potential for the intervention of regulators and doping authorities. We shall begin by looking at whether norms of fair play can be enough alone to deter doping. Cycling, for instance, provides one positive example. A picture of almost universal doping in the peloton that changed after the Festina and Puerto scandals (Lentillon-Kaestner, Hagger and Hardcastle 2012). This appears to follow from a culture shift rather than any change in direct incentives. For instance, cyclists still underestimated the health risks of doping. One possibility is that athletes simply dislike to dope because it is seen as a form of lying or cheating. Then the costs to doping, c, should include a psychological cost of doping. The analysis we have done so far in this chapter, would, however, remain unaltered.

One possibility is that athletes simply dislike to dope because it is seen as a form of lying or cheating. Then the costs to doping, c, should include a psychological cost of doping. The analysis we have done so far in this chapter, would, however, remain unaltered. In particular, the ratio $\frac{c}{W}$ will still be crucial, we just recognize that c might be somewhat larger. It is possible that an athlete would be so averse to cheating that this tips the balance towards not-doping. However, the athlete would have to be incredibly averse to lying if they are willing to forego an Olympic gold model simply because they have lie aversion. There is some evidence of Lie Aversion outlined by Waddington and Smith (2008) however we would typically assume that individuals may be willing to lie for a price, which will be covered more in Chapter 4 & 5. Realistically, therefore, it seems that lie aversion, of itself, is unlikely to count for very much in the world of professional sport.

A more nuanced possibility is explored by Eber (2008). The key idea here is that an athlete experiences a psychological cost if he dopes and others do not, but does not experience any cost if others dope. This trade-off recognizes the potential for norms of fair play. In particular, if there is a norm of not-doping then an athlete may feel negative if he deviates from that norm. To work through the implications let us return to the prisoners dilemma game with which we began the chapter but build in the notion of a norms.

The basic cost of doping remains c, however we now say that if Player 1 decides to dope and Player 2 does not then Player 1 will receive a 'guilt' size of β_1 as the player is aware that they have received an illicit advantage over the other player through cheating. At the same time, Player 2 receives 'annoyance', α_2, as they know that player 2 has enacted a doping decision to gain victory. Similarly if Player 2 decides to Dope and Player 1 decides not to, then Player 2 experiences 'guilt' and Player 1 experiences 'annoyance'

In terms of Nash Equilibrium, it is still a Nash equilibrium for both players to dope (if $2c > W$). However it may also be a Nash equilibrium for both to not dope, If Player 2 does not dope then it is optimal for Player 1 to dope if.

$$W - c - \beta_1 < \frac{W}{2} \tag{2.23}$$

TABLE 2.7: Prisoners dilemma game with guilt and annoyance

		Player 2	
		No Dope	Dope
Player 1	No Dope	$\frac{W}{2}, \frac{W}{2}$	$-\alpha_1, W - c - \beta_2$
	Dope	$W - c - \beta_1, -\alpha_2$	$\frac{W}{2} - c, \frac{W}{2} - c$

This rearranges to

$$\beta_1 > \frac{W}{2} - c \tag{2.24}$$

Provided that both β_1 and β_2 are sufficiently large then a norm of non-doping is possible to be sustained and in this case the game moves from being a Prisoner's dilemma outcome to one of co-ordination.

Although this is a promising outcome, there is reason for skepticism surrounding the capability of all athletes to co-ordinate upon a non-doping equilibrium. Firstly, we need all athletes to stick to the norms. If, for instance, Player 2 does not feel much guilt from the action of doping, β_2 is small, then they will dope and it is in Player 1's best interest to also Dope, no matter how high their own guilt at enacting the decision (β_1) is. It seems unlikely that we can realistically expect all athletes to intrinsically want to stick with the norm.

There is also another, more strategic, reason to question whether a non-doping equilibrium will occur, Risk Dominance.

Suppose Player 1 has no idea what Player 2 will choose, then to capture this complete uncertainty surrounding the action of Player's 2's actions we assume they will dope 50% of the time and Not dope 50% of the time. Given this assumption, the expected payoff of Player 1 when doping is:

$$\frac{1}{2}(W - c - \beta_1) + \frac{1}{2}(\frac{W}{2} - c) = \frac{3}{4}W - \frac{\beta_1}{2} - c \tag{2.25}$$

and the expected payoff if the athlete does not dope is

$$\frac{1}{2}(\frac{W}{2}) - \frac{1}{2}\alpha_1 = \frac{1}{4}W - \frac{\alpha_1}{2} \tag{2.26}$$

Thus the expected Payoff from doping is higher than not doping if:

$$\beta_1 - \alpha_1 < W - 2c \tag{2.27}$$

We would expect that annoyance from cheating exceeds guilt, meaning that $\beta_1 < \alpha_1$. However, this leads to a reduction to the familiar $W > 2c$ and therefore player 1 should decide to dope.

The preceding analysis informs us that the Nash equilibrium where both athletes dope is risk dominant. Basically, doping is the 'less risky' option because it gives a higher expected payoff for a wider set of beliefs about what the other athlete will do. In another sense, not doping is risky because of the chance the athlete will end up with nothing but annoyance due to the other player deciding to dope and receiving the payoff α_1. We have, therefore, a coordination game with a Pareto dominant Nash equilibrium, neither athlete dopes, and a risk dominant Nash equilibrium, both athletes dope. Fortunately, there is a large amount of experimental evidence as to which equilibrium is more likely to emerge in this type of game. And the evidence favours the risk dominant equilibrium being more likely. This again suggests that a norm of non-doping may be hard to sustain.

This section has painted a somewhat pessimistic view as to whether social norms can eliminate doping. What we are arguing is that fairness norms of themselves are almost certainly not enough to eliminate doping. It is simply asking too much for social norms to overcome the huge incentives to dope. Moreover, social norms can actually increase the incentive to dope, such as the annoyance Player 2 might anticipate they will lose if Player 1 dopes. This does not mean, however, that social norms are not an important part of the picture. We have seen that social norms can quite dramatically change the strategic incentives to dope. If this can be harnessed together with other interventions then it may be possible to reduce doping.

2.4 Doping Games with Punishment

The basic objective of current anti-doping policy is clearly to test athletes and punish those caught doping. There are, though, an almost limitless number of ways in which a punishment policy can work. [4]

A benchmark for comparison is a policy in which all athletes have the same chance of being tested and face the same fine if caught doping. In this case we can think of each athlete being independently tested with probability h. If they are tested and have doped then there is probability g the test will be positive. And if the test is positive they get fine F. The expected punishment of someone who dopes is then hgF. This punishment would be a key component of the cost of doping c.

To illustrate, Table 2.8 shows what happens if we rewrite the game in Table 2.3 to explicitly take account of the punishment. In this reformulated version c' stands for 'other' costs such as health costs and the psychological cost of cheating

[4] Note that we shall not distinguish, at this point, between financial penalties and non-financial sanctions, such as media backlash.

TABLE 2.8: Prisoners dilemma game with Punishment

		P2 No Dope	P2 Dope
P1	No Dope	$\frac{W}{2}, \frac{W}{2}$	$0, W - hgF - c'$
	Dope	$W - hgF - c', 0$	$\frac{W}{2} - hgF - c', \frac{W}{2} - hgF - c'$

A standard result in the economics of crime suggests variance between increases in the probability of being caught and level of fine. For instance, doubling the probability an athlete will test positive gives the same expected effect as doubling the fine; both double hgF[5]. This suggests that, given the difficulties in detecting performance enhance drugs, the easiest and most effective way to deter doping is to increase the fine for those caught. In this case, Not doping is optimal for Player 1 if.

$$\frac{W}{2} > W - hgF - c' \tag{2.28}$$

Which can be reduced to.

$$F > \frac{W - c'}{2hg} \tag{2.29}$$

Therefore if the fine is sufficiently high then it can induce a no-doping equilibrium.

While the current punishment for those caught doping does often seem quite lenient, considering that elite level athletes are not completely removed from the competition pool for the entirety of their career should they fall foul of WADA rules surrounding doping practises.

However, attempting to modify current rules to deter may athletes in such a manner may present difficulties. One difficulty may be the credibility of

[5]This in variance is highly dependent on an assumption of risk neutrality.

threatening a significant punishment, like removing the athlete from all future participation. This penalty may not seem like much of a punishment to a young athlete with little chance of making it into the top echelons of the sport and may not act as a deterrent. Imposing a large punishment that acts as a deterrent is therefore easier said than done.

These problems become even more acute if there is asymmetry in ability or the possibility that an athlete will test positive even if they did not dope (Berentsen 2002). To illustrate the point let us reconsider the asymmetric ability game of table 2.5 and suppose that with probability g_F a a test will reveal a false positive and so say someone doped when they did not. The payoff matrix for this example is somewhat messy and so we shall focus purely on the possibility of maintaining a no-doping equilibrium

Consider the incentives for Player 2. Even though they do not dope, Player 2 still has the probability hg_F of testing positive. The expected payoff for Payer 2 is

$$u_2 = (1-p)W - hg_F F \tag{2.30}$$

In this case if $u_2 < 0$ then it is better in expected value terms for Player 2 to simply avoid participating in the game and we would have no contest. In this case we must assume that $u_2 > 0$ for competition to occur. This imposes a lower bound on F such that

$$F < \frac{(1-p)W}{hg_F} \tag{2.31}$$

Now consider Player 1. If Player 1 does not dope then their expected payoff is $u_{BnD} = pW - hg_F F$. If Player 1 does decide to dope then their expected payoff is $u_{BD} = (P + \delta_1)W - hgF - c'$. Allowing for $u_{BD} < u_{BnD}$ gives us the constraint.

TABLE 2.9: Prisoners dilemma game with Punishment

		P2 No Dope	P2 Dope
P1	No Dope	$\frac{W}{2}, \frac{W}{2}$	$hgW, W(1-hg)-c'$
	Dope	$W(1-hg)-c', hgW$	$\frac{W(1-h^2g^2)}{2}-c', \frac{W(1-h^2g^2)}{2}-c'$

$$F > \frac{\delta_1 W - c'}{h(g - g_F)} \tag{2.32}$$

The main issue faced is that it is impossible to satisfy both the participation constraint and the incentive constraint. This will, for instance, be the case if g_F is close to g which is not an unlikely outcome given the difficulty of testing for banned substances. This illustration shows that is very difficult to create a punishment system that is harsh enough to deter deter doping while not being too harsh to deter athletes taking part at all. Again, this comes back to basic issues regarding the credibility of harsh punishment. Punishment of losers, or non-dopers, may simply be impossible or counter-productive. This naturally leads to alternative formulations in which the fine and/or probability of detection depend on the performance of the athlete (Berentsen 2002). This, however, creates a different type of problem.

To illustrate the difficulties with a variable punishment system suppose that if the winning athlete tests positive (and the 2nd placed athlete does not) then the winning prize automatically goes to the second placed athlete.

If the second placed athlete tests positive for an illegal substance then there is no punishment and we then end up with the outcome outlined in table 2.11. In this case Player 1 dopes and Player 2 does not, then with the probability hg Player 1 is caught doping and Player 2 is awarded the Prize, W.

If both decide to dope then the issue becomes slightly more complicated, there is a 50% chance that Player 1 wins and a probability $1 - hg$ that Player 1 passes the doping test then keeps the prize. There is also a 50% chance that Player 2 wins and with the probability $hg(1 - hg)$ they will test positive for using an illegal substance whilst Player 1 does not.

Therefore the probability of Player 1 receiving the prize is $\frac{1}{2}(1 - hg) + \frac{1}{2}hg(1 - h)$

Taking away prize money is more credible than an arbitrarily large fine and should not deter participation. But, how high must the probability of detection be to sustain a no-doping equilibrium? If Player 2 does not dope then Player 1 would prefer to also not dope if

$$\frac{W}{2} > W(1 - hg) - c' \tag{2.33}$$

Which re-arranges to

$$hg > \frac{1}{2} - \frac{c'}{W} \tag{2.34}$$

Clearly, the current record on doping tests would suggest that a probability of detection anywhere near 50 percent is simply not possible for many types of performance enhancing drugs (particularly if we want to avoid false positives). If this form of deterrent is to work it is, therefore, essential that other costs of doping, c', must be sufficiently high. However, this is not something that is directly under the control of the doping authorities.

There are many different punishment mechanisms that one can envisage. The proceeding discussion demonstrates, however, the difficulties in designing a mechanism that works. We either need the fine to be non-credibly high or the probability of detection to be higher than is realistically possible. So, while punishment may seem like a simple solution, in reality it is not. We would, however, reiterate the message with which we finished the last section on the potential benefits of a multi-pronged approach to doping. Social norms may not be enough, by itself, and punishment may not be enough, by itself, but maybe the two in combination can be enough.

2.4.1 Punishment in a many Player game

If there are more than two athletes then some additional issues arise, or at least become more prominent.

We saw above that the possibility of false positive tests could mean an athlete does best to withdraw from competition. False positives are not, though, the only reason an athlete might withdraw from competition. To illustrate consider the following two stage game. In the first stage each of n athletes independently decide whether or not to take part in the competition. Taking part incurs a cost in terms of time and effort of K. Let m denote the number of athletes who take part. In the second stage of the game the m athletes taking part compete for the prize and have the opportunity to dope. Note that this second stage is identical to the situation we considered in Section 2.1.2

Applying the analysis from Section 2.1.2 we have a pivotal threshold of doping

$$d^\star = \frac{W}{hgF + c'} - 1 \tag{2.35}$$

If $m > d^\star$ then we can expect $d^\star$ athletes to dope and for expected payoffs in this second stage to be zero. if $m < d^\star$ then every athlete dopes and expected payoffs are $\frac{W}{m} - hgF - c'$. It clearly only makes sense for an athlete to participate in the competition if he expects to recoup the cost K of taking part. This only happens if less than $d^\star$ athletes take part. Indeed, we need

$$\frac{W}{m} - hgF - c' > K \tag{2.36}$$

This implies that

$$m^\star < \frac{W}{K + hgF + c'} \tag{2.37}$$

Therefore if we increase the level of expected punishment, hgF then the level of $d^\star$ falls. Upon face value it might seem like there is lower levels of doping, however the critical factor is $m^\star$. As the size of punishment increases the equilibrium number of athletes that take part will decrease. This indirectly reduces the number of athletes doping, because every athlete taking part is predicted to dope. But, it is not really clear that this outcome is ideal. On the one hand, the fewer the number of athletes who dope then the less the overall damage to health. Ideally, though, we would also like to increase the chances of someone winning without doping. And this does not happen. Instead, athletes are simply driven away from competing.

The preceding example illustrates a more general principle regarding the possible consequences of sanctions. Namely, that we not only need to think of the direct and immediate effect that sanctions have on existing athletes but also the consequences they have for potential future athletes. If punishments work so well that they eliminate (or significantly reduce) doping then this will surely have a positive effect on the number of athletes competing. If, however, sanctions prove largely ineffective then they may well reduce the number of athletes competing (Hirschmann 2015). This is because a young athlete not only needs to enter a sporting world where doping is present but also has to contend with the potential costs of punishment.

The consequences of self-selection into professional sport are potentially very worrying. In particular, it is those young athletes with the strongest norms against doping that are likely to go elsewhere, while those with the weakest norms stay. This may exasperate efforts to reduce doping in sport. We see yet another reason, therefore, why punishments may not be a simple solution to doping.

2.5 Conclusions

There are two key lessons to draw from this chapter. First, the fact that many athletes dope does not preclude the possibility that all athletes would prefer a world in which there is no doping. Incentives encourage athletes to dope even though they would prefer clean sport. It is, therefore, far too simplistic to simplify vilify athletes for cheating. Instead, we need to recognize the social dilemma that is taking place and appreciate that doping in sport is an institutional problem. Clearly that does not mean we should turn a blind eye to athletes who cheat and lie. It does, though, mean we need to view the problem at an institutional and social level rather than being overly focused on individual athletes.

Given that doping is a dead-weight loss there are very strong arguments for policy intervention to reduce doping. In particular, athletes would choose to have a system where doping is eradicated, even if that system involves costs. We do not, therefore, support calls for the complete liberalization of doping rules. The second key thing we have learned in this chapter, however, is that there is no simple fix for doping. Social norms and doping sanctions are unlikely to be enough, on their own, to eradicate doping.

Chapter 3

Doping as a continuum

3.1 Introduction

The use of performance enhancing drugs has long been the biggest problem facing sports administrators in relation to cheating (Preston and Szymanski 2003). And it is a problem that clearly refuses to go away, despite the ever more concerted efforts of administrating bodies such as the World Anti-Doping Agency (WADA). Indeed, there seems a never-ending cycle of scandals, intrigue and accusations, whether it be state sponsored doping by the Russians, the UK Anti-Doping investigation of Team Sky, or Justin Gatlin winning 100m World Championship gold despite twice being banned in the past for doping violations. There are also constant advances in the methods available to dopers with breakthroughs in biological, bio-molecular and biochemical research. Doping in sport provides, therefore, a fascinating case study on the difficulties of regulating and controlling cheating in a high-stakes environment.

The decision to dope is clearly a multi-faceted one that will depend on individual characteristics, such as willingness to deceive, and cultural characteristics, such as the prevailing norms within a sport or training camp (Ntoumanis et al. 2014). Strategic incentives are, though, likely to prove especially important. In particular, whether it be an elite athlete competing for world fame (and multi-million pound sponsorship deals) or a lower level athlete competing for a place on the team (and enough money to 'pay the bills') the financial incentives for illicit behavior are clear. And a crucial thing to recognize is the inter-dependence between athletes; as one athlete decides whether to dope in order to get ahead of, or keep up with, competitors, those same competitors are independently also deciding whether to dope.[1] We end up, therefore, with a strategic game (Breivik 1987, Haugen 2004).

This chapter adds to the growing body of work that draws on game theory to analyze doping in sport. The key novelty in our approach is to model doping as an all pay auction. Specifically, we consider a two stage game in which players first choose how much to dope and then choose how much effort to exert in training. The combination of ability, doping and effort determine a player's score. Players with the highest score win prizes (where we allow that there may be more than one prize). Because doping and effort costs are sunk and those with the highest scores win we have an all pay auction. Interestingly, the literature on all pay auctions often uses sport to provide motivating examples (e.g. Cohen and Sela 2008, Minchuk and Sela 2014, Franke et al. 2014). The literature on doping in sport has, however, not, to the best of our knowledge, used an all pay auction approach.

We apply a seminal result on all pay auctions due to Siegel (2009) to determine equilibrium levels of doping. The crucial advantage of the Siegel (2009) result is that it allows us to determine expected payoffs without having to explicitly solve for equilibrium effort levels. This means that we can focus our attention on doping decisions and consider a very general framework. We begin our analysis by deriving conditions under which there exists an

[1]For instance, the highest finish for a rider competing in the grand classification of the Tour de France, between 1998 and 2006, who has never been implicating in doping was fourth. Or consider the woman's 1500m race at the 2012 London Olympics, the 'dirtiest race in history', in which 6 of the top 9 athletes have since been found guilty of doping.

equilibrium with no doping. As one would expect this critically depends on the costs to doping. We then look at equilibria with doping. Through a series of examples we show that, depending on the costs and returns from doping, anything is possible. For instance, counter-intuitively, the unique equilibrium may involve a less able player doping while a more able player 'gives up'. We also demonstrate, however, that the doping profile will take a particular form in which those 'close to the margin' are most likely to dope. So, informally, the most able and least able athletes are not predicted to dope but those 'in the middle' are.

One contribution of our analysis is to demonstrate the coordination aspect of strategic doping. To explain, one of our results is that the equilibrium number of players who dope is at most the number of prizes that can be won. So, if there are, say, 10 prizes corresponding to 10 places for funding by a national sports association, then at most 10 athletes will dope. There could, though, be considerable ambiguity over who the dopers will be. Differences in ability provide some guide but there are still likely to be multiple equilibria. This suggests that doping in sport is similar to market entry or congestion games in which players need to coordinate (e.g. Rapoport, Seale and Winter 2000, 2002, Selten et al. 2007). How athletes can 'coordinate' on doping is unclear but, as we discuss in the conclusion, sequential doping choice in which junior athletes take as given the doping decisions of older athletes is one possibility. Another possibility is that factors such as nationality or stage in career become focal norms for doping. Both these things can give rise to cycles in doping behavior over time.

