ECONOMIC ASPECTS OF THE STRUCTURE AND GOVERNANCE OF COMPETITIVE CYCLING

by

DANIEL JOSEPH LARSON

(Under the Direction of Joel Maxcy)

ABSTRACT

The sport of competitive cycling has received very little attention in the area of sports economics despite the fact that the sport contains structures particularly relevant to broader economic questions, and data is available for empirical inquiry. This dissertation first presents a review of the literature in sport economics and establishes that there are untapped economic research opportunities in the context of competitive cycling. A formal economic model of the coaching industry within the sport follows. Given the structural parameters that are consistent with stylized facts about the cycling industry, the model predicts that cyclists' coaches will not be hired by sport organizations (cycling teams), and will instead be hired directly by the individual athletes. These predictions are compared to empirical data collected about current cycling coaches and they appear to be consistent with what is witnessed in practice. Finally, an empirical examination of cycling competition outcomes is included to address a contemporary policy concern, a rule banning two-way radios in the sport. The data gathered from 1436 professional cycling races suggests that the introduction of radio technology did not have a significant impact on flat event outcomes in terms of the likelihood of a breakaway success (*LBS*), but there was a significant change observed in the *LBS* for hilly competitions ($\alpha = 0.05$). A closing discussion also illustrates the radio-policy topic's relevance to current research in industrial organizational theory.

INDEX WORDS: Cycling, Bicycle racing, Economics, Coaching, Industrial organization, Competition rules, Outcome uncertainty, Two-way radios

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DEDICATION

This work is dedicated to my wife Rebecca, a.k.a. the angry midget.

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CHAPTER 1

INTRODUCTION

Sport economics has become a flourishing field of academic inquiry as researchers have highlighted the empirical value of the "economic laboratories" of sports (e.g. Kahn, 2000; Zimbalist, 2001; Seaman, 2003; Szymanski, 2003a; Fizel, 2006). Even the lauded Coase theorem, the foundation of law and economics inquiry (Coase, 1960), had a sports economics predecessor, Simon Rottenberg's (1956) "invariance principle". The readily available and accurate data about many professional sports can offer straightforward opportunities to verify a wide range of economic phenomena, including but not limited to incentive and compensation structures, game theory, contest theory, pricing practices, principal-agent problems, and industrial organization.

Within the subset of sports inquiry however, there have been particular concentrations of investigation that have left large swaths of potential empirical resources untouched (Lee, Hon, & Bruning, 2008). The focus of most sports economists has traditionally been on US professional team sports, European football (soccer), and more recently, public finance of sport structures and mega-events such as the Olympic Games (Andreff & Szymanski, 2006; Rebeggiani & Tondani, 2008). We have seen this contextual consistency throughout the development of sport economics research.

Considered the first significant sport economics paper, the still widely cited manuscript by Simon Rottenberg (1956), "The baseball players' labor market", examined Major League Baseball (MLB) in the U.S. Rottenberg considered the mobility and reserve clause restrictions for professional baseball players and the purported effects on talent distribution. It is this paper that many consider a predecessor to Ronald Coase's "The problem of social cost" (1960) which came to be notable as the "Coase Theorem" (Eckard, 2001). In the next decade, Walter C. Neale (1964) articulated the importance of the "inverted joint product", using boxing as a simple example; a peculiarity to sports where the explicit cooperation between independent businesses can be necessary to produce a consumer product (sports games, matches, or championships). In these discussions, he focused almost entirely on MLB and the National Football League (NFL). These are probably the two most frequently cited and seminal pieces in sport economics research because they are the first and most foundational respectively.

These earliest trickles of sport the economics literature spurned some more extensive interest in sport economics moving into the 1970s. El-Hodiri & Quirk (1971) took up sport economics' proverbial baton with the first formal and general mathematical model of the industrial organization of sports. They modeled sports leagues that incorporated team objective functions, league policies, and generated predictions of competitive outcomes. Still, within their practical discussions, introduction, and review, the focus remained on professional baseball (MLB), with some passing discussion of the NFL. Contemporary Peter Sloane (1969, 1971) was at nearly the same time producing works that were essentially the first economic examinations of professional team sports in a new continental context (European football or soccer). First in the *British Journal of Industrial Relations*, and then the *Scottish Journal of Political Economy*, he delved into the labor market for professional football (soccer) players and began formal discussions of a distinct European model of team sport organization. In particular, he modeled the objective for football club owners as utility maximization, in contrast to the profit-maximizing construct of the economic models applied to American team sport leagues. Although the European sport economics research now nearly rivals U.S. activity, it is still primarily concentrated on the study of professional soccer.

Meanwhile, Gerard Scully (1974) continued in the U.S. with his seminal manuscript about professional baseball player compensation, and the marginal revenue product (MRP) of playing talent, still in the MLB labor market. Additionally, Roger Noll (1974) edited an extensive piece through the Brookings Institution that was a comprehensive review of government anti-trust considerations related to sport. Noll's book, albeit newly influential to sport policy, was like nearly all of its predecessors in that it focused almost exclusively on U.S. professional team-sport leagues.

Sport economics research production continued to grow in the 1980s as scholars worked to empirically test Coase's Theorem/Rottenberg's "invariance principle" using sport league industry and/or labor data. In particular, researchers (e.g. Daly & Moore, 1981; Lehn, 1982) considered the shift of property rights from teams to players given the modification of MLB's reserve clause, and the comparative effects of free agency. These were all useful in that they offered a rare instance where a general economic theory could be tested against empirical data, but they still kept sport economics research swirling in the pool of MLB.

The last 20 years (1990s and 2000s) brought the most rapid growth in the production of writings and research papers in the sport economics field and along with it a new arena of inquiry, economic impact/public subsidy. This may have been a result of increased interest on the part of professional economists, increased solicitation of public subsidies by league teams, or as a result of the increasing availability of sports data and academic publications on the internet. Regardless of the driving forces, most of the new research being published remained in the realm of U.S. professional team sports or European soccer. Some of the first sport economics textbooks were developed during this time (Leeds & Von Allmen, 2002; Fort, 2003), as well as some new books relating sports economics to wider audiences, e.g. James Quirk and Rodney Fort's "Paydirt: The Business of Professional Team Sports" (1992). In addition to that book, which many saw as a catalyst for sport economics research, Fort and Quirk (1995) produced a widely cited *Journal of Economic Literature* paper about revenue sharing and cross-subsidization in sports leagues.[1] Again, these were all still essentially limiting discussions to the U.S. baseball, football, and basketball leagues.

The one new area that was emerging more regularly in the sport economics literature (including in some of these new texts) was the economic impact of sports and public subsidy (Crompton, 1995; Baade & Dye, 1990; Baade, 1996; Noll & Zimbalist, 1997; Jeanrenaud, 1999). Assessments of economic impacts were also becoming more numerous and common in sport management, and travel and tourism journals (e.g. Preuss, 2005; Lee & Taylor 2005; Fourie, 2011). It would seem reasonable that some extension would have been made to study the public economic impacts of professional cycling's largest events, Tour de France, Giro d'Italia, and Vuelta a España, because they travel to, from, and through hundreds of cities with each edition, but very few widely circulated research papers have emerged on the topic. Desbordes (2007) is a rare

[1] *Pay dirt* is still widely cited in the literature with Google scholar tallying over 400 academic citations to the newest edition.

exception.[2] In all of these outlets however, including the broad general texts and the new inquiries of public subsidy, the focus largely remained on U.S. Professional team sports, and European soccer.

With the turning of the century, the sport economics specialty finally founded its own journals, the *Journal of Sports Economics* in 2000, and the *International Journal of Sport Finance* in 2006, after regular fights for space in more general economic journals. Stefan Szymanski's (2003b) seminal piece on the design of sport contests during this time pushed forward the boundaries of economic models of sport, and did include new discussions of individual sports. In particular, he discussed the optimal design of contests and prize structures to engender effort and top performance from individual competitors, and directly adapted existing contest theory literature (Lazear & Rosen, 1981; Dixit, 1987). While there have been some growing lines of inquiry in individual sport settings, particularly competitive golf (Ehrenberg & Bognanno, 1990; Orszag, 1994; Schmanske, 2000; Rishe, 2001; Franke, 2011) and foot races (Lynch & Zax, 2000; Frick, 2003; Maloney & McCormick, 2000), they have received a light treatment relative to the deluge of team league and mega-event topics. This may be either due to a lower level of interest on the part of scholars (they may be team sport fans after all), and/or because the simple design of the individual contests do not lend themselves to economic inquiry.[3] Nonetheless, the empirical work in alternative sport contexts was still lacking entering the next decade (2010s). Much of the focus still remains in the four areas: U.S.

[2] There was also a single dissertation produced in French about the general economics of the Tour de France (Calvet, 1981).
[3] These are typically investigations about prizes, incentives and their relation to participation and performance.

professional team sports, international soccer, public subsidy, and mega-event impacts (Lee, Hon, & Bruning, 2008).[4]

Aside from these repeated contexts of inquiry spanning over half a century, nearly all other sport settings have received limited attention in terms of sport economics research. One context that may suffer from the lack of interest, but not lack of economic relevance is the sport of competitive cycling. Because cycling is essentially a "hybrid" structure, an individual sport practiced in teams, it retains some of the complexity of professional team sports with the underlying importance of individual achievement. The reason this is notable in the wider world of economic research is that it more closely approximates organizational and economic relationships in the broader business environment. There are innumerable instances where laborers work within teams that are judged on the performance of a leader or captain, e.g. trial lawyers, design teams, investment fund management. This opportunity cost of helping for team members is something not common in other team sports settings. In most instances, those team members would be able to perform their small piece of team production and all team members' work would be aggregated into a "team performance", not attributed to any one individual. This is not similar to modern corporate structures that emphasize individual executive and managerial performance. The sport of cycling may prove to be a more appealing analog to corporate team practice, while retaining the desirable characteristics of all sports economics research, i.e. an essentially bounded, controlled, well-defined setting, with easily observable actions and readily available production data.

[4] Increasingly represented by the Olympic Games alongside the championships Super Bowls, and World Cup soccer.

The usefulness of studying the sport of cycling has also slipped by many researchers despite the long history and global popularity of the sport. The Tour de France after all, clearly qualifies as a "mega-event", in that it is followed by millions of consumers worldwide and is only surpassed by the Olympic Games and the Soccer World Cup in popularity (Desbordes, 2006). These two considerations are the basis for this dissertation's construction. It is essentially a call to arms for using cycling as a context for future sport economics research, coupled with two complete examples (research manuscripts) exercising this resource.

As a significant area that has received only limited attention (Rebeggiani & Tondani 2008), the sport of bicycling is practiced by over 44 million Americans (National Sporting Goods Association, 2009), and TV viewership of the Tour de France spans 188 countries with over 3200 broadcasting hours (ASO, 2011a; Desbordes, 2006). Additionally, the estimated the annual turnover for top professional cycling teams is estimated to be €135M in 2004, and the Amaury Sports Organization (ASO) which organizes, promotes, and owns the broadcast rights for the Tour de France to have a turnover exceeding 110M Euro per anum (Desbordes, 2006, 2008).

This dissertation presents three economic papers related to the sport of professional cycling. The first industry review paper constitutes Chapter 2, and consists of an introduction to the sport of cycling's structure and governance; a comprehensive literature review of all academic inquiry into the sport; a thorough discussion of the few existing cycling economics studies; and a discussion of the empirical usefulness of professional cycling data for investigating other economic theories. Chapters 3 and 4 address theoretically and empirically topics specific to the economics of cycling. These two manuscripts offer rigorous investigations of two very unique economic phenomena within the sport of cycling. Chapter 3 concentrates on several peculiarities related to the industrial organization of professional cycling coaches, while Chapter 4 focuses on a specific governance policy change to the sport of professional cycling and its relation to previous sport economics literature about outcome uncertainty and competitive balance. Chapter 5 will offer some broader discussion about the findings and conclusions of these papers, and suggest areas for future research.