There is a large theoretical literature on doping in sport (Dilger, Frick and Tolsdorf 2007). One strand of the literature focuses exclusively on the doping decision and, in doing so, abstracts away from the choice of effort (e.g. Breivik 1987, Bird and Wagner 1997, Berentsen 2002, Haugen 2004, Eber 2008, Stowe and Gilpatric 2010 and Haugen, Nepusz and Petróczi 2013). This work has given crucial insight on how the incentive to dope depends on competitive forces. By construction, though, it can say nothing about the interplay between doping and effort. Another strand of literature looks at doping and effort in combination, using contest theory (e.g. Krakel 2007, Gilpatric 2011, Ryvkin 2013, Mohan and Hazari 2016). Our paper complements this literature, but must not be seen as a direct replacement due to the simplicity of the threashold analysis.

The difficulty with the contest theory approach is that fairly specific functional forms (e.g. Krakel 2007, Gilpatric 2011) or strong assumptions such as homogeneity (Ryvkin 2013) are necessary to obtain results. This makes it a challenge to obtain a flexible approach that can yield general insight. We would argue that our approach offers flexibility and tractability, and can easily be applied to look at a range of policy interventions. Hence, it is a key contribution to the literature. In making this claim we should acknowledge that our approach relies on two key assumptions, namely a strict separation between doping and effort decisions. We shall motivate both assumptions in due course. But, a general point we would make, is the importance of having complementary approaches with which to study doping. Our paper provides a novel approach and, in so doing, moves us closer to this goal.

Before we proceed to the analysis we briefly highlight that, while our model is framed in terms of doping in sport, the potential applications are more general (Berentsen and Lengwiler 2004, Berentsen, Bruegger and Loertscher 2008). In particular, the incentive to circumvent rules is prevalent and rewarding in a wide variety of markets. For instance, within the labour market cheating could entail the willingness of employee to bribe customers or supervisors to increase their position in a hierarchical management structure

(Krakel 2007). Or, within education, individuals may collude in order to increase their ability on academic tests (McCabe, Treviño and Butterfield 2001). Note, however, that, because of the strict separation between cheating and effort, our model is only applicable to situations, like doping in sport, where cheating is planned and pre-meditated. So it fits better a case of, say, academic cheating where a scientist 'knew all along' that they would fabricate data than someone who has some 'bad luck' in the lab and impulsively fabricates data.

This chapter proceeds as follows: In Section 3.2 we introduce the model and notation. In Section 3.3 we solve for equilibrium payoffs in the competition stage of the game where players choose effort. In Section 3.4 we provide a range of results on equilibrium behavior in the doping stage. In Section 3.5 we conclude.

3.2 Model and notation

There are n players competing for prizes. Let $N = \{1, ..., n\}$ denote the set of players. Each player $i \in N$ is endowed with an ability level $a_i \geq 0$ where a high a_i indicates high ability. We refer to $a = \{a_1, ..., a_n\}$ as an ability profile. The ability profile a is assumed to be common knowledge and exogenously determined. For simplicity we assume that no two players have the same ability. Ability will, therefore, be the key source of heterogeneity in our model.

We consider a game with two stages. In the first stage all players $i \in N$ simultaneously choose how much to dope. Hence we refer to this as the *doping stage*. Let $d_i \geq 0$ denote the amount that player $i \in N$ dopes. In interpretation, $d_i = 0$ means that player i does not dope and $d_i > 0$ means he does. The higher is d_i then the higher the level of doping. Player i pays doping cost $f(d_i)$ where we assume that f is a strictly increasing function with $f(0) = 0$. Note that we do not impose any restrictions on d_i other than those implied by f. For instance, if there is a maximum feasible level of doping $\bar{d}$ then we can set $f(d) = \infty$ for all $d \geq \bar{d}$. We refer to $d = \{d_1, ..., d_n\}$ as a doping profile. Crucially, we assume that at the end of the doping stage the doping profile d is common knowledge. This assumption is discussed in more detail after we finish explaining the game.

In the second stage of the game all players $i \in N$ simultaneously choose an effort level. We refer to this as the *competition stage*. Let $e_i \geq 0$ denote the effort that player i exerts. In interpretation, $e_i = 0$ can be seen as a baseline level of effort and $e_i > 0$ more than this baseline. Player i pays effort cost $c(e_i|a_i, d_i)$ where c is an increasing function of e_i and a decreasing function of a_i and d_i. We shall sometimes write $c_i(e_i)$ where the i subscript recognizes the role of a_i and d_i. Note that doping works, in our model, by lowering the cost of effort. Broadly speaking there are two distinct ways that this can manifest itself. First, doping can lower the cost of achieving an effort level that would have been feasible without doping. Second, doping can allow an effort level that is not feasible without doping.[2] The scientific evidence would suggest that both effects are present although the first effect is more relevant for male competition and the second for female competition (Cooper 2013).

We refer to $e = \{e_1, ..., e_n\}$ as an effort profile. For some of our results we shall assume that doping is more effective the less able the player. Specifically,

Assumption 1: For any effort level $e > 0$, doping level $\delta > 0$ and abilities $a_i < a_j$ we assume that $c(e|a_i, d_i = 0) - c(e|a_i, d_i = \delta) \geq c(e|a_j, d_i = 0) - c(e|a_j, d_i = \delta) \geq 0$.

[2]For instance, we might have that $c(e_i|a_i, d) = \infty$ for all $e_i \geq \overline{e(d)}$ for some function $\overline{e(d)}$ that is increasing in d. So, doping pushes out the boundaries of achievable effort.

This assumption would seem broadly consistent with the scientific evidence (Cooper 2013). In particular, doping appears most effective in allowing a less able athlete to 'catch up' with more able athletes.

For each player $i \in N$ the ability a_i together with doping d_i and effort e_i determine a score given by $s_i(e_i, a_i, d_i)$. We assume that $s_i(e_i, a_i, d_i)$ is weakly increasing in all its arguments. Hence, effort, ability and doping combine to increase a player's score. Prizes are allocated on the basis of score. Specifically, the m players with the highest score receive prize V and the $n - m$ remaining players receive prize 0. In interpretation this might be athletes competing to win the 'gold medal' in which case $m = 1$ or it might be junior athletes competing for a 'place on the team' in which case $m > 1$. If scores are tied then we assume that each player in the tie has an equal chance of winning a prize.

Given ability profile a, doping profile d and effort profile e we can determine a score profile $s = \{s_1, s_2, ..., s_n\}$ and determine the expected prize of each player $\{v_1(s), v_2(s), ..., v_n(s)\}$. The final payoff of player $i \in N$ is given by

$$u_i(e, a, d) = v_i(s) - c(e_i|a_i, d_i) - f(d_i).$$

Thus, payoffs are the expected prize minus the cost of effort and the cost of doping. Our framework corresponds to that of an all-pay auction in that highest scores win and all effort and doping costs are sunk.

Throughout the following we shall draw on a parameterized version of the model to illustrate key results. In the example we set

$$c(e|a_i, d_i) = \frac{e - a_i}{1 + d_i}$$

and $s_i(e_i, a_i, d_i) = e_i$. Thus, score is determined by effort with ability and doping making it cheaper to achieve a particular level of effort. Note that this cost function satisfies Assumption 1. Also, we set $f(d_i) = \alpha + \beta d_i$ where α and β are the fixed and variable costs of doping. In this paper we do not explicitly model the role of punishment and of doping authorities but we can think of α and β as being partly under the control of the authorities. For instance, a tougher regime of testing and punishment could be expected to increase α and β. Given that we have claimed that a key advantage of our model is its flexibility, let us highlight that the results to follow are not specific to our parameterized version of the model.

One important thing to clarify about our model is the separation between doping and effort decisions. Our framework assumes that a player chooses whether to dope before they choose effort level. The actual doping may come in hand with effort it is just that the player knows both how much they will dope when choosing effort level and the level of doping that other competitors have chosen. One way to justify this assumption is to note that doping typically has long run effects and involves a sustained program of treatment. While there may be an athlete who 'pops a pill' before a major competition, most doping is far more sophisticated and involved (Huybers and Mazanov 2012). In particular it involves pre-commitment. This would suggest that doping is a conscious decision a person makes about how to proceed with their sporting career. Effort in training would then be adapted as appropriate.

Another critical assumption in our model is that doping decisions are common knowledge. This assumption may seem at direct odds with the inability of the authorities to enforce doping regulations. It does not seem, however, unrealistic to assume that athletes have a good idea about whether their fellow competitors are doping. The difficulty for the authorities is one of obtaining evidence that would stand up in a court of law. Accusations, for instance, about Lance Armstrong were around while he was winning the Tour de France, and his competitors seemed well aware he was doping. It just took time for the evidence to come out. More generally, when an athlete is caught doping the shock seems to be more that they got caught rather than that they were doping in the first place. So, while we recognize the assumption of common knowledge is an important one we think it can be justified as a reasonable approximation in many sports. We discuss this issue further in the conclusion.

3.3 Competition stage

In this section we focus on the competition stage. So, the ability profile $a = \{a_1, a_2, ..., a_n\}$ and doping profile $d = \{d_1, d_2, ..., d_n\}$ are taken as given and common knowledge. It remains for players to simultaneously choose effort level. Let e_i denote the effort level chosen by player i. This determines player i's score $s_i(e_i, a_i, d_i)$. With a slight abuse of notation we shall denote by $c(s_i|a_i, d_i) = c(e_i|a_i, d_i)$ the cost of reaching score s_i. Once we have the score profile $s = \{s_1, ..., s_n\}$ we can determine the expected prize $v_i(s)$ of any player $i \in N$. The payoff of player i in the competition stage can be written

$$\pi_i(s) = v_i(s) - c(s_i|a_i, d_i).$$

In our parameterized version this is given by

$$\pi_i(s) = v_i(s) - \frac{s_i - a_i}{1 + d_i}.$$

Note that doping costs can be ignored in the competition stage because they are made irrevocably in the doping stage.

The competition stage is an all pay auction fitting the framework analyzed by Siegel (2009). Following the approach of Siegel (2009), player i's *reach* is given by the highest score for which the cost of achieving that score equals the value of the prize. So, $r_i = max\{s_i \geq 0 | V = c(s_i|a_i, d_i)\}$. In our parameterized example we get

$$r_i = V(1 + d_i) + a_i$$

Our assumptions guarantee that a unique value for r_i exists for any values of a_i and d_i. Define a player as *marginal* if there are m players with a (weakly) higher reach and $n - m - 1$ players with a (weakly) lower reach. The threshold T of the competition stage is the reach of a marginal player. The threshold denotes the maximum bid of the last possible player to win a prize. Note that because of ties there may be more than one marginal player. This does not alter the value of the threshold but is critical, as we discuss shortly, if we wish to apply the results of Siegel (2009).

The threshold will depend on the ability profile a and doping profile d (but will not depend on the effort profile) and so we shall sometimes use the notation $T(a, d)$. Given ability profile a and doping profile d we say that effort profile e is the Nash equilibrium of the competition stage if no player can strictly gain from changing their effort level given the effort level of others. The following result follows directly from Theorem 1 of Siegel (2009).

Proposition 1: Consider any ability profile a and doping profile d for which the marginal player is unique. Then in any Nash equilibrium e of the competition stage the expected payoff of player i is given by $\pi_i(s) = max\{V - c(T(a, d)|a_i, d_i), 0\}$.

To illustrate the application of Proposition 1 consider our parameterized example. Let j be the marginal player, implying that $T = V(1 + d_j) + a_j$. The cost for player i of achieving the threshold is then $max\{(T - a_i)/(1 + d_i), 0\}$. If $a_i \geq T$ then the cost of achieving the threshold is 0 and the the expected equilibrium payoff of player i is V. If $a_i < T$ then the expected equilibrium payoff of player i is

$$\pi_i(s) = max\left\{V - \frac{T - a_i}{1 + d_i}, 0\right\} = max\left\{\frac{V(d_i - d_j) + a_i - a_j}{1 + d_i}, 0\right\}.$$

Observe that the expected payoff of player i is higher the bigger the gap in doping and ability between him and the marginal player. This provides the incentive to dope which will study more in the next section.

In interpretation of Proposition 1 we can think of the m players with highest reach as the 'winning players' because they have a positive payoff while the remaining $n - m$ players are the 'losing players' because their payoff is 0 (Siegel 2009). Note, however, that the equilibrium may involve mixed strategies and so in any realized outcome the winning players need not win a prize and the losing players may win a prize. We shall not delve further here into the effort levels that players choose. The crucial thing from our perspective is that Proposition 1 allows us to solve for equilibrium payoffs in the competition stage and thus determine optimal doping decisions.

Before we consider the doping stage let us briefly comment on the requirement that the marginal player be unique. This is necessary in order to apply the power condition of Siegel (2009). Without this condition there exists at least one Nash equilibrium as detailed in Proposition 1 but it can no longer be guaranteed that all Nash equilibrium are of this form (see Corollary 2 of Siegel 2009). In the setting of Siegel (2009) it is innocuous to assume that the marginal player is unique. It would be analogous, for instance, to saying that no two players have the same ability. Given, however, that in our setting players choose how much to dope we cannot automatically rule out the possibility that players would choose to have the same reach. This is something, therefore, that we need to verify when looking at the doping stage.

3.3.1 Parameterized model

In order to show the flexibility of our model, we briefly work through the parameterized models considered by Krakel (2007) and Gilpatric (2011).

Let us begin with Krakel (2007). In this case we can think of the the score of player i, for doping d_i, ability a_i and effort level e_i, as given by $s_i = (1+d_i)a_i e_i$. Note that Krakel (2007) considers a binary doping decision but we will not make that restriction here. The cost of effort is then given by $c(e|a_i, d_i) = ke^2/2$ for some parameter k. In this example we can see that the cost of effort does not depend on ability or doping. Instead doping works by increasing score for a given level of effort and ability. This means that assumption 1 is trivially satisfied.

Consider the competition stage. The key thing we need to do is determine the cost of reaching score s_i for player i. Taking a_i and d_i as given we need $e_i = s_i/(1+d_i)a_i$. Hence the cost of score s_i is

$$c(s_i|a_i, d_i) = \frac{k}{2}\left(\frac{s_i}{(1+d_i)a_i}\right)^2.$$

The reach of player i is then given by

$$r_i = (1+d_i)a_i\sqrt{\frac{2V}{k}}.$$

As in our parameterized example, reach is increasing in ability and doping. If player j is the marginal player we have threshold $T = (1+d_j)a_j\sqrt{2V/k}$. The cost for player i of achieving the threshold is then

$$c(T|a_i, d_i) = V\left(\frac{(1+d_j)a_j}{(1+d_i)a_i}\right)^2.$$

This means, applying Proposition 1, that the equilibrium payoff of player i is

$$\pi_i(s) = max\left\{V\left(1-\left(\frac{(1+d_j)a_j}{(1+d_i)a_i}\right)^2\right), 0\right\}.$$

As one would expect, the payoff of player i is increasing in own ability and doping. Interestingly, k drops out of the picture, primarily because it only serves to scale the amount of effort players would exert in equilibrium.

Once we know equilibrium payoffs in the competition stage we can proceed to analyze the doping stage as for our parameterized example. To very briefly illustrate, consider the incentive for athlete 1 to dope if other athletes do not dope. Moreover, suppose that athlete 1 would be a winning player even if he did not dope. Then player 1's payoff if he does not dope is $u(d_1 = 0, d_{-1}) = V(1-(a_0/a_1)^2)$ where a_0 is the ability of the marginal player. If he dopes his payoff is $u(d_1 > 0, d_{-1}) = V(1-(a_0/a_1(1+d_1))^2) - \alpha - \beta d_1$. Note that

$$\frac{\partial u_1(d_1, d_{-1})}{\partial d_1} = 2V\left(\frac{a_0}{a_1}\right)^2 \frac{1}{(1+d_1)^3} - \beta.$$

Ignoring boundary conditions, this gives

$$d_1^\star = \left(\frac{2V}{\beta}\right)^{\frac{1}{3}}\left(\frac{a_0}{a_1}\right)^{\frac{2}{3}} - 1. \tag{3.1}$$

If player 1 chooses $d_1^\star$ then his payoff would be

$$u_1(d_1^\star, d_{-1}) = V\left(1-\left(\frac{\beta a_0}{2Va_1}\right)^{\frac{2}{3}}\right) - \alpha - \beta d_1.$$

From this we can determine whether or not player 1 has an incentive to dope. For instance, if $\beta = 0$ then the optimal level of doping is arbitrarily large meaning that, if he chooses to dope, player 1 receives payoff $V - \alpha$. Thus, doping is only deterred if $\alpha > V(a_0/a_1)^2$. The higher the ability gap the less deterrence is required.

We turn now to the approach of Gilpatric (2011). Here we can think of the score of player i, with doping d_i, ability a_i and effort level e_i, as given by $s_i = a_i + e_i + d_i$. A generic cost function is assumed by Gilpatric (2011) and so let us retain cost function $c(e|a_i, d_i) = ke^2/2$. Again, this means that Assumption 1 is satisfied.

Consider the cost of reaching score s_i for player i. Taking a_i and d_i as given we need $e_i = max\{s_i - a_i - d_i, 0\}$. Hence the cost of score s_i is

$$c(s_i|a_i, d_i) = \frac{k(s_i - a_i - d_i)^2}{2}$$

if $s_i > a_i + d_i$. The reach of player i is then given by

$$r_i = \sqrt{\frac{2V}{k}} + a_i + d_i.$$

If player j is the marginal player we have threshold $T = \sqrt{2V/k} + a_j + d_j$. The cost for player i of achieving the threshold is then

$$c(T|a_i, d_i) = \frac{k}{2}\left(\sqrt{\frac{2V}{k}} + a_j - a_i + d_j - d_i\right)^2$$

if $T > a_i + d_i$. Otherwise it is 0. This means, applying Proposition 1, that the equilibrium payoff of player i is

$$\pi_i(s) = max\left\{V - \frac{k}{2}\left(\sqrt{\frac{2V}{k}} + a_j - a_i + d_j - d_i\right)^2, 0\right\}$$

if $T > a_i + d_i$. Otherwise we have $\pi_i(s) = V$. Again, the payoff of player i is increasing in the ability gap and doping gap between him and the marginal player.

The preceding analysis demonstrates that it is a relatively simple matter to determine payoffs in the competition stage, $\pi_i(s)$, for any specific example of a score and cost function. Once we know $\pi_i(s)$ the analysis can proceed to the doping stage. The ease of this will depend to a large extent on how 'simple' the equations come out and so a result as neat as Proposition 2 may not be possible. Recall, however, that the analysis and results of Section 3.2 is not specific to our parameterized example. Characterizing reach and the threshold is, therefore, enough of itself to gain key insight on doping incentives.

3.4 Doping stage

As this is a dynamic game, In this section we will focus on the doping stage in order to determine a subgame perfect Nash equilibrium. We do so with the assumption that payoffs in the competition stage will be as set out in Proposition 1. Thus, for any doping profile $\{d_1, ..., d_n\}$ we can associate a profile of expected competition payoffs $\{\pi_1(d), ..., \pi_n(d)\}$. This allows us to treat the doping stage as a game in which each player i chooses how much to dope knowing that his final payoff will be $\pi_i(d) - f(d_i)$ where d is the doping profile. We say that doping profile d is a *Subgame Perfect Nash equilibrium of the doping stage* if no player wants to change their doping decision given the decisions of others.

3.4.1 No doping equilibrium

We begin our analysis of the doping stage by exploring the conditions under which there exists a no doping equilibrium, i.e. a Nash equilibrium of the doping stage where $d_1 = ... = d_n = 0$. Without loss of generality we shall focus on player 1. So, of interest is to explore the incentives for player 1 to dope if $d_2 = d_3 = ... = d_n = 0$.