CHAPTER 2

ECONOMIC STUDY OF BICYCLE RACING[5]

[5] Larson, D.L. To be submitted to the *Journal of Sport Economics.*

Abstract

Bicycle racing has a history that is nearly as long as that of the invention itself. While initially individual tests of maximal speed or human endurance, the sport has evolved into a coordinated team contest that features individual champions. This manuscript recounts the historical progression of the sport and highlights the specific features that make it amenable to economic study. In particular, competitive cycling is an individual contest practiced in teams and the unique physics of drafting in cycling allows for dynamic problems to emerge. The previous economic literature in the area of professional cycling is enumerated and summarized, while areas for potential inquiry are highlighted.

Introduction

This literature review will thoroughly explore the sport of cycling's structure, including its developmental history, and enumerate all available literature relevant to the economic study of the sport. This will include but not be limited to primary and secondary sources in: sport history, sport science, sport economics, economic theory, and related empirical economics. This paper will outline the history, background, and structure of the sport of cycling, and the relevance of the sport's unique features to the study of economic theory. In particular, differences will be highlighted between professional cycling and other sports contexts, and the relationship of cycling's structure to broader industrial settings will be established. The specific topics and rationale for the two dissertation chapters to follow will also be discussed.

History

It was not long after the invention of the modern pedal driven bicycle in the 1860s that organized road racing began (Wilson, 2004). The race commonly considered the first took place in 1868 on a 1200 m course in Paris (Maso, 2005). By the turn of the century in 1900, the sport had already seen seven world championships and inclusion in the inaugural Olympic Games in 1896. The world's most prominent cycling race, the Tour de France, began in 1903 and originated the most popular and successful cycle racing format to the present day, the stage race, or *Grand Tour*, e.g. the Giro d'Italia, Vuelta a Espana (Wheatcroft, 2004). The characteristics of these cycling competitions that are most relevant to the study of economics were present in various forms in cycling's infancy, but rose to prominence and regularity with its maturity.

In the first versions of the worlds biggest cycling events, the grand tours, endurance and suffering were primary. In the first 20 years of the Tour de France, the topographical demands and distances the competitors faced drastically increased. From the relatively flat 2428 km first edition, increasingly high and numerous mountain passes were added, and by 1924 riders were completing an arduous 5425 km course (Wheatcroft, 2004). At the time it had been reported that the founder of the Tour de France, Henri Desgrange's, view of an ideal outcome would be one with a single race finisher, *"Le Tour idéal serait un Tour où un seul coureur réussirait à terminer l'epreuve"*- "The ideal Tour would be a Tour in which only one rider survived the ordeal" (James, 2003). In this way, he viewed the sport as an individual test, a spectacle of personal perseverance and suffering. This theme of ultimate physical and psychological challenge was also apparent in the earlier arena-based versions of cycle racing, the American six-day circuit, where competitors raced around the clock for six days straight on steeply banked tracks (velodromes) (Devlin, 2004).[6]

Soon after the development of cycling races, the benefits of *drafting* became apparent and central to attaining the highest possible speeds. While perhaps not fully characterized scientifically at the time, the intuitive benefits of a *pacer* were implemented in practice very early on. The clearest evidence of this practical knowledge was "Mile-a-Minute" Murphy's 1899 record setting ride (57.8 seconds) following directly behind a Long Island Rail Road train on a wooden track installed between the rails (Wheatcroft, 2004). Because the largest form of resistance for a bicycle rider traveling down a road is typically wind resistance (Kyle, 1979, 2003),[7] techniques of drafting quickly evolved

[6] Only in later incarnations were they allowed to trading riding for rest and sleep with a partner
[7] Gravity can be a greater opposing force on steep climbs

such that a rider could reduce his workload by more than 30% simply by following another rider closely or riding in the shelter of a larger group of riders (Olds, et al., 1995; Olds, 1998; Broker, Kyle, & Burke, 1999). Another example of this early appreciation of pacing and drafting techniques emerged in the Olympic Games program. By the 1908 edition, the team pursuit velodrome event was introduced and it is probably the one cycling event that is the most reliant on effective drafting of any type of race (Craig, & Norton, 2001).

Entrants into the early grand tour competitions were able to take advantage of this slipstreaming phenomenon, particularly on flatter courses, and began to work in support of one another or for the benefit of a team "leader" if they were financially supported by a common sponsor, typically a bicycle manufacturer. It was Maurice Brocco's selling of his pacing services to the highest bidder in the 1911 Tour de France that enraged organizer Desgrange to declare, "'*C'est domestique*'- 'He's like a domestic servant'", coining for the first time the now common name for a supportive cycling teammate, a *domestique* (p. 43, Rendell, 2008). Brocco was subsequently expelled from the Tour (Rendell, 2008).

Strangely, the Tour de France organizer, Desgrange, would on the one hand invite teams, but on the other hand not tolerate any intra-team assistance. Clearly, the grand tour organizer was initially reluctant to allow obvious collusive "team" behavior and outlawed such assistance. However, by 1925 formal teams and team specific stages were incorporated into the rules of the sport and the competitive structure of events (Wheatcroft, 2004). One of the most prominent examples of the resulting tension occurred in the 1929 Tour de France, where the Alcyon team nursed their visibly ill team leader, Maurice De Waele through to the overall victory in the closing stages of the race (Wheatcroft, 2004). Desgrange proclaimed "My race has been won by a corpse" and slighted the victor in his own newspaper's press accounts. The 1930 edition of the Tour de France proved to be the turning point of his philosophy as the format was redesigned to include national teams and allow for teammates to work with and for one another with impunity (Wheatcroft, 2004):

> 'The physiognomy of the contest was modified. Racing by team, co-operation between team-mates, self-sacrificial assistance to the leader – whom it became difficult to shake off even after an accident – meant that more and more riders finished in the peloton [racing group]. Stages lasted six hours instead of the fifteen or sixteen of the heroic age. Cyclists no longer rode all night. The tour was humanized.' (p. 104)[8]

Despite this new allowance of intra-team co-operation that brought the sport to more closely resemble its modern counterpart, there remained one final structural resolution necessary to approximate the modern version of the sport, i.e. team sponsorships. Although Desgrange had gotten his wish to spurn the commercially controlled teams in favor of national and regional teams, there remained incentives for riders with common sponsors to subtly collude across team lines based on their own financial interests. Because of the necessary group nature of the sport, this inter-team collusion was simple to perform but difficult to prove. After all, riders performing extra work by leading the *peloton* (the main group or racers) provide a benefit to *all* of the following cyclists, not just their own teammates. The final concession to these commercial forces was made by Desgrange's successors in 1962 when the race reverted

[8] Translated from Portier (1950). *Le Tour de France: Histoire Compléte*

back to commercially sponsored teams (Wheatcroft, 2004).[9] This most recent 50 years has seen the format of the competition remain essentially unchanged, with teams of 9-11 competitors participating on behalf of their financial sponsors.[10] The status of the Tour de France as a global sporting event is confirmed by the breadth of its media distribution (again, broadcast in over 185 countries), and the international composition of its champions, i.e. a Frenchman has not won the overall Tour de France title in 25 years, and there have been winners representing six other countries in that time (ASO, 2011b).[11] As the Tour de France is the preeminent competition for road cycling, the sister Grand Tours (Giro d'Italia, est. 1909; Vuelta a Espana, est. 1935), the Olympic Games Road Race (est. 1924), and the World Championships Road Race (est. 1927) have all followed suit with this same team structure.[12] So typical is the team co-operation of modern cycle racing that it would be extremely unusual to have a cycling event of only individuals, or even for a cycling team to begin a competition without knowing exactly who their designated leaders will be.

Modern professional cycling, and in fact all of global competitive bicycling, is governed by the Union Cycliste Internationale (UCI) based in Aigle, Switzerland. Founded in 1900 and designated by the International Olympic Committee (IOC) as the official International Federation (IF) for competitive cycling, the UCI consists of a governing congress with representatives from 174 National Federations, a 15 member Management Committee, and a 4 member Executive Board. The UCI establishes,

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[9] There was an "experimental" reversion back to the national team format in 1967 and 1968 and suggestion that national teams would be used periodically, but this did not occur.
[10] Tour de France team sizes: 1962-1971, 1974-1987: 10; 1972-1973: 11; 1988-2011: 9
[11] This is a notable spread in that the period also included a 7 time champion, 5 time champion, and two 3 time champions.
[12] The World championships and Olympic Games are run with national teams, but they also typically have substantial financial support through governments and corporate sponsors.

maintains, and enforces international competition rules; manages the international racing calendars (including all professional events); and generally works to develop the sport globally (UCI, 2010).

Road bicycle racing has since grown to become one of the most prominent and commercially successful forms of sport. With the increased popularity of cycling around the world, and the Tour de France's growth to become the worlds 3rd most popular sporting event behind the Olympics Games and the soccer World Cup (Desbordes, 2006).

The Structure of Professional Cycling

In motivating the study of the economics of cycling it is useful to catalog its current characteristics. The recent historical structure of professional cycling is largely retained in present-day competition and still consists of individual riders competing as members of teams of 6-9 riders per event. Events still vary in both length and terrain, from flat short (1-2 hour) circuit events called criteriums, to the Grand Tours which take place over a three week period passing over many of a country's largest mountains. Despite the wide variation in the "playing field" context, the team structure of cycling remains constant. A team member with most promise of winning or placing well in an event is designated as a leader or captain. The remaining *domestiques,* also known as *gregari,* are team members with the clear purpose of supporting that individual by blocking the wind for the majority of a competition, typically at a cost of their own chances of performing well at the finish. Team support riders can also provide mechanical assistance, and spend much of their energies retrieving food and water for team leaders from following support vehicles. It is this unique team structure that requires individuals to trade-off their labor efforts among the options of leadership, helping, and autarky that both sets cycling apart from other sports while at the same time makes it much more applicable to traditional business setting comparisons.

Professional Cycling Industrial Organization.

Unlike other professional team sports where the competitions are a collaborative production of just two teams, or teams within a league, professional cycling events are hosted and produced by completely independent promoters and/or organizers, such as Henri Desgrange, and often feature up to 21 teams. This adds an additional stakeholder group —event organizers— to the normal team-league self governance relationships we see in other team sports (the league in its function as a governing body serves at the pleasure of its member teams).

Cycling event organizers are not only independent from the team organizations, but are also independent of the UCI. Although they largely comply with UCI regulations and decisions, and rely on UCI official rules and enforcement (employing UCI *commissaires* (officials)), they do, however, have independent interests that are not always in line with the other interested parties. For example, when the organizers of the 2008 Tour de France wanted more latitude in their team selection process than the new UCI ProTour rules allowed, there was a 4 month standoff and the event was ultimately sanctioned by the French Cycling Federation (FFC), not the UCI (Quénet, 2008). The UCI threatened to retaliate against the FFC in terms of World Championship and Olympic qualifications, but those actions were never realized (Quénet, 2008).[13] While the parties resolved their grievances for the following season, it was clear that the organizers could assert their independence, but that all parties had an interest in working together. Because this additional stakeholder is unlike any in other team sports, professional

[13] Incidentally, the IOC sided with the Tour organizer, the ASO.

cycling team organizations must rely on their own ability to garner invitations to participate in events and/or acquire guarantees of entry (via UCI regulation), in order to fill their competition calendar. These conditions can lead to some uncertainty for potential cycling team sponsors and also some heterogeneity of teams in professional events. While teams registered in the top tier (a total of 18), the ‘Pro Tour’, are guaranteed entry into the world’s largest events (by UCI regulation), the second tier (19) ‘Professional Continental’, and third tier (122) ‘UCI Continental’ professional teams must acquire event organizer “wild card” invitations in order to compete. In mid-level professional events, teams of all three tiers may compete, but must be invited by the organizer (no regulatory guarantees), and in the lower level professional events, the highest level teams (Pro Tour) are excluded from participation.