If player 1 does not dope then the threshold in the competition stage will be entirely determined by relative abilities. Specifically a player is marginal if there are m players with a (weekly) higher ability and $n - m - 1$ players with a lower ability. Thus, the m winning players will be the m players with highest ability and the $n - m$ losing players will be those with lowest ability. Note that in order for the marginal player to be unique it would be enough that no two players have the same ability. Let T_0 denote the reach of the marginal player. There are two cases for us to consider: (a) player 1 is in the set of m players with highest ability or (b) he is not. We consider each in turn.

If player 1 is in the set of m players with highest ability then he would be in the set of winning players if he chose not to dope. Applying Proposition 1, his expected payoff would be $u(d_1 = 0, d_{-1}) = V - c(T_0|a_1, d_1 = 0) > 0$. The potential advantage of doping is that it would lower the cost of achieving a high score. If he dopes $d_1^\star > 0$ then his expected payoff would be $u(d_1^\star, d_{-1}) = V - c(T_0|a_1, d_1^\star) - f(d_1^\star)$. It is, therefore, in his interest to dope if and only if there exists some $d_1^\star > 0$ such that

$$c(T_0|a_1, d_1 = 0) - c(T_0|a_1, d_1^\star) > f(d_1^\star). \tag{3.2}$$

In other words, the reduced cost of effort must compensate for the cost of doping.

To put this in context we can work through our parameterized example. In this case $T_0 = V + a_0$ where a_0 is the ability of the marginal player. If player 1 does not dope his expected payoff is simply $u(d_1 = 0, d_{-1}) = min\{a_1 - a_0, V\}$. Let $\Delta_0 = a_1 - a_0$. If $\Delta_0 \geq V$ then player 1 cannot possibly gain from doping because the gap in ability is already enough that his payoff will be V.

So, consider $\Delta_0 < V$. In this case, if he dopes $d_1 > 0$ then his expected payoff would be $u_1(d_1, d_{-1}) = (Vd_1 + \Delta_0)/(1 + d_1) - \alpha - \beta d_1$. Note that

$$\frac{\partial u_1(d_1, d_{-1})}{\partial d_1} = \frac{V - \Delta_0}{(1 + d_1)^2} - \beta.$$

So, if he dopes it is optimal for player 1 to set

$$d_1^\star = \frac{\sqrt{V - \Delta_0}}{\sqrt{\beta}} - 1. \tag{3.3}$$

Clearly this is only a feasible solution if $V - \Delta_0 > \beta$. If $V - \Delta_0 > \beta$ and player 1 chooses $d_1^\star$ then his payoff would be

$$u_1(d_1^\star, d_{-1}) = V - 2\sqrt{\beta(V - \Delta_0)} - \alpha + \beta.$$

Recall that $u(d_1 = 0, d_{-1}) = \Delta_0$. It is, therefore, optimal for player 1 to not dope if and only if

$$V - \Delta_0 - 2\sqrt{\beta(V - \Delta_0)} - \alpha + \beta \leq 0. \tag{3.4}$$

For instance, if $\beta = 0$ we require $V - \Delta_0 < \alpha$.

We shall revisit the example shortly. The key thing to highlight at this point is how the preceding discussion demonstrates that it can be in an athletes interest to dope even if he would be a winning player without doping. The intuition for this is that doping makes it easier for him to achieve the level that he would have been able to achieve with costly effort. Put another way, doping reduces the cost of the effort he needs to exert to be a winning player.

We now turn to the losing players. If player 1 is in the set of $n - m$ players with lowest ability then his expected payoff if he does not dope is $u(d_1 = 0, d_{-1}) = 0$. The potential advantage of doping is that it can elevate him to the set of winning players. If player 1 joins the set of winning players then the marginal player necessarily changes. Specifically, the player with the m'th highest ability would now become marginal, and no longer be a winning player. Note, that it is not in player 1's interest to 'match' the marginal player because then his expected prize would still be 0 but he would have the cost of doping. It is only in player 1's interest to dope, therefore, if he puts himself ahead of the marginal player. This is enough to rule out any tie for the marginal player (if ability is heterogeneous). Let $T_{00} > T_0$ denote the reach of the new marginal player.

If he dopes $d_1^\star > 0$ then player 1's expected payoff would be $u(d_1^\star, d_{-1}) = V - c(T_{00}|a_1, d_1^\star) - f(d_1^\star)$. It is, therefore, in his interest to dope if and only if there exists some $d_1^\star > 0$ such that

$$V > c(T_{00}|a_1, d_1^\star) + f(d_1^\star). \tag{3.5}$$

In other words, the prize from becoming a winning player must be sufficient to compensate for the cost of effort and the cost of doping. Let us highlight how the trade-offs for a losing player are different to those of a winning player in that doping *increases* the equilibrium cost of effort for the losing player while it decreases it for a winning player. This is because a losing player who dopes increases effort in order to secure the gain from doping.

In the parameterized example we have $T_{00} = V + a_{00}$ where a_{00} is the ability of the new marginal player. The first thing to consider is how much player 1 needs to dope in order to become a winning player. The reach of player 1 is $V(1 + d_1) + a_1$ while the reach of the marginal player is $V + a_{00}$. So, player 1 becomes a winning player if and only if

$$d_1 > \bar{d} = \frac{a_{00} - a_1}{V}.$$

For $d_1 > \bar{d}$ we have $u_1(d_1, d_{-1}) = (Vd_1 + a_1 - a_{00})/(1 + d_1) - \alpha - \beta d_1$. Let $\Delta_{00} = a_{00} - a_1$. Then

$$\frac{\partial u_1(d_1, d_{-1})}{\partial d_1} = \frac{V + \Delta_{00}}{(1 + d_1)^2} - \beta.$$

So, if he dopes it is optimal for player 1 to set

$$d_1^{\star\star} = \frac{\sqrt{V + \Delta_{00}}}{\sqrt{\beta}} - 1. \tag{3.6}$$

Setting $d_1^{\star\star} > \bar{d}$ gives condition $\beta < V/\sqrt{V + \Delta_{00}}$. Suppose that β is sufficiently small and player 1 chooses $d_1^{\star\star}$ then his payoff would be

$$u_1(d_1^{\star\star}, d_{-1}) = V - 2\sqrt{\beta(V + \Delta_{00})} - \alpha + \beta.$$

Recall that $u(d_1 = 0, d_{-1}) = 0$. It is, therefore, optimal for player 1 to not dope if and only if

$$V - 2\sqrt{\beta(V + \Delta_{00})} - \alpha + \beta \leq 0. \tag{3.7}$$

For instance, if $\beta = 0$ we require $V < \alpha$.

We have just seen that a losing player may have an incentive to dope in order to become a winning player. We previously saw that a winning player may have an incentive to dope in order to lower the costs of effort. Only if the costs of doping are sufficiently high will, therefore, we obtain a non-doping equilibrium. To bring the analysis together our next proposition provides a simple sufficient (not necessary) condition for the existence of a no-doping equilibrium in our parameterized example.

Proposition 2: There exists a no-doping subgame perfect Nash equilibrium of the doping stage, in the parameterized example, if $\sqrt{V} \leq \sqrt{\alpha} + \sqrt{\beta}$.

Proof: Consider first a winning player. We adopt the notation used above. A limiting case is $a_1 \approx a_0$ meaning that $\Delta_0 \approx 0$. It is clear that a player in this position would have most incentive to dope. (See Proposition 4, to follow, for a formal proof of this.) Applying equation (3.4) we know that he would not dope if $V - 2\sqrt{\beta V} - \alpha - \beta \leq 0$. This can be rewritten $(\sqrt{V} - \sqrt{\beta})^2 \leq \alpha$. We know this holds given that$\sqrt{V} \leq \sqrt{\alpha} + \sqrt{\beta}$. Consider next a losing player. Again, the limiting case is $a_1 \approx a_{00}$ meaning that $\Delta_{00} \approx 0$. It is clear that a player in this position would have most incentive to dope. (See Proposition 5 for a formal proof of this.) Applying equation (3.7) we know that he would not dope if $V - 2\sqrt{\beta V} - \alpha - \beta \leq 0$. The argument then follows through as for a winning player. QED

Whilst Proposition 1 is specific to our parameterized example, it illustrates how equations (3.2) and (3.5) can be applied to yield insight. In particular, Proposition 2 gives an easily interpretable condition on the required costs of doping necessary to make no-doping an equilibrium. One interesting element of Proposition 2 is that the number of players, n, and number of prizes, m, drop out of the story. Technically speaking this is because we provide sufficient and not necessary conditions. There is, though, a more general lesson that can be discerned in this regard, as we now discuss.

The crucial thing that determines incentives is the relative advantage (or disadvantage) a player has compared to the marginal player. This means that the gap between the m'th most able player and the $m + 1$'st most able player is all important. If that marginal ability gap is large then there is little incentive to dope. If that gap is small then there is more incentive to dope. The values of n and m only matter through the effect they have on the marginal ability gap. Intuitively, one would expect that an increase in the number of players lowers the marginal ability gap.[3] Similarly, if high ability is more exceptional then an increase in m could be expected to lower the marginal ability gap. In Proposition 2 we assume the gap is zero and so provide an upper bound on how large the costs of doping must be to deter doping.

3.4.2 Doping equilibrium

In this sub-section we look at conditions under which there will be players who dope. We have already discussed the incentives to dope if others do not dope. Here we focus more on the incentives to dope if others dope. The following result is trivial but important in interpretation.

Proposition 3: If doping profile $d = \{d_1, ..., d_n\}$ is a Nash equilibrium of the doping stage and $d_i > 0$ then $\pi_i(d) > 0$.

Proof: Suppose, to the contrary, that $d_i > 0$ and $\pi_i(d) = 0$. The overall payoff of player i is $u_i(d) = -f(d_i)$. Recall that f is a strictly increasing function with $f(0) = 0$. So $u_i(d) < 0$. If player i were to not dope then his payoff would be $u_i(d_i = 0, d_{-i}) \geq 0$. QED

Proposition 3 implies that if, in equilibrium, a player dopes then he must be a winning player. Crucially, this implies that at most m players will dope. It is interesting to reflect that this finding differs from the standard prisoners dilemma type argument that all players will dope (e.g. Berentsen 2002; Haugen 2004). The primary difference is the possibility of ties. In our setting, no two players will have the same score and there is nothing to be gained from having the $m + 1$ highest score. In other settings ties are possible (Haugen 2004) or score has a random component (e.g. Gilpatric 2011). Both these

[3] It need not. To illustrate suppose that initially there are 5 players with high ability and 5 players with low ability and $m = 6$. Then the marginal ability gap is small. Now add another higher ability player, keeping $m = 6$. Then the marginal ability gap has increased.

things can mean that mean that more than m players dope in equilibrium. The more interesting question in our model will be whether less than m players dope meaning that some winning players do not dope.

Propositions 2 and 3 leave open the possibility that anything between 0 and m players could dope. To illustrate the distinct ways in which doping can arise in equilibrium it is useful to contrast possible outcomes in the parameterized example, where we focus on the simplest case of $m = 1$ and $n = 2$, meaning that there are two players competing for one prize. Suppose that $a_1 > a_2$ and so player 1 is the more able player. To simplify the exposition we shall pay particular attention to the situation in which player 1 chooses between $d_1 = 0$ and $d_1 = d_1^\star$ and player 2 chooses between $d_2 = 0$ and $d_2 = d_2^\star$ (where $d_1^\star$ and $d_2^\star$ are given by equations (3.3) and (3.6)).

Consider, first parameters $V = 1, \beta = 0.01, a_1 - a_2 = 0.5$ and $\alpha = 0.1$. Table 1 details the payoffs for six possible outcomes. We want to argue that *there exists no (pure strategy) Nash equilibrium of the doping stage*. To make the case, note that if player 1 does not dope then player 2 has an incentive to dope in order to become the winning player. The logic for this was discussed in the previous section. More relevant here is to look at the optimal response of player 1 if player 2 chooses $d_2^\star = 11.25$. It turns out that the optimal response would be for player 1 to dope himself and choose $d_1 = 33.1$. If player 1 dopes as much as this then the optimal strategy for player 2 is to not dope at all. But, if player 2 does not dope then it is optimal for player 1 to choose $d_1^\star$. And, if player 1 chooses $d_1^\star$ then it is optimal for player 2 to dope. Table 1, together with Proposition 3, is enough to tell us that there exists no pure strategy equilibrium in this game.

The primary reason that there exists no equilibrium in the preceding example is that the cost of doping is relatively small. Keeping everything else the same suppose that we increase α to 0.2 and β to 0.05. Table 2 details the payoffs in

TABLE 3.1: Payoffs in the doping stage when $V = 1, \beta = 0.01, \Delta_0 = 0.5$ and $\alpha = 0.1$.

		Player 2	
		0	$d_2^\star = 11.25$
Player 1	0	0.5, 0	0, 0.67
	$d_1^\star = 6.07$	0.77, 0	-0.16, 0.17
	33.1	0.55, 0	0.22, -0.21

TABLE 3.2: Payoffs in the doping stage when $V = 1, \beta = 0.05, \Delta_0 = 0.5$ and $\alpha = 0.1$.

			Player 2	
		0	$d_2^\star = 4$	7.56
Player 1	0	0.5, 0	0, 0.30	0, 0.25
	$d_1^\star = 1.89$	0.53, 0	-0.31, -0.09	-0.31, -0.01
	8.98	0.30, 0	-0.15, -0.42	-0.46, -0.58

this case. Here we can see that there are two Nash equilibria of the doping stage. In particular, if player 2 dopes $d_2^\star = 4$ then the optimal strategy of player 1 is to not dope.[4] This means we have an equilibrium where player 2 dopes and becomes the winning player. If player 2 does not dope then it is optimal for player 1 to dope. And if player 1 dopes $d_1^\star = 1.89$ then it is optimal for player 2 to not dope.[5] So, we have an equilibrium where player 1 dopes and reduces the cost of effort.

The game we obtain in Table 2 is a form of the 'chicken' game. There is an *equilibrium where player* 1 *dopes and reduces the cost of effort* and there is an *equilibrium where player* 2 *dopes in order to become a winning player*. Clearly, equilibrium in this case requires an element of coordination because one, and only one, player should dope.

To complete the picture we provide two further examples. In our next example there exists a *unique equilibrium where the more able player dopes*. We set $\alpha = 0$ meaning that there is no fixed cost of doping but $\beta = 0.45$ meaning a relatively high marginal cost. The low fixed cost incentivizes the more able

[4]The optimal strategy of player 1 if we set $d_1 > 0$ is to choose $d_1 = 8.98$. As you can see in Table 2 this does not yield a positive payoff and so it is optimal to set $d_1 = 0$.

[5]In this case the optimal doping level if we set $d_2 > 0$ would be $d_2 = 7.56$.

TABLE 3.3: Payoffs in the doping stage when $V = 1, \beta = 0.45, \Delta_0 = 0.5$ and $\alpha = 0$.

		Player 2		
		0	$d_2^\star = 0.83$	0.86
Player 1	0	0.5, 0	0, -0.19	0, -0.19
	$d_1^\star = 0.05$	0.501, 0	-0.02, -0.22	-0.02, -0.22
	0.72	0.39, 0	-0.09, -0.37	-0.11, -0.39

TABLE 3.4: Payoffs in the doping stage when $V = 1, \beta = 0.01, \Delta_0 = 0.5$ and $\alpha = 0.4$.

		Player 2		
		0	$d_2^\star = 11.2$	26.5
Player 1	0	0.5, 0	0, 0.37	0, 0.28
	$d_1^\star = 6.07$	0.47, 0	-0.46, -0.13	-0.46, 0.06
	33.3	0.25, 0	-0.08, -0.51	-0.52, -0.67

player to dope in order to reduce the cost of effort. The high marginal cost means that the less able player cannot gain from doping because it is simply too expensive to dope enough to overcome the ability gap. The payoffs are given in Table 3.3.

In the next example there exists a *unique equilibrium where the less able player dopes*. We set $\alpha = 0.4$ meaning that there is a high fixed cost of doping but $\beta = 0.01$ meaning a relatively low marginal cost. The high fixed cost deters the more able player from doping. The low marginal cost means that the less able player can gain from doping. In particular, the payoff gain from becoming a winning player is enough to offset the high fixed cost of doping. The payoffs are given in Table 3.4. That we obtain a unique equilibrium in which the more able player is the losing player may seem perverse. The intuition, however, is relatively straightforward. Essentially, the more able player can tell the less able player has an incentive to dope. And if the less able player dopes then the more able player has nothing to gain from a doping arms race.

Before we move on from the two player case let us highlight that in all the preceding examples the values of V and δ_0 were left unchanged. Changing the values of α and β was enough, therefore, to generate a wide range of equilibrium outcomes. This has crucial implications if we think of policy as partly determining α and β. In particular, it shows that policy is not just about deterring doping but also about influencing the forms that doping may take. For instance, the political and legal realities may make it impossible to simply increase α and β to the point where nobody wants to dope. Instead, the authorities may have to trade-off changes in the fixed cost, α, with marginal cost, β. Our last example illustrates that, if we consider it undesirable that the less able player dopes to get ahead, we need to raise the marginal cost of doping, rather than focus on the fixed cost of doping. We will return to this point in the conclusion.

We have now looked at four specific examples and seen that anything is possible. We can have a unique equilibrium where the more able player dopes, no equilibrium, etc. An 'anything goes' result in the simplest two player setting of our parameterized example may suggest it is difficult to say much in the general case. Note, however, that in the two player case, the losing player is, by definition, the marginal player and the winning player is 'just' above the margin. We are automatically, therefore, focusing in on the the most crucial interaction. This allows us to move relatively easily to the many player setting.

3.4.3 Threshold analysis

To illustrate, consider a very trivial example. We set $n = 4$ and $m = 2$ and so there are four players competing for two prizes. For instance, it might be athletes competing for a place on the Olympic squad. Suppose that $a_1 = 100, a_2 = 50.5, a_3 = 50$ and $a_4 = 0$. Recall that in the parameterized example the reach of player i is given by $r_i = V(1 + d_i) + a_i$. It is also worth noting that in the four games we have just looked at we never had reason to consider $d_i > 40$. This all means that player 1 is so far ahead in terms of ability that he will be a winning player and has no reason to dope. Even if other players decided to use maximized doping strategies to reduce their cost of effort and increase their score, they would not be able to outbid player 1 in the auction stage.

Similarly, player 4 is so far behind in terms of ability that he will be a losing player who has no reason to dope. The interest, in terms of doping, comes, therefore, between players 2 and 3, where $a_2 - a_3 = 0.5$. This is where the real competition for squad places is going to be won and lost and the two player case is enough to give insight on this competition.

Our next two results apply to the many player general case and show that players closest to the margin in terms of ability are 'most likely' to dope. There are two sides to this. First, consider two players i and j where $a_i > a_j > a_0$ and a_0 is the ability of the marginal player. Here the focus is on relatively able players. We show that if there is an equilibrium in which player i dopes, then so does player j. Hence, players who are above the marginal player in terms of ability, but may be superseded by the marginal player should they decide to enact doping, have the 'most' incentives to dope.

Proposition 4: Suppose that players are ordered in terms of ability so that $a_1 > a_2 > ... > a_n$. Also, suppose that doping profile $d^\star$ is a Nash equilibrium of the doping stage and player l is the marginal player. If Assumption 1 holds and $d_i^\star > 0$ for some player $i < l$ then $d_j^\star > 0$ for any player $i < j < l$.

Proof: Take as given a Nash equilibrium of the doping stage $d^\star = \{d_1^\star, ..., d_n^\star\}$ with marginal player l. Suppose $d_i^\star > 0$ for some $i \in N$ where $i < l$. Pick any player $i < j < l$. If no such player exists or $d_j^\star > 0$ then we are done. So, suppose $d_j^\star = 0$. Proposition 3 implies that $d_l^\star = 0$. This, given that $a_j < a_l$, means that player l is a winning player whatever the level of d_j. This, in turn, means the threshold $T(a, d^\star)$ is independent of d_j. Applying

Proposition 1 we then have that $\pi_k(d^\star)$ for all $k \neq j$ is also independent of d_j. We can, therefore, change d_j without in any way effecting the payoffs or incentives of any player other than j.

Player j's expected payoff is $u(d_j^\star = 0, d_{-j}^\star) = V - c(T|a_j, d_j = 0)$ where T is the threshold. Player j may gain from doping if it reduces the cost of effort. Suppose that we set $d_j = d_i^\star$. Then his expected payoff would be $u(d_i^\star, d_{-j}^\star) = V - c(T|a_j, d_j = d_i^\star) - f(d_i^\star)$. Given that player i chooses to dope we know that $c(T|a_i, d_i = 0) - c(T|a_i, d_i = d_i^\star) > f(d_1^\star)$. Because, $a_j < a_i$ we have, by Assumption 1, that $c(T|a_j, d_j = 0) - c(T|a_j, d_j = d_i^\star) > f(d_1^\star)$. This means that it cannot be optimal for player j to set $d_j = 0$. QED

For our next result consider two players i and j where $a_i < a_j < a_0$. Here the focus is on relatively less able players. We show that if there is a Nash equilibrium of the doping stage where player i dopes then there must exist an equilibrium (not necessarily the same one) where player j dopes. Hence, players just below the marginal player in terms of ability have 'most' incentive to dope.

Proposition 5: Suppose that players are ordered in terms of ability so that $a_1 > a_2 > ... > a_n$. Also suppose that doping profile $d^\star$ is a Nash equilibrium of the doping stage and player l is the marginal player. If $d_i^\star > 0$ for some player $i > l$ then for any player j such that $i > j > l$ there exists an equilibrium d^1 where $d_j^1 > 0$.

Proof: Take as given a Nash equilibrium of the doping stage $d^\star = \{d_1^\star, ..., d_n^\star\}$ with marginal player l. Suppose $d_i^\star > 0$ for some $i > l$. Pick any player $i > j > l$. If no such player exists or $d_j^\star > 0$ then we are done. So, suppose $d_j^\star = 0$. Consider the doping profile d^1 in which $d_i^1 = 0$, $d_k^1 = d_k^\star$ for all $k \neq i, j$ and d_j^1 is set to maximize payoff (given d_{-j}^1). Note that we have essentially switched players i and j.

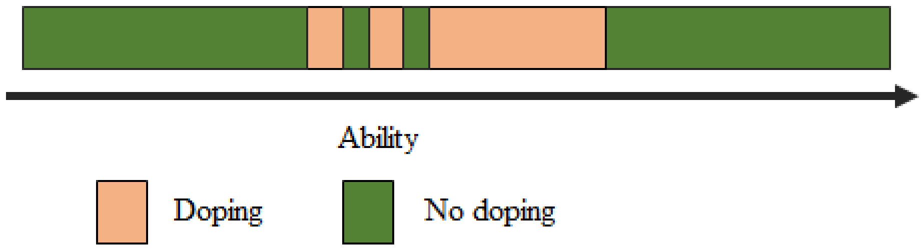
Assume, for now, that player l is the marginal player given doping profile d^1. Then $T(a, d^\star) = T(a, d^1)$ and so, applying Proposition 1, the incentives of all players $k \neq i, j$ are the same given doping profile d^1 as $d^\star$. It remains, therefore, to check the incentives of players i and j and check that player l does indeed remain the marginal player.

Consider player j. If player j does not dope then his payoff will be 0. So, it is optimal for player j to dope if there exists $d_j^1 > 0$ such that $V > c(T(a, d^\star)|a_j, d_j^1) + f(d_j^1)$. Given that $d^\star$ is a Nash equilibrium we know that $V > c(T(a, d^\star)|a_i, d_i^\star) + f(d_i^\star)$. Moreover, $a_j > a_i$. So, given that c is a decreasing function of ability, implies that $c(T(a, d^\star)|a_i, d_i^\star) > c(T(a, d^\star)|a_j, d_i^\star)$. This proves that it is optimal for player j to dope.

Consider next player i and strategy profile d^1. If player i does not dope then his payoff will be 0. If he did dope in order to become a winning player then the marginal player would necessarily change. Let T^1 denote the revised threshold. In order for d^1 to be a Nash equilibrium, it must be that there exists no $d_i > 0$ such that $V > c(T^1|a_i, d_i) + f(d_i)$. Given that $d^\star$ is a Nash equilibrium we know that there exists no $d_j > 0$ such that $V > c(T^1|a_j, d_j) + f(d_j)$. Also, $c(T^1|a_i, d_i) > c(T^1|a_j, d_i)$ for all $d_i > 0$. This proves that it is optimal for player i to not dope. Moreover, we can see that player l remains the marginal player. QED

Note the slight asymmetry between Propositions 4 and 5. With Proposition 4 we find that *every player* within a certain ability range above that of the marginal player is predicted to dope. The intuition behind this result is that doping reduces the cost of being a winning player, for someone who was destined to be a winning player anyway. Assumption 1 means that those of lowest ability gain most from doping and so those just above the margin have most incentive to dope. With Proposition 5 we find that *some players*

FIGURE 3.1: Schematic of a possible Nash equilibrium outcome.



within a certain ability range below that of the marginal player are predicted to dope. Here we obtain a market entry, 'chicken' type environment in which players need to coordinate on who dopes. The intuition here is that players who dope are going to be winning players but there can only be so many winning players meaning that an element of coordination is required.

A highly stylized schematic of the kind of outcome we might obtain is depicted in Figure 3.1. Here we see that the most able and least able players do not dope. We then obtain a region 'in the middle' with a mix of dopers and non-dopers. Clearly, given Proposition 3, we know that the number of prizes is crucial. In particular, the kind of outcome we depict in Figure 3.1 is dependent on there being a lot of prizes on offer. Again, however, we would reiterate the different levels at which doping can take place. Winning gold is obviously a strong incentive but many athletes who dope are on the margins of being a professional or making it to the Olympics. It is at this level that the outcome depicted in figure 3.1 is most apt. It clearly shows that incentives to dope can interact in non-trivial ways with ability and success.

3.5 Concluding discussion

In this paper we have proposed a new model to analyze doping in sport. The model consists of two stages in which athletes choose their level of doping and then level of effort. Payoffs are subsequently determined through an all pay auction where 'score' depends on ability, doping and effort. By using a seminal result due to Siegel (2009) we are able to obtain general insight on the incentives to dope. Indeed a key contribution of our paper is to propose a model that can be applied widely and is not restricted to particular functional forms.

A fundamental assumption of the model is a separation between doping and effort. Technically speaking, we assume that doping decisions are common knowledge before athletes choose effort. At first sight this may seem a strong assumption, although it could be justified by the notion that athletes have a good idea what other athletes 'are up to'. Note, however, that we focus, as is standard, on pure strategy Nash equilibria and any such equilibrium implies that players correctly predict what others will do (Ryvkin 2013). This means that our results are not dependent, per se, on the assumption that doping is common knowledge. But it is critical that doping decisions are *fixed* before effort decisions.[6] This assumption seems mild given that doping in professional sport is not done on a whim.[7] Doping, particularly given the efforts of the authorities to catch drug cheats, is a systematic and highly involved process.

[6]To explain the point, suppose that all doping and effort decisions are made and we consider whether an athlete could gain from deviating in his choices. Our results are dependent upon the fact that if the athlete were to deviate in his doping decision then others may deviate from their current effort decisions. In this regard our model differs from that of Ryvkin (2007), where doping and effort decisions are, from a strategic point of view, made simultaneously.

[7]The exception here could be recreational drugs that are banned but not taken for their performance enhancing effects.

To say that doping is fixed before effort choices are made is not to say that an athlete cannot change his behavior during his career. It is merely to say that in building up to specific events or goals effort choices are made after doping choices have been decided (even if the doping may overlap with training). As an athlete goes through their career we would expect that ability, together with the costs and benefits of doping and effort may change. This could change doping behavior (Petróczi and Aidman 2008). For instance, an athlete who was used to winning without doping may be more inclined to dope as his ability level falls with age. And our analysis suggests, as we shortly explain, that things like age may play a critical role in shaping doping culture.

A key insight of our analysis has been the coordination problem in doping. More specifically, our analysis suggests that only a limited number of athletes will dope in equilibrium and it may be ambiguous who dopes. It is worth noting that this result contrasts with the relatively standard finding in the literature that all or many athletes will dope, particularly in the absence of large costs to doping (Breivik 1987, Haugen 2004). The key thing driving our results is the deterministic nature of our model whereby the athlete with the highest score gets the highest payoff. Equilibrium doping is higher when outcomes are probabilistic, either because multiple athletes can end up with the same score (e.g. Haugen 2004) or outcomes are subject to noise (e.g. Krakel 2007). Clearly sport is subject to random shocks as athletes get injured or under-perform etc. Even so, one is reminded of the well known quote (often associated with golfer Gary Player) that 'the harder you practice, the luckier you get'. We should not overestimate the role of luck in sport. Moreover, luck often involves an able athlete not being able to compete, which could be captured in an extension to our model, rather than fluctuations in score (see Ryvkin 2013 for similar approach). If outcomes are deterministic then the incentive to dope for 'non-marginal' athletes (both those good enough to win easily and those who are unlikely to win) decreases. Equilibrium doping may not, therefore, be as high as we might expect.

An interesting issue is how athletes could 'coordinate' on who dopes. Clearly, this is unlikely to happen through explicit collusion. More likely are that certain observable factors serve to signal doping, whether that be age, nationality etc. For instance, we might obtain doping cycles in which one generation dopes and the next does not. This could be consistent with equilibrium in the sense that there is no point in the young athletes doping if the older ones do. Then as the young athletes become senior in their sport 'opportunities' open up for the next generation to dope. All kinds of subtle indicators of doping may emerge. And this offers a connection between the individualistic approach of game theory and the role of cultural influences emphasized by others (e.g. Ohl et al. 2015). At its most basic level doping is an individual decision, including the possibility for coaches, parents etc. to advocate doping. Cultural influences and norms may though influence how those individual incentives play out.

Let us finish by briefly commenting on policy implications. Our objective in this paper was to set up and analyze a model of doping in order to gain insight on the structure of equilibrium doping. In doing this we have abstracted away from policy considerations. The costs of doping can, though, capture policy to some extent, particularly if we think of interventions as primarily coming ex-post (after the winners are determined) rather than ex-ante (before the competition). Similar to Berentsen (2002) we found that somewhat perverse outcomes are possible in which doping results in the less able athlete benefiting. This highlights that policy is not just about deterrence of itself but also about the kind of outcome we want. Do we want the most able athletes to win?

Our model suggests that the distinction between fixed and marginal costs of doping is crucial. Current anti-doping policy would seem to focus more on fixed than marginal costs. High fixed costs come from the fact that any violation of policy, no matter how minor, results in a career threatening ban. Low marginal costs come from the fact that severe violations do not result in substantially higher punishments, particularly if the offender 'cooperates' with the authorities. Our results would suggest that this approach is fundamentally flawed. High fixed costs to doping deter the more able athletes from doping but low marginal costs incentivize less able athletes to dope. We are likely, therefore, to end up in the worst of worlds where doping takes place and the less able athletes benefit most. We would suggest moving to a system with lower fixed costs and higher marginal costs.

Imposing high marginal costs may well be difficult in practice because it creates the legal minefield of trying to define more severe doping violations. Efforts, though, could still be made in this regard. And even if imposing high marginal costs is not possible there may still be valid arguments for lowering marginal costs. In particular, lower marginal costs mean that the more able athletes have stronger incentives to dope and this, of itself, may deter overall doping given the effect it has on less able athletes. This is not to suggest that a laissez-faire approach is best because we would strongly advocate against this. It is more to highlight the importance of thinking through the implications that policy has for incentives across the ability spectrum. The best intentions could easily create perverse incentives to dope.

Chapter 4

Prize distributions and the incentive to cheat

4.1 Introduction

Monitoring output in contests or competitive environments is often imperfect. For instance, a worker can exaggerate their contribution and achievements in order to win promotion or secure a new job. Similarly, a firm can manipulate financial results or exaggerate sales in order to secure a lucrative deal with a new client. Lying in such contexts can lead to significant inefficiency, both in terms of a mis-allocation of resource (the job going to the wrong worker) and the crowding out of genuine effort. Relatively little is known, however, about the willingness of individual's to lie in contests. In this paper we compare theoretically and experimentally cheating in a contest where winner-take-all to a contest with a linear prize structure.

If individuals can lie at little cost then a selfish individual should lie with impunity. An extensive experimental literature shows, however, that most people are lie-averse (see Rosenbaum, Billinger and Stieglitz 2014 and Capraro 2018 and references therein). A key question we want to address in our work is how an individuals willingness to lie is influenced by strategic incentives.

To appreciate the issues consider first a setting with perfect monitoring. In our theoretical model we find that equilibrium effort is higher with a winner-take-all prize structure than a linear prize structure. This is consistent with prior theoretical results (e.g. Moldovanu and Sela 2001, Sisak 2009). Experimental studies also show that winner-take-all generates high effort, when predicted to do so (e.g. Sheremeta 2011, Dechenaux et al. 2015).

What happens if we have imperfect monitoring with little direct cost of lying? Selfish individuals would lie with impunity and so a baseline prediction would be that any gap in output between the winner-take-all and linear prize structure disappears. The evidence for lie-aversion suggests, however, an alternative possibility. While lying has no direct material cost it does have an indirect psychological cost. Instead, therefore, of outcomes being determined by effort, and heterogeneity in ability, they may become determined by lying and willingness to lie (Gneezy, Rockenbach and Serra-Garcia 2013). If so, we will still see greater output with the winner-take-all prize structure but this is now capturing lying, which is arguably a bad thing, rather than effort, which is a good thing.

Our experiment employs a 2x2 between subject design in which we vary the prize structure and monitoring of output. Subjects are randomly split into groups of 6 and given 10 minutes to solve as many mazes as they can. Prizes are determined by the number of mazes completed. In a winner-take-all treatment the winner receives a prize of £20 and everyone else £5. In a linear prize treatment the prizes go from £10 for the first ranked down to £5 for the 6th ranked. Note that the total prize fund is the same in both settings. In a monitoring treatment the instructions contain wording which suggest the mazes will be checked before determining the rank. In an imperfect monitoring treatment the instructions make clear that the mazes will not be checked.

Comparison across the 4 treatments allows us to explore how output (the number of mazes completed) varies with the prize structure and monitoring prime.

Our main hypothesis suggests that output will be higher in the winner-take-all prize structure irrespective of whether subjects are primed about monitoring of output.However, We only find qualified support for this hypothesis. Specifically, subjects that performed the task twice with feedback.

The first time the task was performed output was higher with a linear prize structure (although there is evidence that cheating was more prevalent with the winner-take-all prize structure). The second time the task was performed, however, output was higher with the winner-take-all prize structure. Moreover, this change appeared to be driven by increased cheating in the case of winner-take-all. Our results suggest that learning from feedback is a crucial part of the picture.

In terms of the prior literature our approach is closest to that of Conrads et al. (2014). They consider two player tournaments in which subjects self report the outcome of a die role. In their T5 treatment the winner receives 5 and the loser 0, in the T3 treatment the respective payoffs are 4 to 1 and in the T3 treatment they are 3 to 2. This is similar to our approach in comparing a winner-take-all prize structure with more linear incentives. They find that output (and therefore cheating) increases as the prize spread widens. Our experiment differs in that we consider larger groups (size 6) and experience. This difference seems crucial given that we only find higher output in the winner-take-all prize structure after experience.

A number of studies compare the effect of payment incentives on cheating without directly comparing the winner-take-all and linear (or ranked) prize structure. For instance, Conrads et al (2013) find more lying in a team setting (where subjects are put in groups of two) compared to an individual setting, even though the strategic gain from lying is lower in the team than individual setting.[1] Cadsby, Song and Tapon (2010) compare piece rate with a bonus based on absolute performance and a bonus based on relative performance. Productivity was the same across the three schemes but cheating highest with a bonus based on absolute performance. Schwieren and Weichselbaumer (2010) compare a piece rate payment with a winner-take-all prize structure in groups of 6. They find increased cheating with winner-take-all, driven by subjects of lower ability. Finally, Cartwright and Menezes (2014) compare cheating in a setting with no performance bonus, to a treatment where the top 6 out of 15 receive a prize and one where the top 2 win a prize. They find, as predicted by strategic incentives, that cheating is highest for intermediate levels of competition where there are 6 prizes.

A related literature has looked at sabotage. For instance, Carpenter, Matthews and Schirm (2010) compare piece rate with a tournament (which was piece rate plus a bonus for the highest ranked worker) in settings where sabotage is or is not possible. They find that sabotage is significant and crowded out effort. In particular effort was lower in a tournament with sabotage because subjects seemingly expected sabotage and so lowered own effort. Charness, Masclet and Villeval (2013) find that subjects are willing to sabotage others to improve their ranking - even if there are no material benefits to a higher ranking. Tournaments and competition may, therefore, have a corrupting effect. For example, Kilduff et al. (2016) find that cheating depends partly on rivalry and prior relations.

The broad lesson from these studies is that incentives influence cheating. That, in turn, means that the optimal prize structure should take account of the effect incentives will have on cheating. Our study reinforces that notion with specific evidence on the winner-take-all prize structure and the role of

[1] Lying benefited the team-mate and so we may be observing altruistic lying.

experience. We proceed as follows. Section 2 introduces a benchmark case of perfect monitoring. Section 3 provides theoretical results for this case and Section 4 provides results for the case of imperfect monitoring. Section 5 outlines our experimental design and Section 6 the results. We conclude in Section 7.

4.2 Perfect monitoring

We begin by considering a model in which there is perfect monitoring of output. There is a set of players $N = \{1, ..., n\}$ competing in a competition. Each player $i \in N$ simultaneously and independently chooses a level of effort $e_i \in \{0, 1\}$ where 0 is interpreted as low effort and 1 as high effort. For simplicity we assume effort can only take two levels but we do not believe our results are overly sensitive to this assumption. Let $h = \sum_{i \in N} e_i$ denote the number of players who choose high effort and let $h_{-i} = h - e_i$ denote the number of players other than i who choose high effort.

Once all the players have chosen an effort level a ranking is determined from lowest to highest. Let $r_i(e_i, h_{-i}) \in \{1, ..., n\}$ denote the ranking of player i where $r_i = n$ indicates lowest and $r_i = 1$ indicates highest. We assume that a player who exerts high effort always beats a player who exerts low effort. The ranking of players who exert the same level of effort is randomly determined with each player having the same chance of a high ranking. Note that this is consistent with all players being of the same ability. The probability of player $i \in N$ receiving rank k is, therefore,

$$Pr(r_i(e_i, h) = k) = \begin{cases} \frac{1}{h} \text{ if } e_i = 1 \text{ and } k \leq h \\ 0 \text{ if } e_i = 1 \text{ and } k > h \\ 0 \text{ if } e_i = 0 \text{ and } k \leq h \\ \frac{1}{n-h} \text{ if } e_i = 0 \text{ and } k > h \end{cases} \tag{4.1}$$

Let V_k denote the prize received by a player ranked k where $V_1 \geq V_2 \geq ... \geq V_n$. Also let the cost of high effort be given by c. The expected payoff of player $i \in N$ given outcome (e_i, h) is

$$u_i(e_i, h_{-i}) = \sum_{k=1}^{n} Pr(r_i(e_i, h) = k)V_k - ce_i. \tag{4.2}$$

So, the payoff of the player is his expected prize minus the cost, if any, of high effort. A strategy for player $i \in N$ consists of a probability $p_i \in [0, 1]$ with which he chooses high effort. The expected payoff of player $i \in N$ given strategies $p_1, ..., p_n$ is

$$\pi_i(p_1, ..., p_n) = \sum_{e_i=0}^{1} \sum_{h=0}^{n-1} Pr(e_i, h_{-i}|p_1, ..., p_n)u_i(e_i, h) \tag{4.3}$$

where $Pr(e_i, h_{-i}|p_1, ..., p_n)$ denotes the probability of outcome (e_i, h_{-i}).