The industrial organization arrangements and stakeholder difficulties that arise from these arrangements were initially catalogued by Desbordes (2006, 2008) and Morrow & Idle (2007). Morrow & Idle (2008) authored a more specific paper discussing governing body regulation changes and their effects on the stakeholder power relationships in the sport. Cycling has many stakeholders involved in the process of producing professional cycling events and the governance and revenue arrangements offer a complicated setting for industrial organizational research. The major stakeholders include the team organizations, the cyclists, the event organizers, the sponsors, and the sport governing body. Figure 2.1 is a graphical representation that Morrow and Idle produced to represent these stakeholder relationships and linkages.

There have been a handful of starts at examining the broader industrial organization (IO) of cycling. The IO and governance writings that have occurred have largely been broad industry descriptions and it seems only a single manuscript in a peer reviewed outlet performed both a robust theoretical modeling and an empirical testing of the IO (Rebeggiani & Tondani, 2008). Desbordes (2006) produced a chapter devoted to describing the economics of professional cycling in a text edited by some of the leading academics in the field of sport economics, Wladimir Andreff and Stefan Szymanski (2006), while Morrow & Idle (2007) discussed the industrial structure of the sport in another edited sport management volume (Chadwick & Arthur, 2007).

In essentially all of the previous IO papers related to cycling (Rebeggiani & Tondani, 2008; Desbordes, 2006, 2008; Morrow & Idle, 2007, 2008), particular attention has been paid to the governance implications of the “ProTour” policy. In an attempt to add some stability and regularity to the competitions and calendar, the UCI instituted the ProTour in 2005. This policy involved a combination of limiting the number of “big league” ProTour licensed teams and the granting of start guarantees for those teams at the world’s biggest events, e.g. Grand Tours, large one day “classic” races.

In terms of highly developed theory and empirical exploration, Rebeggiani and Tondani (2008) were the first researchers to go beyond description to discuss a model of the industry that included a Cournot framework, product differentiation, and efficiency benchmarks to rigorously examine and ultimately critique that ProTour policy change of the UCI. This work was again a view of the broader industry of competitive cycling, but also included the strategic considerations of team’s efforts in the home markets of sponsors relative to the ProTour policy intentions and regulations. Desbordes’ (2008) discussion of the industrial organization of cycling was a case study critical of the ProTour structure as well. This writing is the only one to date that has critiqued the financing model for the sport and its movement toward a "Formula 1" model. These topics again are tightly related to complex relationships between the main stakeholders of the sport.

These works reflect the rich context for future discussion and analysis of industrial organization in terms of revenue distribution, boundaries of the firm, and collusive behaviors of the professional sport organizations.

Professional Cycling Revenue Streams

From competitive cycling's earliest history, the commercialization of the events was primary. The Tour de France for example, was originally created to offer a promotional/circulation edge to Desgrange's newspaper *L'Auto* over a bitter rival publication *Le Velo* (Reed, 2003). This marriage of commercial sponsorship and sport competitions has remained the life-blood of professional cycling. From a financial standpoint, professional cycling teams are organized in such a way that nearly 100% of a team's revenue is generated through corporate or private sponsorships (Desbordes, 2006). Teams operate on budgets of €15M Euro or more for Tour de France level clubs down to €250,000 for smaller national level professional teams (Desbordes, 2006). Ultimately, sponsorship revenue is driven by the extent of consumer exposure a cycling team can generate. Sponsors aim to form associations between the competitive success, drama, and excitement of sporting contests, and their company's brand or product (Howard & Crompton 1995). Professional cycling provides a vehicle for increased brand awareness, positive association, and image enhancement.

Event organizers, on the other hand, develop their revenue through the sale of broadcast rights and/or TV advertising, event sponsorships,[14] and from local subsidies, e.g. local town sponsoring a start or finish of a stage (Morrow, & Idle, 2008). Unlike other spectator sports, event organizers do not generate significant revenue through ticket sales or admissions because events happen predominantly over public roads and highways. From the perspective of the organizer, broadcasting revenue is the largest revenue stream. For example, the Tour de France organizers, the Amaury Sports Organization (ASO), has been estimated to earn around 44% of their annual race related revenue (€77 million) from broadcasting (Desbordes, 2006), and the ASO's total revenue has been growing over the past ten years from less than €100 million to over €145 million (Wilcockson, 2010).[15] The broadcast rights holder in the United States (where the sport has only fringe popularity) generates roughly $9.5 million annually in advertising sales and averages almost a half a million viewers (Andrews, 2010). None of the revenue that broadcasters or event organizers collect is shared with the cycling teams (Calvet, 1981, Desbordes, 2006).

Despite the unique separation of these stakeholders, the cycling teams and the event organizers, the largest components for both of their revenue generation is reliant on a large TV audience. Therefore substantial and sustained TV exposure is critical for the survival of both cycling teams and event organizers. The organizers' command of rights fees and the implicit value of a cycling team's sponsorship rest on developing a wide, interested audience. The Tour de France was broadcast in 188 countries in 2010, with 60 broadcasting the event live (ASO, 2011), so maintaining the interest of these new

[14] In the Grand Tours, the sponsored "publicity caravan" that precedes the race's passage is a significant source of revenue

[15] Figures on the finances of the A.S.O. are sparse as it is a private family owned business.

audiences is critically important. Therefore, the characteristics and appeal of the product being displayed must be considered carefully.

It is broadly accepted that an important aspect of the consumer demand for sports products is largely derived from outcome uncertainty and competitive balance (Kesenne 2007; Andreff & Szymanski 2006). Like other sport competitions, cycling races are non-scripted events with unknown outcomes. That uncertainty undoubtedly factors into its appeal to television audiences. While outcome uncertainty and competitive balance are extensively studied and measured in other team sports contexts (Fort 2006), no formal empirical measures of these characteristics have been presented for the sport of cycling. The link between sponsorship revenues and the spectacle that is produced (TV) makes this measure all the more relevant.

Outcome uncertainty/Competitive balance.