Without loss of generality we can set $V_n = 0$. Let $W = \sum_k V_k$ denote the total prize fund. In the following we pay special attention to two specific forms of prize structure. (a) In a winner-take-all structure we set $V_2 = V_3 = ... = V_n = 0$ and $V_1 = W$. As the name would suggest, this prize structure means that only the highest ranked player receives a prize. (b) In a linear prize structure we set $V_{k-1} - V_k = D > 0$ for all $k > 1$. So, any increase in ranking results in a gain of D. Note that this would require.[2]

$$W = \frac{n(n-1)D}{2}. \tag{4.4}$$

[2]Set $D + 2D + ... + (n-1)D = W$.

Where appropriate we shall refer to the winner-take-all game and linear game respectively to reflect the relevant prize structure.

4.3 Baseline theoretical results

Given that we have assumed all players are ex-ante identical it seems natural to assume that all players will use the same strategy. We, therefore, focus on symmetric strategy profiles in which $p_1 = ... = p_n = p$. We now consider in turn the winner-take-all and linear prize structure and solve for the set of symmetric Nash equilibria.

4.3.1 Winner-take-all game

Consider, first, the winner-take-all prize structure and fix a probability p that every other player chooses high effort. The expected payoff of player $i \in N$ if he chooses low effort is given by

$$\pi_i(e_i = 0, p) = (1 - p)^{n-1} \frac{W}{n}. \tag{4.5}$$

This expression captures the fact that the player can only be highest ranked, and therefore win the prize, if every other player also chooses low effort. In this case he has a one in n chance of winning. The expected payoff of player $i \in N$ if he chooses high effort is given by

$$\pi_i(e_i = 1, p) = \sum_{g=0}^{n-1} \binom{n-1}{g} p^g (1 - p)^{n-1-g} \frac{W}{g+1} - c. \tag{4.6}$$

This expression captures the fact that the player has a one in $g + 1$ chance of being highest ranked where g is the number of other players who choose high effort.

Let us first consider whether $p = 1$ can be a Nash equilibrium. This would require that $\pi_i(e_i = 1, p = 1) \geq \pi_i(e_i = 0, p = 1)$. Substituting in the relevant payoffs and rearranging gives result: p=1 is a Nash equilibrium of the winner-take-all game if and only if $c \leq c^\star$ where

$$c^\star = \frac{W}{n}. \tag{4.7}$$

Consider next whether $p = 0$ can be a Nash equilibrium. This would require that $\pi_i(e_i = 1, p = 0) \leq \pi_i(e_i = 0, p = 0)$. Substituting in the relevant payoffs and rearranging gives result: $p = 0$ is a Nash equilibrium of the winner-take-all game if and only if $c \geq c^{\star\star}$ where

$$c^{\star\star} = \frac{W(n-1)}{n}. \tag{4.8}$$

Note that $c^{\star\star} \leq c^\star$ for $n > 2$ and so there is a range of values of c where neither $p = 1$ nor $p = 0$ are a Nash equilibrium. In this case we looked for a mixed strategy equilibrium where $\pi_i(e_i = 0, p) = \pi_i(e_i = 1, p)$. This requires

$$c = W\left(\sum_{g=0}^{n-1}\binom{n-1}{g}\frac{p^g(1-p)^{n-1-g}}{g+1} - \frac{(1-p)^{n-1}}{n}\right). \tag{4.9}$$

An explicit expression for the value of p that solves this equation is not obtainable. For specific values of c, W and n it is possible, however, to solve for the equilibrium value of p.

4.3.2 Linear game

Consider now the linear prize structure. The expected payoff of player $i \in N$ if he chooses low effort is given by

$$\pi_i(e_i = 0, p) = \sum_{g=0}^{n-1} \left(\binom{n-1}{g} p^g (1-p)^{n-1-g} \sum_{k=g+1}^{n} \frac{D(n-k)}{n-g} \right). \tag{4.10}$$

This expression captures the fact that the player will effectively be competing with the $n-1-g$ players who choose low effort (where g is the number of players who choose high effort) for the lower rankings. The expected payoff of player $i \in N$ if he chooses high effort is given by

$$\pi_i(e_i = 1, p) = \sum_{g=0}^{n-1} \left(\binom{n-1}{g} p^g (1-p)^{n-1-g} \sum_{k=1}^{g+1} \frac{D(n-k)}{g+1} \right) - c. \tag{4.11}$$

This expression captures the fact that the player is effectively competing with g other players who chose high effort for higher rankings.

In this new context we consider afresh whether $p = 1$ can be a Nash equilibrium. Setting $\pi_i(e_i = 1, p = 1) \geq \pi_i(e_i = 0, p = 1)$ and rearranging gives result: $p = 1$ is a Nash equilibrium of the linear game if and only if $c \leq \hat{c}$ where

$$\hat{c} = \frac{(n-1)D}{2}. \tag{4.12}$$

Note that $\hat{c} = c^\star$ if we impose condition (4.4).

Consider next whether $p = 0$ can be a Nash equilibrium. Setting $\pi_i(e_i = 1, p = 0) \leq \pi_i(e_i = 0, p = 0)$ and rearranging gives result: $p = 0$ is a Nash equilibrium of the linear game if and only if $c \geq \hat{c}$. Thus, setting aside the limiting case of $c = \hat{c}$ we find that the linear game only gives rise to pure strategy Nash equilibria. If the cost of effort is more than $\hat{c}$ then everyone exerts high effort and if it is less than $\hat{c}$ then everyone exerts low effort.

4.3.3 Comparison of incentives

Table 1 summarizes our findings so far. We can immediately see from this analysis that the winner-take-all structure is expected to elicit at least as high a level of effort as the linear structure. To put some context on this let us, without loss of generality, fix $W = 1$. It is, therefore, sufficient to consider only c and n. We have $c^\star = \hat{c} = 1/n$ and $c^{\star\star} = (n-1)/n$. So, the larger is n the more incentives in the winner-take-all and linear prize structure diverge. Indeed, for large n, the equilibrium prediction in the linear game is of nobody choosing high effort (unless the cost of effort is very low) while in the winer-take-all game we still see a positive probability of high effort.

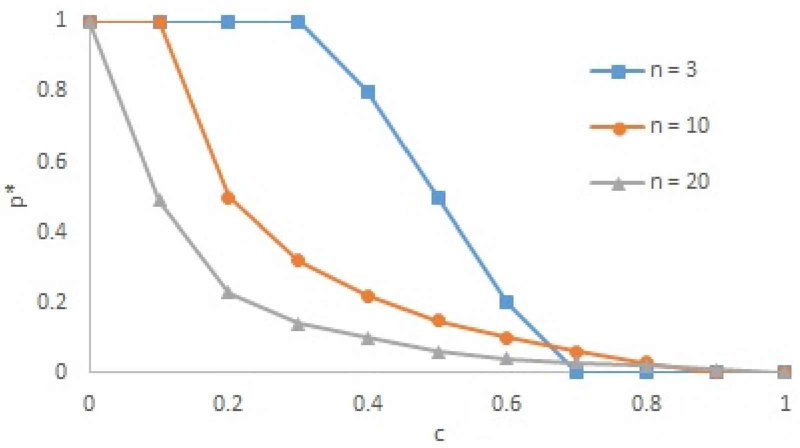
TABLE 4.1: Equilibrium predictions for different incentives.

	Winner-take-all	Linear
If $c \leq c^\star$	$p = 1$	$p = 1$
If $c^{\star\star} > c > c^\star$	$0 < p < 1$	$p = 0$
If $c \geq c^{\star\star}$	$p = 0$	$p = 0$

To gain additional insight, Table 4.1 plots the equilibrium value of p in the winner-take-all game for three different values of n. Hence, the equilibrium probability of high effort in the winner-take-all game drops steeply towards zero beyond $c^\star$. The probability of at least one player choosing high effort remains above zero, denoted as $1 - (1-p)^n$. If, for instance, we consider $c = 0.5$ the equilibrium probability of at least one player choosing high effort is 0.88, 0.80 and 0.71 respectively for $n = 3$, 10 and 20. This compares to an equilibrium probability of 0 in the linear game.

We see, therefore, a very different set of incentives in the winner-take-all game as compared to the linear game. This is as expected given the prior literature (Sisak 2009). The key thing we want to explore are the consequences of cheating. For this we need to slightly extend the model.

FIGURE 4.1: Equilibrium value of p for winner-take-all game.



4.4 Imperfect monitoring

Suppose that there is a way for a player to achieve the rewards from high effort without paying cost c. Specifically, suppose that each player $i \in N$ simultaneously and independently chooses between level of effort $e_i \in \{0, 1, Q\}$ where 0 is low effort, 1 is high effort and Q is to *cheat*. Let b_i denote the cost to player i of cheating which includes possible sanctions if caught and any psychological cost of cheating. We make no assumption at this stage that b_i is more or less than the cost of effort c. For some players the cost of cheating may be less than that of effort (because, say, they have nothing to lose) and for some it is more (because of potential costs to reputation).

We will assume that those who cheat gain a high ranking. We, therefore, have in mind a setting where the gains to cheating are potentially high. For instance, the person willing to lie on their CV or fabricate experimental data can easily outdo the hard work of others. Let h denote the number of players who choose high effort and q denote the number who cheat. Then extending equation (1) we have the probability of player $i \in N$ receiving rank k is,

$$Pr(r_i(e_i,h,q)=k)=\begin{cases}\frac{1}{q}\text{ if } e_i=Q \text{ and } k\leq q\\ 0 \text{ if } e_i=Q \text{ and } k>q\\ \frac{1}{h}\text{ if } e_i=1 \text{ and } q<k\leq h+q\\ 0\text{ if } e_i=1 \text{ and } k<q \text{ or } k>h+q\\ 0\text{ if } e_i=0 \text{ and } k\leq h+q\\ \frac{1}{n-h-q}\text{ if } e_i=0 \text{ and } k>h+q.\end{cases}$$

Expected payoff is naturally extended to include the possibility of cheating,

$$u_i(e_i,h,g)=\sum_{k=1}^{n}Pr(r_i(e_i,h,g)=k)V_k-m(e_i)$$

where $m(0)=0$, $m(1)=c$ and $m(Q)=b_i$.

Insights from the analysis of the previous section naturally extend to this more complex environment in which we have three possible actions and heterogeneity of costs. Let us begin with the simpler case of a linear prize structure.

4.4.1 Linear game

Suppose that $e_j=0$ for all $j\in N$ and consider the incentives of player i. Applying the analysis of section 4.2 we see that player i would have an incentive to cheat if and only if $b_i<c$ and $b_i<c^\star=W/n$. The possibility to cheat only, therefore, influences incentives if it is relatively low cost. And the larger the n the lower need be costs. Small costs are, therefore, enough to deter cheating and there is now extensive evidence that lying typically involves some psychological costs (Gneezy et al. 2013). In interpretation we can see that the incentives to increase ranking in the linear prize structure are low. As a consequence there is little incentive to put in effort and, equally, little incentive to cheat. The possibility to cheat may, therefore, make little difference.

We should, however, recognize that if someone faces no cost, psychological or otherwise, from cheating, $b_i = 0$, then clearly they have an incentive to cheat. This means that some may cheat. How does this change the incentives of others? Suppose that player i believes that proportion l of the population has no psychological cost for lying, and will therefore cheat. Assuming players are randomly selected from the population we get

$$\pi_i(e_i = 0, l) = \sum_{g=0}^{n-1} \left(\binom{n-1}{g} l^g (1-l)^{n-1-g} \sum_{k=g+1}^{n} \frac{D(n-k)}{n-g} \right)$$

and

$$\pi_i(e_i = Q, l) = \sum_{g=0}^{n-1} \left(\binom{n-1}{g} l^g (1-l)^{n-1-g} \sum_{k=1}^{g+1} \frac{D(n-k)}{g+1} \right) - b_i.$$

It follows that the higher is l the less incentive to cheat. So, if $b_i < c^\star = W/n$ player i has no incentive to cheat irrespective of the effort or cheating he expects of others. Overall, therefore, we may expect some to cheat (because cheating has no direct material cost) but cheating should not be widespread given psychological costs.

Also note that cheating does not crowd out effort. At a simplistic level this is because there is limited incentive for effort with our without the possibility of cheating. At a slightly deeper level, however, we can see that the incentives to exert effort are relatively unaffected by cheating. In particular, if $b_i > c$, and so cheating is more costly for player i than effort, then player i may have an incentive to exert effort. This is because effort would still push player i up the ranking and any gains in ranking have the same marginal benefit.

4.4.2 Winner-take-all game

Let us consider afresh what happens if $e_j = 0$ for all $j \in N$. Applying the analysis of section 4.3.1 we see that player i would have an incentive to cheat if and only if $b_i < c$ and $b_i < c^{\star\star} = W(n-1)/n$. For large n the condition $b_i < c^{\star\star}$ is likely to be satisfied in a setting where cheating cannot be monitored. An equilibrium with no cheating would, therefore, seem unlikely. In interpretation, this is because cheating would result in a large material gain and so the psychological cost from lying would have to be very large to deter that. This compares with a linear game where cheating only marginally increases expected payoff and so is less 'tempting'.

If some players cheat, or are expected to cheat, how does that change the incentives of others? If player i expects that at least one other player will cheat then the payoff from not cheating (whether he puts in effort or not) is 0. Cheating is, therefore, the only hope of a positive payoff. In short, we see that cheating replaces effort as the determinant of the prize winning allocation. If cheating is less costly than effort then we can expect more cheating in equilibrium than we would expect high effort in a setting with perfect monitoring. And it is interesting to note that the psychological costs of cheating may be diminished in settings where cheating is 'normalized' (Eber, 2012). If, therefore, cheating is expected the costs of cheating are even less.

4.4.3 Differential consequences of imperfect monitoring

Let us summarize and reiterate some of the points made above. In the linear game we see that there is relatively little incentive to exert effort or cheat. Only those with a very low cost of cheating will have an incentive to cheat. Also cheating should not completely crowd out effort in the sense that, for those who prefer effort to cheating, the incentives to exert effort remain, if somewhat diminished. By contrast, in the winner-take-all game we see that there is a much larger incentive to cheat. Moreover, cheating can be expected to completely crowd out effort because effort cannot compete against cheating.

If we consider effort is 'good' and cheating is 'bad' then we see that the optimal prize structure depends on monitoring. If monitoring is perfect then the winner-take-all prize structure best incentivizes effort. But, in the case of imperfect monitoring, the winner-take-all prize structure may merely incentivize cheating. If so, the linear prize structure would be preferable. To investigate this further we need a better understanding of individual's willingness to cheat in competitive settings. If, for instance, people cheat with impunity, then cheating will be high under a linear prize structure as well as winner-take-all. This motivates our experiment.

4.5 Experiment design

We employed a 2x2 between subject design that varied the prize structure and priming for output monitoring. In each session subjects were dispersed around a large classroom. They were then given 10 minutes to solve as many mazes as they could from a booklet with 10 mazes. The mazes, taken from https://krazydad.com/mazes/, are difficult and so the 'average' person could only be realistically expected to solve two to four mazes in the 10 minutes. An example of a maze is given in Appendix A.[3] Subjects were given a sheet to record their outcomes. On the sheet they were asked to write the time they finished each maze, from a countdown clock projected onto a screen at the front of the room and clearly visible to all. At the end of the 10

[3]An online maze game was used by Schwieren and Weichselbaumer (2010) (see also Gneezy, Niederle and Rustichini 2003).

minutes they were asked to write down how many mazes in total they had completed.

Subjects were told that their performance, measured by the number of mazes completed, would be compared to 5 other randomly selected people taking part in the experiment. Their performance will then be ranked from 1st (completed the most mazes) to 6th (completed the least). Ties were randomly resolved. Payment was then based on either a winner-take-all or linear prize structure. In a *winner-take-all treatment* the subject received £20 if they were ranked 1st and £5 otherwise. In a *linear treatment* the subject received £10 if ranked 1st, £9 if ranked 2nd, down to £5 if ranked 6th. In both cases the total prize fund is £45. Note that the minimum £5 was a form of show-up fee for subjects. The Experiment was funded by the University of Kent and had a budget of £1000.

We varied the priming subjects received in terms of monitoring. Let us clarify that the number of mazes completed was not checked (during the experiment) and so we were entirely reliant on self-reporting. Subtle differences in the wording of the experiments made this more or less transparent to subjects. Specifically, in a *no-monitoring treatment* subjects were told 'Note that you are free to draw on the maze if you want but all we require you to do is write down the time on the record sheet.' This makes explicit that there will be no monitoring of output. In a *monitoring treatment* subjects were told 'In order that we can verify the maze was completed please indicate the correct route on the maze. Note that we do not need this to be neat or tidy. We just need to see that you found the correct path.' This wording suggests there will be monitoring and indeed we were able to subsequently check whether mazes were completed as reported.[4]

[4]Monitoring treatment may require subjects to do something they do not need to do in the no-monitoring treatment - i.e. draw on the maze - and this could slow things down. It is, however, far more difficult to solve the maze without drawing on the paper (because these are very difficult mazes) and so there should be no difference in practice.

Given the instructions merely stated that performance will be compared to 5 randomly selected other people we were not constrained to explicitly put subjects into groups of 6. This meant that an experimental session could have any number of subjects (of 6 or above). A predetermined algorithm compared performance and determined payoff based on subject number. At the end of the task subjects were given feedback on their rank and the number of mazes completed by the first ranked. The task was then repeated a second time with the exact same incentive structure. This allows us to see if there are any dynamic effects[5]. A total of 65 subjects too part split over four sessions for each of the four treatments.

4.5.1 Experiment hypotheses

In the monitoring treatment subjects were primed to think that some form of monitoring of their output would be performed. In particular, they were asked to record a route on the maze. This meant that cheating could be observed and subjects new that. At the very least, this should raise the psychological cost of cheating and so this will be treated as our baseline case. Consistent with the analysis of Section 3 we make the following hypothesis.[6]

Hypothesis 1: Output will be higher in the winner-take-all treatment than linear treatment with monitoring.

[5]Subjects were informed at the start of the experiment that the experiment would consist of multiple parts. They were not told that the specific task would be repeated twice.

[6]Our theoretical model assumed a discrete choice between low effort, high effort or cheating. In the experiment subjects had a continuous choice set in that they could expand more or less effort and cheat a little or a lot. In practice we would argue that this difference is not crucial. In particular, subjects in the experiment still face the basic choice between exerting high effort or cheating. Moreover, the main results from our theoretical model are note sensitive to the assumption of a binary choice between low and high effort.

In the no monitoring treatment subjects were directly told that there would be no monitoring. This means that cheating is not observable and so it seems natural to hypothesize increased cheating.

Hypothesis 2: Output will be higher in the no monitoring treatments than monitoring treatments.

Our main hypothesis, however, is that cheating will not fundamentally influence the output difference between the winner-take-all and linear treatments. This reflects less incentive to cheat in the linear treatment.

Hypothesis 3: Output will be higher in the winner-take-all treatment than linear treatment with no monitoring.

4.6 Results

For each subject and both rounds of the experiment we have the output (i.e. number of mazes) that they self-report to having done. We also have the book of mazes to verify (after the experiment) how many mazes they actually solved. The difference between self-reported and actual output is a measure of cheating. Recall that subjects in the no monitoring treatments were told that they did not have to complete the maze book by hand. To complete a maze without using a pen is, however, difficult and more time-consuming that using a pen. We discount, therefore, the possibility that a subject solved a maze without that being detectable from the maze booklet.

Our primary focus is on cheating. Let us, however, first look at self-reported output. Table 2 shows the average of self-reported output by treatment in rounds 1 and 2. We see that in round 1 the winner-take-all with no monitoring treatment has output lower than predicted (by both hypotheses 1 and

2) compared to the other treatments (p = 0.04, two-sided Mann Whitney). This ultimately drags down the overall output in the winner-take-all and no-monitoring treatments.[7] By round 2, however, the effect has disappeared. Across the board we see a rise in output and the effect is particularly pronounced in the winner-take-all with no-monitoring treatment. In round 2 there is evidence in support of Hypotheses 1 to 3 although the differences across treatments are statistically insignificant (Mann Whitney test).

TABLE 4.2: Self-reported output by treatment and round.

	Round 1			Round 2		
	Winner	Linear	Both	Winner	Linear	Both
No monitor	2.56	3.37	2.97	3.78	3.58	3.68
Monitor	3.07	3.00	3.04	3.57	3.29	3.43
Both	2.78	3.21		3.69	3.45	

The amount of cheating is detailed in Table 4.2, as measured by the discrepancy between self-reported and actual output. In round 1 we can see, as predicted, that there was more cheating in the no-monitoring treatments (p = 0.09, one-sided Mann Whitney). Cheating, however, was lower in the winner-take-all treatments (p = 0.68, two-sided Mann Whitney). By round 2 this effect has been reversed primarily because of a large increase in cheating in the winner-take-all with no-monitoring treatment. Specifically, in round 2 we see an even bigger effect of monitoring (p = 0.04, two-sided Mann Whitney) but still an insignificant effect of winner-take-all (p = 0.31, two sided Mann Whitney). Although the amount of cheating is marginally higher in the winner-take-all with no monitoring treatment than other treatments (p = 0.06, one-sided Mann Whitney).

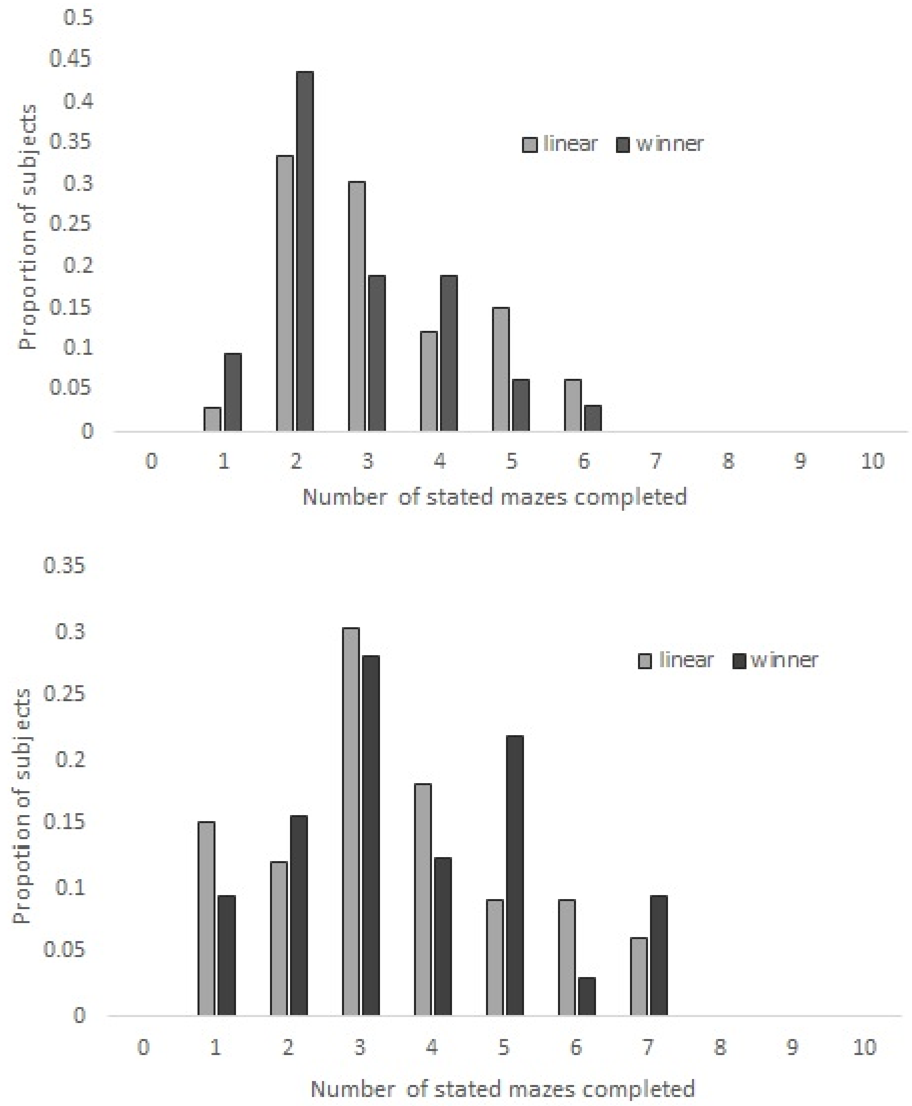
To give additional insight Figure 4.2 plots the distribution of self-reported output comparing the winner-take-all and linear-treatments. In the linear treatments we can see a slight rightward shift in the distribution. In the winner-take-all treatments there is a more pronounced shift to the right.

[7] All other pairwise comparisons are statistically insignificant.

TABLE 4.3: Cheating by treatment and round

	Round 1			Round 2		
	Winner	Linear	Both	Winner	Linear	Both
No monitor	0.61	1.05	0.84	1.56	1.11	1.32
Monitor	0.36	0.21	0.29	0.57	0.29	0.43
Both	0.50	0.70		1.13	0.76	

FIGURE 4.2: Distribution of self-reported output in linear and winner-take-all treatments in round 1 (top) and round 2 (bottom).



To formalize the analysis we report some regression results. We begin with a Logit regression that take as a dependent variable whether or not a subject cheated. Table 4.4 provides the results looking at both rounds 1 and 2 separately. We can see that monitoring shows some effect on cheating, particularly in round 2, but there is no evidence that the prize structure influenced the probability of cheating.

TABLE 4.4: Logit Modelling, Round 1 & 2

Variable	R1 (1)	(2)	R2 (1)	(2)
All Pay	0.20 (0.66)	0.16 (0.66)	0.64 (0.58)	0.62 (0.57)
Monitored	-0.63 (0.67)	-0.68 (0.66)	-0.99 (0.58)*	-0.97 (0.59)*
Number of Mazes (Stated complete) In Round	0.84 (0.37)***	0.95 (0.28)***	0.63 (0.29)**	0.48 (0.18)***
Average time Per Maze (minutes)	-0.34 (0.44)		0.13 (0.23)	
Constant	-2.67 (1.72)	-3.81 (1.08)***	-3.24 (1.75)***	-2.25 (0.82)***
Observations	65	65	65	65
Likelihood Ratio χ^2	17.25***	16.61***	13.19**	12.76***
Pseudo r^2	0.22	0.22	0.15	0.15

Next we can look at the absolute amount of cheating as given by the discrepancy between actual and self-reported output in Table 4.5. We report the results of tobit regressions[8] with the discrepancy as the dependent variable. Again we see that the lack of monitoring does increase cheating but the type

[8] Where $p^{\star} < 0.1$, $p^{\star\star} < 0.05$ $p^{\star\star\star} < 0.01$

of prize structure does not. The winner-take-all coefficient is, though, positive and so there is some sign that cheating is higher in the winner-take-all treatments.

TABLE 4.5: Tobit Modelling for cheating in Round 1 & Round 2

Variable	R1 (1)	(2)	R2 (1)	(2)
All Pay	0.33 (0.82)	0.31 (0.83)	0.85 (0.79)	0.83 (0.79)
Monitored	-1.29 (0.83)	-1.32 (0.84)	-2.01 (0.85)**	-2.04 (0.85)**
Number of Mazes (Stated complete) in Round	1.08 (0.35)***	1.26 (0.38)***	1.09 (0.24)***	0.89
Rank in Round 1			0.29 (0.24)	
Average time Per Maze (minutes)	-0.57 (0.55)		0.21 (0.33)	
Constant	-2.94 (2.24)	-4.95 (1.62)***	-5.07 (2.51)**	-3.60 (1.23)***
Observations	65	65	65	65
Uncensored	18	18	24	24
Likelihood Ratio χ^2	20.11***	18.90***	20.67***	20.18***
Pseudo r^2	0.15	0.22	0.12	0.12

4.7 Conclusions

In this Chapter we have compared theoretically and experimentally a contest with a winner-take-all prize structure to one with a linear prize structure. We also compared a setting which primed for monitoring of output to one with no monitoring. Our theoretical results suggested that output would be higher with the winner-take-all prize structure. In fact we found that effort was lower with the winner-take-all the first time subjects did the task but higher the second time they performed the task. This change was cause by a rise in cheating the second time around.

One explanation for why we did not observe higher output the first time subjects performed the task is risk aversion. Kalra and Shi (2001) show the critical role of risk aversion. In their theoretical model they find that the winner-take-all prize structure maximizes effort if players are risk neutral but if they are risk averse the optimal incentive structure involves multiple winners. Similarly, Krishna and Morgan (1998) find that winner-take-all prize structure is optimal with 2 or 3 players and for 4 players if those players are risk neutral. But if there are 4 risk averse players the optimal prize structure involves 2 winners. While these results are derived for different models the basic idea that risk aversion may diminish incentives to 'go for' a single prize is intuitive.

Lim, Ahearne and Ham (2009), building on the approach of Kalra and Shi (2001), find that effort is higher with multiple prizes in both a lab and field experiment. Even so, our incentive structure is such that risk aversion (particular the mild risk aversion observed by Kalra and Shi (2001)) should still leave the winner-take-all prize structure as the one that most incentives effort. So, the reason we observe less effort in the winner-take-all treatments is still a puzzle. Although, our finding is not too dissimilar to that of Sheremeta

(2011). He compares a winner-take-all contest to one with two different prizes (more similar to our linear prize structure) and finds that output is higher in the winner-take-all but only just, and with a difference much smaller than predicted.

That output was higher with the winner-take-all prize structure the second time subjects performed the task is the main thing we would emphasize. Our prior hypothesis was that the possibility to cheat would not lead to excessive cheating in the linear prize structure. As such, the winner-take-all prize structure most incentives cheating. That we observe a dramatic shift the second time subjects performed the task, while unexpected, reinforces this hypothesis. Essentially, the second time they performed task subjects were well aware that they could cheat with impunity (because they saw what happened the first time) and cheating rose dramatically in the winner-take-all treatments.

So, the main implication we would take from our study is the need to take into account the ability to monitor output when designing contest incentives (see also Conrads et al. 2014). If output can be perfectly monitored and high effort is considered desirable then the prize structure that maximizes output is ideal. But what if output is imperfectly monitored? Then to incentivize effort may be simply to incentive cheating, and that may not be desirable. The linear prize structure, which minimizes cheating, may be optimal even though it leads to lower output.

As an example consider doping in sport. Sport is primarily built around a winner-take-all prize structure in which most of the rewards go to the top athlete. This may incentivize effort. But, similarly, it may incentivize cheating through illicit doping or similar. The authorities need to consider which prize structure best matches their ability to monitor output. Contrast, for example, rowing and cycling. It would be naive to think that doping is not an issue in rowing (for instance 2004 Olympic gold medalist Sergei Fedorovtsev tested positive for a banned substance). Doping scandals have, however, clearly plagued cycling over many decades, particularly with regard to the Tour de France. The high stakes for success in cycling, compared to the relatively evenly distributed rewards in rowing, are surely part of the explanation for these differences.

Chapter 5

Framing and Dishonesty

5.1 Dishonesty in Sport

Sport, whether professional or amateur, presents many opportunities for 'dishonest' behaviour. Examples range from match fixing (a criminal offence), to the use of prohibited performance enhancing drugs (violating the rules of a governing body), to feigning injury for competitive advantage within a game. Abundant evidence of dishonest behaviour exists (see, for instance, Carpenter (2012) on match fixing, Dilger, Frick and Tolsdorf (2007), Pitsch, Emrich and Klein (2007) and Pitsch and Emrich (2012) on doping in sport and Kavussanu, Seal and Phillips (2006) on anti-social behaviour in football games). But what motivates an athlete to cheat? In this paper we explore the idea that an individual is more prone to dishonest behaviour when they are engaged in sport than they are in other areas of life.

The literature, particularly on doping in sport, has identified a multitude of potential factors that influence dishonest behaviour (see Morente-Sánchez and Zabala 2013 and Ntoumanis et al. 2014 for reviews). Broadly speaking within this web of social, contextual and personal influences we can categorize factors into two types. First there are individual or attitudinal differences that means some athletes are more willing to engage in dishonest behaviour.

For instance, some may feel less negative emotions from cheating (Lazuras et al. 2010), be more morally disengaged (Kavussanu 2008, Ring et al. 2018), get less intrinsic enjoyment from sport (Ntoumanis and Standage 2009), believe that others are more likely to cheat or have different expectations about likely consequences (Mazanov and Huybers 2010). Here we get a between athlete comparison in saying some are more likely to be dishonest than others [1]. This notion fits the common 'tabloid' characterization of doping as the dishonest cheats versus the honest clean athletes.

A second category of factors that can influence cheating are cultural and situational influences from the sporting environment. For instance, the social influence of team-mates, coaches and family can have a strong effect on the decision to cheat (Ohl et al. 2015). Similarly, a young, injured athlete may face a completely different cost-benefit trade-off to an experienced athlete (Huybers and Mazanov 2012, Ring et al. 2018). Willingness to cheat has also been found to correlate with strategic incentives such as the extent of competition and spread of prize money (Schwieren and Weichselbaumer 2010, Cartwright and Menzes 2014, Conrads et al. 2014). Crucially, this allows a within athlete comparison in saying that a person may be more or less likely to cheat depending on the environment within which he or she happens to compete. Such subtleties fit less well the tabloid desire to distinguish cheats versus honesyt but arguably have a great deal of support within the academic literature.

Individual and environmental factors can interact in interesting ways. For instance, different cultural and situational influences on a young athlete may shape subsequent beliefs (Ntoumanis, Taylor and Thøgersen-Ntoumani 2012). Or coaching style may have different effects depending on the underlying

[1] Cultural factors may feed into any between subject comparisons. Even so, taking that cultural background as fixed and given we can then see that some athletes may be more prone to dishonesty than others.

motivation of the athlete (Hodge and Lonsdale 2011). More generally, a particular environmental factor may mean that a person becomes less morally engaged. These interactions are crucial to the approach we take in this paper. Our main claim is that sport, of itself, makes people less honest. Or to put things differently, a person may be less honest in the sporting environment than they would be in other areas of their life. We apply the social cognitive theory of moral action and the theory of self-concept maintenance to argue our point. Will shall see that various aspects of the sporting environment allow 'honest people' to 'cheat a little' and maintain high moral standards and self-concept.

We also report on an experiment designed to test our main hypothesis that the sporting environment makes people dishonest. Subjects undertook a standard coin-tossing task in which there is the opportunity to be dishonest (e.g. Bucciol and Piovesan 2011, Houser, Vetter amd Winter 2012, Gino and Wiltermuth 2014, Pascual-Ezama et al. 2015). Specifically, a subject is paid based on his or her self-reporting of ten coin-tosses. By recording dishonestly a subject could guarantee a maximum payoff of £10 (compared to the expected fair payoff of £5). Our treatment variable was a priming task that subjects performed before the coin-tossing task. Around half of the subjects were given a series of three questions asking them to think about their experience with sport while the other half were gives questions about education. We find significantly higher payoffs (and, therefore, dishonesty) following the sport priming.

Our approach draws on that of Cohn, Fehr and Marechal (2014) who find that workers employed in the banking industry are more dishonest when primed to think about banking. The implication is that bankers are not dishonesty per-se but may behave dishonestly within a banking environment. Similarly, our results point to the potential corrupting effect of the sporting environment. As we discuss in below, there may be limits on how much the climate of sport can be changed. Even so, a recognition that sport may have a tendency to 'bring out the worst in people' may be useful in designing incentives to discourage dishonest behaviour. It also may help in keeping some perspective on the immorality of cheating in sport. In particular, our analysis suggests that cheating in sport does not necessarily mean an individual would be any more dishonest than others in different areas of life.

Before we proceed to the theoretical discussion let us highlight two specific aspects of our experimental design. First, dishonesty cannot be observed (and the subject knows that). If, therefore, a subject behaves honestly that must because of internal or intrinsic motivation rather than, say, any fear of social disapproval. This is not to say that external forces are not relevant. A footballer may, for instance, be less likely to feign injury in a game being shown live on television, with cameras all-around, than in a lower league game with few people watching. There are, though, many opportunities to cheat in sport without anyone knowing (at least in principle) whether that be doping, match fixing or on-field actions. We shall, therefore, focus here on intrinsic motivation.

A second aspect of our experimental design is that subjects can cheat a little (or a lot). The possibility to cheat less than is theoretically possible can be a crucial factor in incentivizing someone to cheat (Gneezy, Kajackaite and Sobel 2018). In elaborating on this point let us highlight that sport is relatively unique in the extent of its rules. Such rules means that cheating is objectively verifiable, in principle, even for the most minor of rule violations. This directly reduces an athlete's wiggle room to claim a particular behaviour 'is not cheating'. If, however, cheating falls on a continuum between minor and major it restores some wiggle room to 'interpret' minor transgressions as honesty. This is clearly a relevant factor in sport where the opportunities to cheat fall on a wide spectrum from very minor rule violations, such as a golfer failing to replace their ball in exactly the right place, to illegal activity, such as a golfer accepting money to shoot a particular score on a hole.

5.2 Moral Disengagement

A large literature has looked at moral disengagement in sport, drawing on and applying Bandura's (1991) Social Cognitive Theory of Moral Action. Given the extent of the literature (see, for instance, the excellent review article of Boardley and Kavussanu 2011) we limit ourselves here to picking up some issues that seem pertinent to the topic at hand. The underlying idea behind Bandura's (1991) Theory is that an individual seeks internal (or external) approval for 'moral' acts and fears disapproval for 'immoral' acts. This, though, is insufficient to rule out immoral acts because the individual may use mechanisms of moral disengagement to consciously inhibit moral standards (Boardley and Kavussanu 2011).

Moral disengagement is conventionally viewed at a between athlete level. In particular, some athletes may feel less strongly about immorality or may find it easier to inhibit moral standards. For our purposes it is interesting to look at the within athlete level and ask whether an individual may find it easier to inhibit moral standards in sport than other areas of life. Bandura (1991, 1999) distinguished eight mechanisms of moral disengagement, which were converted to a sporting context by Boardley and Kavussanu (2007, 2008). In working our way through these eight mechanisms we very loosely partition them into three sets to capture specific aspects of the sporting environment. These aspects are the existence of clearly defined rules, competition and teamwork.

One very specific aspect of sport is that it takes place within clearly defined rules and in a clearly defined setting. In a golf tournament, cycle tour or football match, for instance, there is a rule book that defines precisely what is and what is not allowed and there are referees and umpires to make sure the rules are adhered to. We can think of no other aspect of life with such clearly defined rules. This is not to say that ambiguity is completely removed but there is, for instance, far more ambiguity in, say, the application of employee contracts and employment law within the workplace. A lack of ambiguity on the rules has the direct effect of making it harder to justify cheating because there is less wiggle room. Indirectly, however, the clearly defined nature of the sporting arena may make it easier to inhibit immoral behaviour.

One thing to consider is the notion that 'what happens on the pitch stays on the pitch'. Consider the image of rugby players who stamp on each other, gouge out each other's eyes and then, at the final whistle, shake hands and go and share a beer together (Daniell 2009). This caricature suggests that anti-social behaviour on the field of play is different to anti-social behaviour off the field. There is a sense in which anti-social behaviour is a part of sport. The clear dividing line between the sporting and non-sporting arena that facilitates this transition. As does the fact that opponents on the field may be good friends off the field (because they are, say, former teammates or know each other well over many years of competing together). Two mechanisms we can bring into the discussion at this point are advantageous comparison and distortion of consequences.

Advantageous comparison allows someone to inhibit moral standards by recognising that there are worse things that could have been done. Distortion of consequences involves the cognitive minimization of anti-social outcomes. By way of illustration, Boardley and Kavussanu (2007) measure these mechanisms with the questions, respectively, 'shouting at an opponent is okay as long as it does not end in violent conduct' and 'insults among players do not really hurt anyone'. The notion that what happens on the pitch stays on the pitch suggests a lot of room for advantageous comparison and distortion of consequences. In particular, anything that happens in the name of sport could be claimed as less bad than things which happen outside of sport.