Because sporting events are most often produced jointly by multiple organizations (teams), there are implications of how their comparative performance occurs. While there are implications for the optimal organization of competitions and leagues, there are also important questions about how comparative performance relates to consumer demand. As we assume consumer demand is derived at least in part by a desire to view a close but uncertain outcome, practitioners have an interest in finding the optimal level of this parameter. Cycling is unique in this regard because competitive balance, typically defined by some overall measure of dispersion across the competitors, can effectively be disentangled from a more particular measure outcome uncertainty and one that involves consumer demand. This is because cycling competition is an individual sport, has comparatively large numbers of competitors, no head to head team match-ups, and no team victories or championships. None of the methods for measuring competitive balance/uncertainty of outcome used previously are sufficiently relevant to professional cycling. It is not a problem of *who* is winning, as much as *how* they are winning. In an alternative view, outcome uncertainty in cycling races' may be more broadly interpreted to include the entire sequence of events or recurring narratives present in cycling competitions. It may be that perceived differences in the quality of the spectacle i.e. the story, are what matters to the professional cycling consumer (fan). A new measure designed to gauge outcome uncertainty for the sport of cycling is important to develop, and to date, there has been no apparent research conducted in this area.

Internal Organizational Structure of Teams

The organization of cycling teams in modern professional cycling was first articulated by Michel Desbordes (2006) in the background material for his review of the overall industrial structure and governance of the sport. Within that study, the typical internal organizational designs were outlined, specifically that teams consist of a group of competitors employed by *managers*, directed in events by *director sportifs*, and supported by *soigneurs* (trainers) and professional *mechanics*.

Managers essentially concentrate on maintaining the financial stability and resources of the overall organization. They will solicit and service sponsors, and manage the overall strategic (out of competition) and marketing plans of the organization. They will also typically have final say in athlete hiring and contract negotiations. The *director sportifs*, under the supervision of (and hired by) the manager, will fill the role of "in-competition" manager/director of the athletes. He/she is responsible for all competition strategy, communication, direction, and decision-making during a competition, akin to other traditional team sport “head coaches”. Mechanics and *soigneurs* respectively grease the wheels literally and figuratively. Mechanics are charged with the care and maintenance of all team equipment ranging from the competitive bicycles to the team cars and equipment. *Soigneurs* on the other hand, are charged with the complete care of the athletes’ bodies, performing massage, preparing meals, etc. Both are highly integrated into the day to day logistics of the team. While this hierarchy is generally maintained, the overall size of a professional cycling organization does vary based on its competitive tier level. Table 2.1 illustrates current role representations for professional team employees.

The designs of the cycling organizations themselves have not yet been studied in sport economics, but may embody some important economic concepts that influence their size, employee functions, and hierarchies. For example, the selection processes in the hiring of coaches in professional cycling are unique relative to other individual and team sports. As apparent from the descriptions above, there is no clear mention of coaches being a part of the cycling team organizations. This is surprising because other team sport organizations hire many coaches to prepare their athletes, e.g. a MLB team will have no less than 6 coaches on staff (mlb.com) and NFL teams can have between 14 and 25 (nfl.com). Additionally, we would presume that cyclists could realize performance gains from receiving coaching just as other individual endurance athletes do. Furthermore, this question may relate to the hiring of consultants/coaches in other business-team settings.

The most recent industrial organization theory formulated to address these types of structural questions has been generated by Luis Garicano. Garicano’s (2000, 2004, 2006) recent works have built upon the foundational discussions of Hayek (1945) in that he focuses his models on the unequal distribution of knowledge in the world. Hayek’s seminal work "The Use of Knowledge in Society", first laid out the importance of knowledge in the world to explaining some of the failures of neoclassical economic theory in the practical world. These additional insights not only led to revelations about markets, pricing, and exchange (e.g. Williamson, 1975; Grossman, 1976; Smith, 1982), but have also led to many applications in modeling industrial organizations that account for these knowledge considerations. For example, Garicano (2000) models organizational hierarchy determination with the complexity, uniqueness, and expense of solving problems in production. In addition to being relevant for traditional industrial production, these ideas may be useful in explaining the resultant structures and peculiarities we see in sport organizations.

As in other athletic endeavors, cycling participants often use, or fall under the tutelage of, some form of coach. The term "Coach", originating from the concept of a tutor conveying a student through an examination, as in a carriage (coach), first appeared in the athletic sense in the 1860s and likewise referred to private tutoring and preparation for competition (Liberman, 2005). This individual typically provides instruction, guidance, and objective feedback on activities in order for a client to improve their current performance, or help them develop new skills. In an individual sport setting, such as running, golf, or tennis, a coach will typically be working with a single individual and will primarily be concerned with training, practice, and preparation of an athlete *before* a competition. In many traditional team sports such as football, baseball, and basketball, these coaches also play the role of leader or director *during* competitions. They are charged with a variety of tactical, strategic, managerial, and operational roles. These can vary from shouting for an immediate reactive action, to calling a play, to managing a roster and substitution choices.

Because cycling is an individual sport practiced in teams, the role and residence of a coach can be ambiguous. Although a cycling team's "in-competition" roles are similar to other team sports, requiring direction, coordination and communication, the fact that cycling is first and foremost an individual competition, i.e. team wins and losses are not necessarily scored, establishes a more dire need for specialized individual coaching *before* competitions. As discussed previously, all of the roles a traditional team sports coach takes on *during* competition are charged to the director or team manager of a cycling team but unlike in traditional team sports where the head coach or assistant coaches within a team's sport organization will fulfill this preparatory role, cycling team directors typically do not (Larson & Maxcy, 2011). Furthermore, in addition to this divergence, we've found that professional cycling athletes will typically employ their own coach on an individual basis, similar to what we see from other individual sport athletes (Larson & Maxcy, 2011).

Other Economic Questions

There are a variety of other interesting economic questions that originate from the unique structure of professional cycling and the design of the sport. These can be organized into the broad research categories of *performance,* and *micro-economic theory* and discuss the previous research efforts (if any) in each area.

Performance

The work on performance has focused on ranking or modeling performance using sport event results data. These primarily consisted of retrospective or prospective models of the outcomes of competition. Prinz (2005) was the first to examine the determinant of success for Tour de France cyclists, and he highlighted the importance of body mass (BMI) as a major determinant of overall success in that race. This was followed by Cherchye & Vermeulen (2006) worked on more robust retrospective rankings of professional cyclists and did add some more metrics of performance, i.e. sprint, stage, and climber competitions. Nearly concurrently, Torgler (2007) considered team position, experience, and country of origin in determining the athletes' performance outcomes.