Another related aspect of sport is that it is competitive. The objective is 'to win'. This would seem to allow further leeway to excuse behaviour that happens in the name of sport. To expand on this let us bring in three more mechanisms. Euphemistic labelling is a way of disguising immoral behaviour, such as 'bending the rules is a way of evening things up'. Dehumanization is a way of reducing opponents to non-human level, such as 'it is okay to treat badly an opponent who behaves like an animal'. Finally, attribution of blame is to pass on blame to victims, such as 'players who are mistreated have usually done something to deserve it' (Boardley and Kavussanu 2007).

All three of these mechanisms would appear to be easier to apply in a sporting context given the clearly defined environment and competitive nature of that environment. For instance, it is easier to say that a sporting opponent is behaving like an animal than to say someone in everyday life is behaving like an animal. It is excusable, maybe even part of sport with some euphemistic labelling, for someone to behave that way. Moreover, this can justify reacting in-kind. Similarly, blame could be attributed on the sporting environment itself. Its competitive nature would seem to positively invite 'bending the rules' as much as possible.

One further factor in sport is the integral notion of teamwork. Even in individual sports an athlete may feel responsibility to coaches, parents and others who have helped along the way. With this in mind we can introduce the final three mechanisms. Moral justification is a mechanism for turning bad into good, such as 'it is okay for players to lie to officials if it helps the team'. Displacement of responsibility sees a person shift responsibility on social pressures, such as 'a player should not be blamed for injuring an opponent if the coach reinforces such behaviour'. Finally, diffusion of responsibility sees a person diffuse blame through the group, such as 'it is unfair to blame players who only play a small part in unsportsmanlike tactics used by their team'. The strong notion of teamwork inherent in sport allows ready appeal to all three of these mechanisms.

In this section we have argued that sport has unique characteristics – namely clearly defined rules, competition and teamwork – that facilitate the eight mechanisms of moral disengagement recognised by Bandura (1999) and Boardley and Kavussanu (2007). That would suggest that sport is an environment where we may see enhanced dishonesty. In making this point it is worth clarifying that this is not just because consequences are less in sport. To illustrate, consider a footballer who deliberately sets out to injure an opponent and in doing so does such a bad tackle that it ends the opponent's career. The footballer can use all the mechanisms of moral justification, displacement of responsibility, etc. Ultimately, though, the footballer has changed someone else's life in a fundamental way. It would seem fair to say that the footballer who would be highly unlikely to perform such an act away from the football pitch would provide selective moral disengagement.

5.3 Self-Concept Maintenance

In the preceding section we focused on the Social Cognitive Theory of Moral Action. In this section we consider related theories of moral action beginning with the Theory of Self-Concept Maintenance (Mazar, Amir and Ariely 2008). This theory starts with the notion that most people value honesty, have a strong belief in their own morality and strive to maintain this positive self-concept. An individual, therefore, will typically only behave dishonestly if they can do so in a way that does not threaten their positive self-concept. Or, put somewhat differently, the individual must overcome the ethical dissonance that results from an inconsistency between own behaviour and ethical values (Ayal and Gino 2011).

There are various cognitive tricks (or mechanisms) that someone can employ to maintain positive self-concept. Mazar et al. (2008) highlight two such tricks – categorization and attention to standards. Categorization is a process of interpreting actions in a way that makes them seem more morally acceptable. While the lower the attention to standards the easier it is for an individual to cheat and maintain self-concept. There are clear parallels here with the eight mechanisms discussed in the previous section. For instance, moral justification and euphemistic labelling are forms of categorization. Also one could argue that attention to standards are lower in sport because 'it is just sport' and 'what happens on the pitch stays on the pitch'.

Shalvi et al. (2015) further develop a theory of ethical dissonance distinguishing between pre-violation and post-violation justifications for immoral behaviour. As the names would suggest, pre-violation justifications are tricks an individual can use to justify actions he wants to choose while post-violation justifications are used to lessen the dissonance from an action already chosen. They discuss three types of pre-violation justification – ambiguity, self-serving altruism and moral licensing – and three types of post-violation justification – cleansing, confessing and distancing. Self-serving altruism (similar to the moral justification mechanism and also sometimes called local social utility) is the idea that immoral behaviour which benefits others is easier to justify (Gino, Ayal and Ariely 2009). This, as we have already discussed above, has clear relevance in a sporting context where actions can benefit team members. Indeed, we may see a form of team moral disengagement (Mallia et al. 2016). Distancing (similar to the displacement and diffusion of responsibility mechanisms) primarily involves pointing to other immoral acts done by others. This, again, is easy to see as relevant in sport.

From our perspective, the more novel cognitive tricks coming out of the approach of Shalvi et al. (2015) are those of moral licensing, cleansing and confessing. The idea behind moral licensing is that an individual will find it easier to justify immoral behaviour if he has recently engaged in pro-social behaviour. Sport is often associated with pro-social acts whether that be charitable work, support and mentoring of children and young athletes, or simply giving a supporter an autograph. Such acts, particularly given that they are often directly related to the individual's sport, may offer a ready excuse for immoral behaviour. For instance, the footballer who visited the local hospital on Friday, to do some charitable work on behalf of his club, may use this as a justification for immoral behaviour in a game on the Saturday. Similarly, interacting with young supporters before and after the game may counteract immoral behaviour.

Cleansing is a physical or symbolic process of 'washing' away immoral behaviour. So, showering after a game and putting on a shiny suit may do more than wash away the dirt. Again, we see here the importance of that clear distinction between what happens on and off the pitch. Pain is also a recognized form of cleansing that may be relevant to sport. Confession is the process of recognizing immoral acts in order to obtain forgiveness. Interestingly, however, the evidence suggests individuals may choose to confess a little and deny they did anything particularly bad (Peer, Acquisti and Shalvi 2014). This is another form of advantageous comparison. In sport there are ample opportunities for confession such as talking to teammates, opponents, or the media after a game. Indeed, within a team there may be a collective process of confession and deflection through advantageous comparison.

In comparison to the Social Cognitive Theory of Moral Action the Theory of Self-Concept puts slightly more emphasis on the interaction between cognitive tricks and the choice environment. A particular relevant issue for us is the idea of cheating 'a little bit' (which is not unrelated to the idea we have just discussed of confessing 'a little bit'). The evidence suggests people more readily cheat a little bit than a lot (e.g. Hilbig and Hessler 2013, Gneezy et al. 2018). Both categorization and low attention to standards allow someone to cheat a little bit and maintain self-concept. For example, the golfer that fails to replace her ball in the right spot can claim that on the scale of things that is a small violation. If that is 'all she has done' then she is an honest golfer. More generally, there are host of ways in which an individual can cognitively re-interpret cheating 'a little bit' as a good thing. It readily allows for advantageous comparison and distortion of consequences because the individual 'could have done worse'. It also allows for self-serving altruism in that the individual 'helps' an opponent by not doing worse. Similarly, it allows for distancing because others 'would have done worse'.

With this in mind let us consider again the consequences of sport being a domain with a clearly defined set of rules. The direct effect of a reduction in ambiguity is to provide a barrier to immoral behaviour. For instance, the rules of golf are unambiguous on the procedures that need to be followed when replacing a ball (and at a professional level referees would be on hand to advise if necessary). So, a player cannot reasonably claim 'they did not know'. To adhere to all the rules, all the time, would, however, be superhuman. Precisely because the rules of sport are so clearly defined down to the finest detail, it becomes almost inevitable that an individual at some point is going to bend the rules 'just a little bit'. The golfer is not going to replace her ball in exactly the right spot, the footballer is going to push an opponent off balance, the basketball player is going to travel more than allowed, and so on.

If minor violations of rules can easily be justified then minor violations may become normal. For example, it may become a norm that anything the referee or umpire does not spot is not cheating (even if it is a clear violation of the rules). This is a potentially slippery slope to further, and more serious, immoral behaviour. For instance, doping in sport may result from a process in which athletes move from supplements and legal substances (with potentially invasive methods of deliver) to banned substances (Moller 2009). Behavior can also be influenced by others (Gino, Ayal and Ariely 2009) creating a dangerous cycle. For example, Kavussanu, Seal and Phillips (2006) observe increased anti-social behaviour through young adolescence which appears to be influenced by the motivational climate in the team.

5.4 Cost-Benefit Analysis

The theory of self-concept Maintenance is based on individuals (explicitly or implicitly) weighing up the costs and benefits of dishonesty. This crucially implies that dishonesty will be increasing in the potential gains from dishonesty. There is ample evidence that individuals do respond to strategic incentives to lie in competitive environments (Schwieren and Weichselbaumer 2010, Cartwright and Menezes 2014, Conrads et al. 2014). In particular dishonesty is positively related to the expected gains from dishonesty.

Consequently, an individual's willingness to engage in dishonest behavior in sport is likely to depend on incentives such as prize money and the gains from winning, particularly if we look at pre-meditated behavior like doping.

The key point to appreciate is that the sporting arena may provide an environment where the rewards to cheating are relatively high. This will depend on the sport and type of competition but the highly attritional nature of sport combined with a winner takes all reward system means that small acts of cheating can potentially yield large payoffs. If so, then putting aside all of the arguments made in the previous two sections, we would still expect to see higher levels of dishonesty in sport than most other areas of life. But these various factors are likely to be reinforcing. For instance, if sport is an environment when cheating is more prevalent then the various mechanism and justifications discussed above become reinforced. So, competition can be a mediating factor in justifying dishonesty.

5.5 Methods

5.5.1 Participants

Participants were 152 members of the general public (83 male). The study was conducted over three sessions on the University of Kent campus. One session was run on an open day and the subsequent two sessions were widely advertised around the university. Participants could drop-in at any time and take part during the course of a session (with no participant allowed to take part more than once). The participants ranged in age from 16 to 68 with an average of 23.4 (SD = 8.0). Participation lasted around 10-15 minutes.

5.5.2 Measures

Honesty, or dishonesty, was measured using a coin tossing task based on that of Cohn et al. (2014). Specifically, participants were told 'You now have the chance to win some money. We want you to toss a coin 10 times. Depending on whether the coin comes down heads or tails (see below) you can win £1. We ask you to record for each toss whether or not you win the £1 (please circle yes or no). Once you have finished please enter in the box below your total winnings. For instance, if you win 8 times please enter £8. Then bring over all your sheets and we will pay you the amount you have won.' Participants then filled in a table similar to Table 1 and entered total winnings.

TABLE 5.1: A copy of the table participants were asked to fill in recording how much money they won.

	Heads	Tails	Did You Win?
Toss 1	Win £1	Do not win	Yes No
Toss 2	Do Not win	Win £1	Yes No
Toss 3	Win £1	Do not win	Yes No
Toss 4	Do Not win	Win £1	Yes No
Toss 5	Win £1	Do not win	Yes No
Toss 6	Do Not win	Win £1	Yes No
Toss 7	Win £1	Do not win	Yes No
Toss 8	Do Not win	Win £1	Yes No
Toss 9	Win £1	Do not win	Yes No
Toss 10	Do Not win	Win £1	Yes No

The crucial thing to appreciate is that participants tossed the coin and filled in the table without any independent verification of the coin tosses. Participants could, thus, report any outcome. This creates the incentive to behave dishonestly and report high winnings. Note, however, that we cannot tell whether an individual participant was dishonest or not. For instance, a participant may genuinely win £10 because of the way the coin lands. Our focus is, thus, on treatment differences in observed winnings. Specifically we will compare the winnings of participants exposed to a sporting prime with those exposed to a neutral education prime, looking for a shift in the distribution of winnings. This approach allows participants freedom to behave dishonestly without any judgement from the experimenter, as is standard in experimental work on dishonesty (Cohn et al. 2014).

5.5.3 Procedures

Participants were recruited from those attending a University open day (session 1) and from across the University population (sessions 2 and 3). They were informed that participation was voluntary and that data was anonymous. They were then asked to fill in a five part survey. The first three parts are unrelated to the present study (two parts on a public good game and one on attitudes to cyber-security). Part 4 was our priming task which we shall describe shortly. Part 5 is the coin tossing task discussed above.The experiment was funded by the University of Kent and the budget for the experiment was set at £1250.

Approximately half of the participants (74 out of 152) were given a sporting prime and the others an education prime. Following the approach of Cohn et al. (2014) both primes began with questions on life satisfaction. First they were asked (on an 11 point Likert scale) 'How satisfied are you at present with your life in general?'. Then they were asked four questions (on a 6 point Likert scale) 'Happiness means for you that you… and your family are healthy? Are able to enjoy small things? Have time for your own interests? Don't have to worry about money?' Participants were then exposed to the prime.

Participants in the sport prime were asked: 'Do you currently play sport, or have you played sport in the past? If so, which sports and at what level?', 'What personal characteristics do you think are important to be a successful sportsperson?', and 'What are the most memorable sporting moments that you have been involved in, as a participant or spectator?'. Each question had a box for subjects to write an answer. Participants in the education prime were asked: 'What is your level of education and have you any experience of teaching?', 'What personal characteristics do you think are important to be a successful teacher?' and 'What are the most memorable moments you have from teaching, either as a pupil, student or teacher?'.

The role of the prime is to expose subjects to either a sporting or neutral educational frame before the coin tossing task. Our main hypothesis was that participants would be more likely to behave dishonestly in the coin tossing task after they had been exposed to the sporting prime. Participants were randomly assigned to a prime within each session. The life satisfaction questions are the same for all participants and so allow a basic test of homogeneity between treatments. After completing the coin tossing task participants could hand in their sheets and be paid. The average payoff was £5.53.

5.6 Results

5.6.1 Life Satisfaction

The five questions that participants were asked about life satisfaction are not of interest, of themselves, but do provide a basic test of unobserved heterogeneity between treatments. As Table 2 reports we find no differences between treatments.

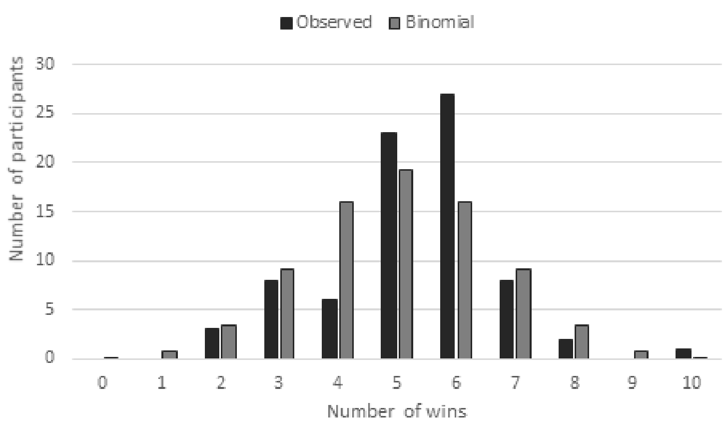
TABLE 5.2: Life Satisfaction by Treatment and results of Mann-Whitney Two-sided test.

Question	Education	Sport	z	P
Life in General	7.59	7.36	0.75	0.46
Family are Healthy	4.61	4.57	0.22	0.82
Enjoy Small things	4.08	4.03	0.08	0.93
Own Interests	4.13	4.08	0.60	0.55
Money	3.89	4.06	-1.10	0.27

5.6.2 Education Prime

Figure 5.1 plots observed winnings and those expected according to the binomial distribution (with a fair coin). You can see a pronounced skew to the right relative to the binomial distribution. This would suggest some dishonesty. A binomial test does not, however, provide compelling evidence that winnings are not random, p = 0.054 one-sided test with 413 successes out of 780 tosses. This level of honesty is consistent with prior experimental evidence (Cohn et al. 2014, Abeler, Nonsenzo and Raymond 2018).

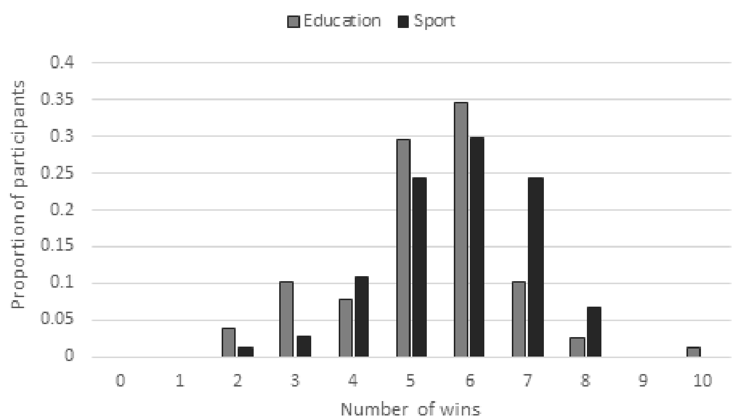
FIGURE 5.1: Observed winnings in the education treatment and those expected by chance



5.6.3 Sporting Prime

Figure 5.2 plots the distribution of wins in the sporting treatment compared to the education treatment. The distribution shows that with a sport priming there is a clear shift to the right. Hence, with the sport prime we can reject the null hypothesis that winnings are random,Additionally, a two-sided rank sum test shows significantly higher winnings in the sport treatment, z = -2.24 and p = 0.025. Hence, the evidence supports our hypothesis that dishonesty is higher with the sporting prime.

FIGURE 5.2: Observed winnings in the sport and education treatments



5.6.4 Gender and Age

Table 5.3 reports the results of OLS regressions [2] in which the dependent variable is the number of wins and the independent variables include a dummy for sport framing, a dummy for male, age, a dummy for student, a dummy if the student said they were experienced in sport (this information is only available for those in the sport frame) and the 5 measures of life satisfaction (not reported here). Specification (1) simply includes the sport dummy while specification (2) includes all variables. As expected the number of wins is

[2] Where $p^{\star} < 0.1$, $p^{\star\star} < 0.05$ $p^{\star\star\star} < 0.01$

TABLE 5.3: OLS regression results with number of heads as the dependent variable

Variable	(1)	(2)
Sport Prime	0.49 (0.22)**	0.78(0.37)**
Male		0.37(0.24)
Age		-0.04(0.017)***
Student		-0.42(0.44)
Experienced in Sport		-0.40(0.39)
Constant	5.29(0.15)***	6.29(1.17)***
n	152	148
r^2	0.03	0.11

TABLE 5.4: Poisson regression results with number of heads as the dependent variable

Variable	(1)	(2)
Sport Prime	0.90(0.41)**	1.11(0.48)**
Male		0.67(0.42)
Age		-0.07(0.03)**
Student		-0.59(0.67)
Experienced in Sport		-0.68(0.48)
Constant	1.67(0.03)***	1.87(0.12)***
n	151	150
Psuedo r^2	0.03	0.12
Wald χ^2	5.00**	14.85***
Deviance Goodness of Fit	53.81***	50.25***
Pearson Goodness-of-fit	50.71***	48.06***

significantly higher with the sport prime (t = 2.21 in specification (1) and t = 2.07 in specification (2)). The coefficient for males is positive but not statistically significant (t = 1.54). The coefficient on age is statistically significant (t = -2.28) indicating that younger participants were more likely to be dishonest.[3]

In order to verify the results, table 5.4 reports the results of a poisson regression[4] in which the dependent variable is the number of wins and the independent variables include a dummy for sport framing, a dummy for male, age,

[3]For more on the role of age and anti-social behaviour in sport see Kavussanu, Seal and Phillips (2006).

[4] Where $p^{\star} < 0.1$, $p^{\star\star} < 0.05$, $p^{\star\star\star} < 0.01$

a dummy for student, a dummy if the student said they were experienced in sport (this information is only available for those in the sport frame) and the 5 measures of life satisfaction(not reported here). Specification (1) simply includes the sport dummy while specification (2) includes all variables. We note that the findings of the OLS regression seem to be upheld.

5.7 Discussion

The current study found that people were more likely to be dishonest if they were primed to think about sport than education. More specifically, the self-reporting of participants given the education priming were statistically indistinguishable from a binomial distribution, suggesting honesty, while the self-reporting of participants given the sport prime were skewed to the right, suggesting dishonesty. Our findings are evidence that merely thinking about sport can result in increased dishonesty. This reinforces the notion that dishonesty and anti-social behaviour in sport is about more than 'some athletes who cheat'. The culture and attributes of sport may well bring out dishonest behaviour.