Most recently, in an 'Economics of Sports' special issue of *Economic Analysis and Policy*, Torgler (2009) further commented on his study of cyclist performance, and Dilger & Geyer (2009) present a new study of the racing dynamics involved in sprint finishes, drawing on not only historical performance data, but also theories of natural physics for their modeling.

In many ways, the performance studies conducted in cycling are limited in that they have difficulty handling the practical complexity of cycling competitions, particularly at the Grand Tour level. In those events, there are numerous potential objectives, individual strategic choices, and dynamic team interactions. In order to get beyond generalities, i.e. lighter riders perform better in Grand Tours (e.g. Prinz, 2005), or extreme specifics, i.e. having no reliable real world application (Olds, 1995; 1998); this free-rider, team dependent, multi-objective, strategic framework will need to be more fully characterized. This provides yet another arena for future research in cycling economics.

Principal-agent problems

The production and performance of any team may or may not be optimal and the design of organizations can improve or compromise their efficiency (Alchain & Demsetz, 1972). The key problems we may see in sports structures have been studied in more general economic theory are most typically principal-agent problems that arise with contracted organization members. The classic modeling of these types of problems were most notably discussed by Alchian & Demsetz (1972), Groves (1973), and Holmstrom (1982), and they highlight the importance of moral hazard and outcome measurement. These papers however, primarily focus on the principle agent issues associated with the separation of ownership from management and the group *free-rider* problem. In a sports team context such as cycling, we may be more concerned with intra-team alignment of effort and reward. For example, this area has seen some exploration in professional team leagues in terms of shirking and contract length (Maxcy, Krautmann, & Fort, 2002; Krautmann & Oppenheimer, 2002; Berri & Krautmann, 2006; Krautmann & Solow, 2009), but cycling has not been considered despite the fact that some preliminary data suggests that cyclists are nearly always employed with one year contracts (Larson, 2010). Because a majority of professional cyclists must substantially sacrifice their performance for a team leader, but may at the same time face repeated employment negotiations based largely on their own personal performance history, one might expect that there are incentives to forgo team helping in some cases (perhaps just prior to contract negotiations) in the interest of boosting their own future earnings (or for that matter securing a leadership position on a different team). However, the comprehensive study of the sport of cycling has been somewhat hindered by the lack of accessible employment and compensation data for the cycling ProTour compared to the U.S. professional team leagues.

Professional cyclists are known to have unusual compensation structures in that they are compensated not only through team salaries and bonuses, but also through sharing the prize money that their team leader wins. Their accumulated prize payments are a significant proportion of their annual earnings and come directly from the race organizers. The interesting arrangement behind this fact is that all team members split prize winnings equally. For example, the Astana team earned over €697,000 in the 2009 Tour de France (Tyler, 2009), and once split among the 9 participants (€77,400 each), even this *one* event share outweighed the *annual* minimum professional rider salary of around €65,000 (UCI, 2011) for a team *domestique*. The support of team leaders in an effort to capture extremely top-heavy rewards is essentially rewarded directly by the team leader's redistribution of these prizes. While Candelon & Dupuy (2010) has begun to acknowledge this implicit labor market in a working paper, no other in-depth research has examined these hybrid compensation features.

Incentive structures

Not only are these arrangements a unique case among all sports, but they also may have significant analogous applications for corporate team production. How this implicit labor market (splitting of prizes) interacts with the market for employment within teams (organizational salaries) could be especially relevant to team structures and compensation situations in broader corporate practices. For one particular example, we can consider the financial management industry which operates largely in research teams (*domestiques?*) in support of fund managers who claim the individual "victories". The structure of competition within and among these teams, as well as the labor compensation consequences for participants may show many similarities i.e. lavish perquisites distributed among the team perhaps. These team production functions and organizational hierarchies in general lend themselves to study of incentive design and moral hazard in comparison to competitive cycling.

Team dynamics

Finally, the structure of teams that arises within competition, i.e. how competitors determine how much they will contribute to another's performance (teammate), is the contribution of the previously mentioned working paper by Candelon and Dupuy (2010). The team dynamics of cycling perhaps hold the most promise for application in analogous commercial contexts, as we know of many professional endeavors that operate in similar teams: trial lawyer, financial management, design teams, etc.

Summary

Taken as a whole, the review of sports economic literature, and the sparse literature directly related to the sport of competitive cycling, suggests that many economic issues in cycling have been broadly under-investigated. The remainder of this dissertation will present two topical examples of these research opportunities, and highlight their usefulness for broader economic inquiry. Despite these two efforts, there will by no means be a shortage of remaining topics salient to economists and sport scholars for future research efforts in the context of competitive cycling.

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Tables

Table 2.1

Full time employees of a professional cycling team

Employee	Pro Teams (I)	Pro Continental (II)	UCI Continental (III)
Managers	1-2	1-2	0-1
Directors	4-6	1-6	0-2
Mechanics	4-9	1-9	0-3
Soigneurs	5-14	1-10	0-2
Riders	24-30	15-26	8-15
Other (Marketing/Secretary)	2-6	0-3	0-1

(Source: UCI, 2010; and 2010 team website staff listings)