A question that our study cannot address is why sport leads to increased dishonesty. Our theoretical analysis suggested that there are particular aspects of sport that make it easier to justify anti-social behaviour or cheat and maintain positive self-concept. This would suggest that it is inevitable there would be more dishonesty in sport that other domains. We cannot, however, rule out that we observed increased dishonesty because of the particular culture and views of sport that prevail at the moment in the UK. For instance, thinking about sport may make someone think about the dishonest behaviour they observe in sport and then be less honest in our experiment. Most likely, though, is that these two processes reinforce each other.

Specifically, sport leads to more dishonesty because of its particular aspects which then leads people to associate sport with more dishonest behaviour which, in turn, makes them more likely to be dishonest. Kavussanu, Roberts and Ntoumanis (2002), for example, argue that anti-social behaviour in sport is strongly influenced by behaviour in one's own team and the norms that become predominant over time (see also Ntoumanis, Taylor and Thøgersen-Ntoumani 2012).

The picture is further complicated by the fact that individual characteristics influence dishonest behaviour and also interact with factors that may mediate dishonesty (Grosch and Rau 2017). For instance, Ntoumanis and Standage (2009), applying self-determination, find that controlled motivation was a strong predictor of anti-social attitudes. This means that athletes who are motivated by extrinsic reward and external pressures are more likely to engage in cheating. Motivation, however, is not entirely a static, individual characteristic but also partly dynamic. Coaches, parents and team-mates, for example, can help instil intrinsic motivation. Dishonest behaviour is also influenced by beliefs. Zelli, Mallia and Lucidi (2010), for example, find that doping intentions amongst adolescents are strongly influenced by beliefs. Moreover there are interesting interaction effects between factors, including the idea that someone who has a more positive attitude to doping may be more influenced by others (Zelli, Mallia and Lucidi 2010). Participation in sport may also make someone less moral in other areas of life (Kavussanu and Ntoumanis 2003) creating a further feedback loop.

The complex causes of anti-social behaviour in sport suggest a need for well designed policy intervention. If participation in sport, of itself, increases dishonesty then it further undermines the merits of a policy simply aimed at catching and punishing cheats. Instead we need to think about the whole culture around sport and, in particular, the support around young athletes

(Ntoumanis, Taylor and Thøgersen-Ntoumani 2012). Crucially, it may also be beneficial to recognise the incentives to be dishonest and have an open discussion about ethical dilemmas (Roberts and Ntoumanis 2002). This is a complex issue because any move towards recognising the inherent incentives to dishonesty may be interpreted as condoning dishonesty. It would seem better, however, to tackle issues head-on than to simply assume them away.

Chapter 6

Conclusion

In this thesis we looked at rationality in individual decision making. In that context, rationality essentially equates with maximizing expected payoff. We have extended the notion of rationality to encompass strategic interdependence. The crucial thing this adds to the story is the importance of beliefs. In particular, we can expect that athlete's behaviour will be highly dependent on beliefs about the actions of others, and to fully capture these beliefs we need to model the actions of others.

In Chapter 2 we focused upon the Doping decision that may be taken by players in a game. We provided a generalized model that included the expected utility of undertaking a doping decision, all facets of the decision and broke down the expected utility from doping into its component parts and looked at the specific aspects of strategic interaction. One of the basic assumptions surrounding strategic interaction is that a person forms correct beliefs about the actions of others. This consistency of beliefs fits within the concept of rationality. However, optimal decision making for expected utility maximization will depend upon the accuracy of each individual agents belief structures and the analysis of beliefs will inevitably bring out the interdependence between athletes.

The importance of beliefs is formally captured within game theory by the concept of Nash equilibrium and it's generalizations. The basic idea behind Nash equilibrium is that everyone: (a) maximizes their payoff given their beliefs about the likely actions of others, and (b) has correct beliefs about the actions of others. Note that neither (a) nor (b) on its own is enough for equilibrium because means an athlete is doing 'something wrong'. For instance, it is not in an athlete's interest to act on the belief that no others will dope if others are going to dope. Nash equilibrium captures, therefore, the inherent payoff interdependence between individuals.

One important thing to appreciate is that while the Nash equilibrium captures the notion that nobody does 'anything wrong' it does not mean that nobody has regrets. In equilibrium everybody maximizes their expected payoff. In hindsight an athlete may regret the choice they made. For instance, the athlete who is caught doping may have made the right choice, because the probability of being caught was very small, and yet still regret the choice they made, because they were caught. Nash equilibrium is, therefore, an ex-ante rather than ex-post concept of equilibrium. This is an interesting thing to keep in mind when interpreting the views of those caught doping. While they may claim remorse and regret we should not underestimate the likelihood that they took the 'right choice' at the time and only regret their actions because they came out unlucky.

With that in mind let us tackle some of the main criticisms of the game theoretic approach. The main criticism of game theory stems from its reliance upon highly stylized and simplified models of reality. The primary defence of this critique is one that we have already rehearsed, namely that models should be judged on their insight and not their assumptions. A game theoretic model is not designed in any way to be faithful reproduction of reality. It is designed to have just enough realism to reveal novel findings and it is the natural tool with which to capture the strategic inter-dependence that is at the heart of sport.

It is not difficult to come up with complex games that more closely capture reality than those considered in the literature. Typically, however, complexity only serves to obscure insight. The prisoners' dilemma, for instance, is as simple a game as one can imagine but that very simplicity allows us to make incredibly general conclusions about the consequences of doping. In a similar manner. Chapter 3 boils down the all pay contest with N players down to its simplest form with threshold analysis, To criticize these models for their simplistic nature to miss the point. Studying the simplest prisoners' dilemma outcome tells a significant amount about the incentive structure of the individuals competing and allows us to derive testable predictions. More complex games can give additional insight but do not seem to overturn the conclusions derived from studying the prisoners' dilemma.

A related criticism of these models are the parameterization of outcomes and probabilities. Consider again, for instance, the figure 2.1. Our prediction of behaviour is based upon the the value of W,p,q,HS. Without definitive measures we will have to rely upon the stylized facts derived from assumptions. In order to counter this, we do not assume that athletes consciously work out a value they are willing to put on, say, premature death. All we require is that athletes behave in a consistent way. If athletes are behaving in a consistent way, and we would suggest they do most of the time, then there is a number that accurately measures the value they place on health. The much bigger problem, therefore, is discerning what this number might be.

In this regard we acknowledge that the game theoretic model of doping needs to improve. The models considered in the literature and in this thesis make assumptions about the factors influencing the doping decision and the strength of those factors without much recourse to the relevant psychological and sociological evidence. This is a concern. It only serves to highlight, however, the complements between different approaches to studying doping in sport. In particular, game theory gives predictions based on modelling assumptions, and it is vital those assumptions are based on sound evidence and the predictions are tested in a robust way. This suggests the need for a truly integrative social science of doping in which game theoretic, psychological and sociological approaches build on each other, rather than being seen as substitutes

We also need to recognize that a game theoretic model is only as good as its assumptions. To elaborate at this point consider a (non-game theoretic) model proposed by Petróczi and Aidman (2008). In their model, doping grows out of habitual engagement with acceptable performance enhancing practices. Moreover, their model recognizes the influence of the social, political, economic and culture environment. For example, the more athletes use medical interventions the more readily they might accept using illicit substances. Seemingly consistent with this view, it also seems that athletes are more 'accepting' of drug use to recover from injury (e.g. Anshel 1991) and so the boundaries between legitimate and illicit use may become blurred.

The model proposed by Petróczi and Aidman (2008), and others like it, focuses on the influences an athlete is subject to. That is quite different to a game theoretic model which focuses on how an athlete will react to the influences they face. These two modelling approaches should be seen as complementary rather than substitutes. Therefore, a game theoretic approach is naturally suited to answering a different set of questions to, say, a sociological approach. Game theory is particularly valuable in modelling the consequences that result from the incentives and influences faced by athletes however it does not have anything to say about what those incentives and influences might be.

Therefore, in future work we would need to incorporate more elements of behavioural economics in order for us to fully understand the costly, albeit rational, decisions of agents to use doping decisions. One method may be to look into payoff structures and the impact that loss aversion and other elements of prospect theory have upon competitors actions within a game. Whilst we feel that a contribution to the literature has been made in Chapter 2 by organizing a generalized model and analyzing its composite parts, more aspects of the doping decision could be looked at in the future.

In Chapter 3 we characterized a two stage game in which players first choose how much to dope and then choose how much effort to exert in training. The combination of ability, doping and effort determined a player's score and because of the way the competition was structured inside a All-Pay framework. Using an application of Siegel (2009) we were able to obtain general insight on the incentives to dope.

The key contribution of this chapter was to propose a more generalized model that can be applied widely and is not restricted to particular functional forms in order to help design policy objectives. As previously mentioned, the literature in this field is primarily designed contest theory and limited to fairly specific functional forms or models that include strong assumptions such as homogeneity which may not be realistic.

Furthermore, the strong assumptions of contest theory make it a challenge to obtain an approach that can generally yield insight or help design policy around. We would argue that our approach offers flexibility and tractability which allows the model to be easily applied to look at a range of policy interventions. However, one thing to mention is that the chapter is seen as complimentary to the contest theory papers, not as a direct substitute for the technical analysis demonstrated in these papers.

With that being said, there are some drawbacks to the approach undertaken.

Whilst the fundamental assumption of the model we outline in Chapter 3 surrounding the separation between doping and effort might seem like a reasonable assumption to make, the assumption that doping decisions are common knowledge before athletes choose effort might be pushing the boundary of realistic assumptions. It could be justified by the notion that athletes generally have a good idea of what other athletes behaviour generally is in their field and have a strong inclination of other athletes actions surrounding illegal activities might be, but there would probably need to be further research into whether or not this is actually the case in most amateur and professional sports.

In Chapter 4 we compared a contest with a winner-take-all prize structure to one with a linear prize structure both theoretically and experimentally. We also compared a setting which primed for monitoring of output to one with no monitoring to observe whether there were higher incidences of cheating under no monitoring as would be expected from Our theoretical results. Our theoretical assumptions also suggested that output would be higher with the winner-take-all prize structure rather than a linear prize structure. our finding is not too dissimilar to that of Sheremeta (2011) and gives additional credence to the analysis from that paper.

In the experiment, we found that effort was lower with the winner-take-all the first time subjects did the task but higher the second time they performed the task. This we suggest is linked to higher levels of cheating observed in the second round of the experiment. One explanation for why we did not observe higher output the first time subjects performed the task is risk aversion and that may be something interesting to incorporate into future experiments. However, we did not find any statistically significant differences between the all-pay structure and the linear structure of payoffs.

The main implication we would take from our study in Chapter 4 is the need to take into account the ability to monitor output when designing contest incentives. If output can be perfectly monitored and high effort is considered desirable then the prize structure that maximizes output is ideal. One drawback is that if output is imperfectly monitored, If that is the case then in order to induce and incentivize effort we may have to incentivize cheating, In that case we suggest that the linear prize structure, which minimizes cheating, may be optimal even though it leads to lower output.

In Chapter 5 we analysed the effect that framing had upon peoples willingness to cheat. Specifically, we tested the claim that a person may be less honest in the sporting environment than they would be in other areas of their life and that a sporting environment is so competitive that it causes additional dishonesty to be present in comparison to everyday environments.

In order to test this, we applied the social cognitive theory of moral action and the theory of self-concept maintenance to argue our point. We also reported on an experiment designed to test our main hypothesis that the sporting environment makes people dishonest. In the experiment, subjects undertook a standard coin-tossing task in which there is the opportunity to be dishonest. The subject was paid based on his or her self-reporting of ten coin-tosses, therefore there was an incentive for the participant to misrepresent their 'true' outcome by artificially inflating the number of positive results in order to increase their payoffs.

Our treatment variable was a priming task that subjects performed before the coin-tossing task where around half of the subjects were given a series of three questions asking them to think about their experience with sport while the other half were gives questions about education.

We found significantly higher payoffs following the sport priming in comparison to the education priming, which suggests higher levels of dishonesty in the former. This would also suggest that merely thinking about sport can result in increased dishonesty and that the culture and competitive nature of sport may lead to higher levels of dishonesty and cheating.

Despite the result, we cannot answer why sport leads to increased dishonesty, which could be something to look for in future research. Our theoretical analysis suggested that there are particular aspects of sport that make it easier to justify anti-social behaviour or cheat and maintain positive self-concept but that in and of itself may not provide a satisfactory answer as to why dishonesty increases with a sport priming. Another issue that complicates the result is that individual characteristics that influence dishonest behaviour also tend to interact with factors that may mediate dishonesty. In future research we may need to find a way to disentangle these motivations in order to provide a clearer result.

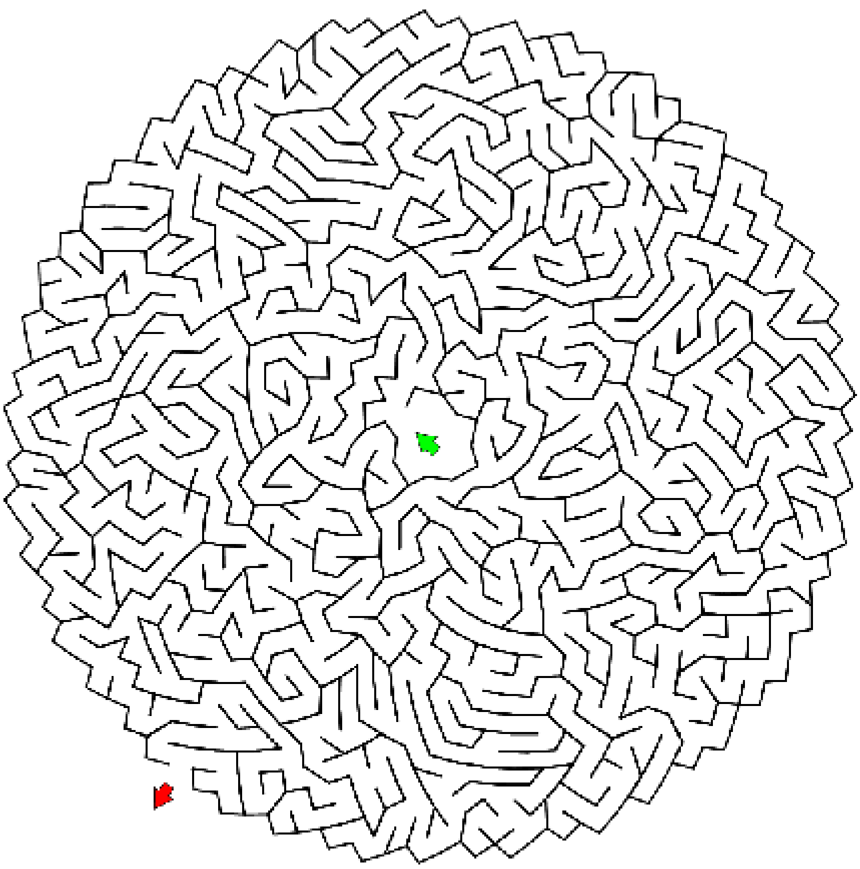
Furthermore, whilst the chapter makes an important first step in exploring whether sport, of itself, makes people more dishonest. We found a highly statistically significant effect due to priming but it is still only one study. In future work it would be desirable to explore this question further by, for instance, distinguishing between competitive athletes and the general public or between young and old. It would also be interesting to see whether the extent of the sport priming is stronger and weaker for different personality types and whether this correlates with general attitudes to morality. Finally, we need to further quantify the extent of dishonesty. In our experiment dishonesty increases with the sporting prime but participants are still far from being as dishonest as they could.

Overall, we feel we have made a decent contribution to the literature through these chapters. However, we do note that there is still a significant amount of work to be done in order to fully understand the rationality behind why individuals decide to undertake costly doping decisions and why there iscontinue to be significant instances of cheating within the sporting industry.

Appendix A

Maze Example

FIGURE A.1: An example of a maze. These are taken from https://krazydad.com/mazes/.

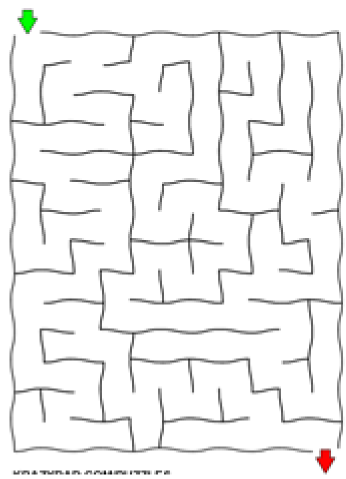


Appendix B

Experiment instructions

The experiment will consist of two parts (and a questionnaire). This is part 1. At the end of the experiment we will randomly choose one of the two parts of the experiment and pay you based on your performance in that part. So, please read the instructions carefully.

On your table you will find a Record Sheet and a booklet containing 10 mazes like the one below. Please do not look at the mazes in the booklet until instructed to do so.



At the front of the room will be a clearly displayed clock counting down from 10 minutes.

Your task is to complete as many mazes as possible from the booklet within the 10 minutes. A maze is completed if you correctly identify an unobstructed path through the maze from one arrow to another. Once you have completed a maze please write down on your record sheet the time remaining as displayed on the clock. For instance, if you finish the first maze with 8m 45s showing on the clock then write 8m 45s next to maze 1 on your record sheet.

Once you have completed a maze and recorded the time please move onto the next maze. Note that you are free to draw on the maze if you want but all we require you to do is write down the time on the record sheet. [In order that we can verify the maze was completed please indicate the correct route on the maze. Note that we do not need this to be neat or tidy. We just need to see that you found the correct path.]

Once the 10 minutes are up we ask you to record on the record sheet the total number of mazes that you completed. Your performance will then be compared to five other randomly selected people taking part in the experiment. You will be given a rank from 1st (completed the most mazes) to 6th (completed the least). Note that in the event of a tie, where you complete the same number of mazes as someone else, it will be randomly determined who has the higher rank of the two of you.

If you are paid for this part of the experiment then you will receive a payment based on your rank, as follows:

If ranked 1st you will get £20.

If ranked 2nd, 3rd, 4th, or 5th, you will get £5.

[If ranked 1st you will get £10. If ranked 2nd you will get £9.

If ranked 3rd you will get £8. 'If ranked 4th you will get £7.

If ranked 5th you will get £6.   If ranked 6th you will get £5.]

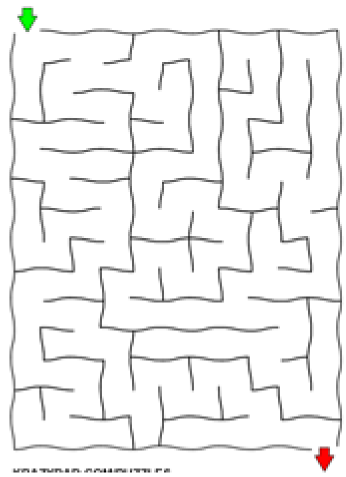
In part 2 of the experiment the maze task will be repeated. Everything remains the same except that there will be a new set of 10 mazes to solve. Again, we would like you to record the time remaining when you complete a maze on the record sheet.

In part 1 of the experiment your rank was

The number of mazes completed by the highest ranked person was

The experiment will consist of two parts (and a questionnaire). This is part 1. At the end of the experiment we will randomly choose one of the two parts of the experiment and pay you based on your performance in that part. So, please read the instructions carefully.

On your table you will find a Record Sheet and a booklet containing 10 mazes like the one below. Please do not look at the mazes in the booklet until instructed to do so.



At the front of the room will be a clearly displayed clock counting down from 10 minutes.

Your task is to complete as many mazes as possible from the booklet within the 10 minutes. A maze is completed if you correctly identify an unobstructed path through the maze from one arrow to another. Once you have completed a maze please write down on your record sheet the time remaining as displayed on the clock. For instance, if you finish the first maze with 8m 45s showing on the clock then write 8m 45s next to maze 1 on your record sheet.

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In part 2 of the experiment the maze task will be repeated. Everything remains the same except that there will be a new set of 10 mazes to solve. Again, we would like you to record the time remaining when you complete a maze on the record sheet.

In part 1 of the experiment your rank was

The number of mazes completed by the highest ranked person was

Appendix C

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