Figures

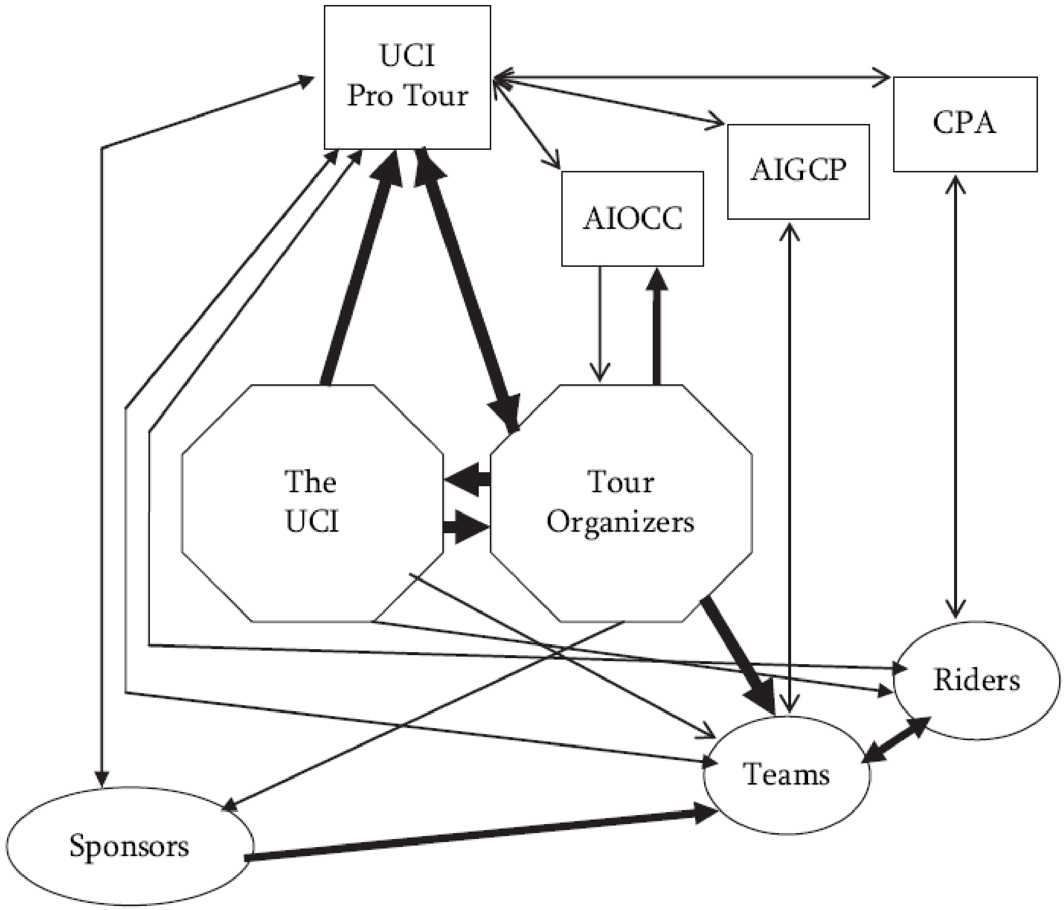

Figure 2.1. From Morrow & Idle (2008). The organizational structure of professional road cycling. UCI Pro Tour: governed by the UCI Pro Tour Council, it manages the UCI Pro Tour on behalf of the UCI. AIGCP: International Association of Professional Cycling Groups (umbrella organization for the cycling teams). CPA: Association of Professional Cyclists (umbrella organization for the riders). AIOCC: International Association of Organizers of Cycling Races (umbrella organization for the race organizers).

CHAPTER 3

INDUSTRIAL ORGANIZATION OF CYCLING COACHES[16]

[16] Larson, D.L., Turner, J., and Maxcy, J. To be submitted to *Economic Inquiry*

Abstract

The structural components of sports competitions and the characteristics of sport practices can vary significantly. These differences may be translated into different optimal employment arrangements for professional coaches. While there has been some academic inquiry into sport coaching practice, there has been no apparent research into the industrial organization of sport coaches. This paper presents a formal model of coaching practice that generates employment arrangement predictions based on known model parameters. Using some established stylized facts about competitive cycling, the models predictions are compared to empirical data about the cycling coaching industry; that prediction being that coaches would not generally be hired by cycling teams, but rather by the individual athletes. The model predictions are consistent with the stylized facts and empirical evidence, i.e. most athletes hire their own coaches and those coaches typically are not employed by teams.

Introduction

Generally, competition outcomes (Prinz, 2005; Cherchye & Vermeulen, 2006; Torgler, 2007; Dilger and Geyer, 2009) and overall industrial governance (Rebeggiani & Tondani, 2008; Desbordes, 2006, 2008; Morrow & Idle, 2008) have been the primary considerations for previous economic inquiries into professional cycling. There has been little if any discussion of the 'non-competition' industry details such as administration and coaching. While all of the previous works have rigorously considered professional cyclists' individual production, and the organizational structure of the sport, sport coaching and production management were simply not addressed. Larson and Maxcy (2011) conducted a basic study of the clientele and human capital of practicing U.S. cycling coaches. However, their study was limited to descriptive analysis, and although suggested in their discussion, no theoretical advancements were attempted.

This manuscript will focus on developing the economic model of the industrial organization of sport coaching, which may help to explain the employment arrangements of cycling coaches and their peculiarity relative to other sport contexts. Specifically, stylized facts about the industry will be discussed and compared to a general theoretical model of sport coaching. The model predicts that cycling coaches will not work within professional cycling teams, but will instead be independently contracted by individual cyclists. Data for the empirical examination are drawn from two sources: an internal survey of licensed coaches conducted directly by USA Cycling in 2008, and a more thorough independent industry survey of U.S. Cycling coaches (licensed and non-licensed) and U.S. Professional and Elite cyclists conducted in 2010.

Literature review

There have been widespread academic and practical investigations of sport coaching in terms of pedagogy (Cassidy, Jones, & Potrac 2008; Light & Dixon, 2007), practical application (Hoigaard, Jones, & Peters 2008; Hollembeak & Amorose 2005; Douge, & Hastie 1993), and human resources (Ryan & Sagas 2009; Rocha & Turner, 2008; Graham, Wedman, & Garvin-Kester 1994), but little apparent *economics* work has focused on the industrial organization of sport coaching (Larson & Maxcy, 2011). There are few discussions of human capital (Singell, 1991; Larson & Maxcy, 2011), examinations of compensation (Humphreys, 2000; Kahn, 2006; Frick & Simmons, 2008), and investigations into coaches' contributions to production (Clement & McCormick, 1989), but the topic of overall coaching industry structure has been relatively untouched. This may be due to the fact that coaches are, in a majority of sports, simply viewed as incorporated (black box) employees or labor inputs in the production of their sports products (competitions). Coaches of team sport athletes who might operate independently and outside the employ of professional teams do not fit into this standard mold. Furthermore, coaches of *professional cyclists,* who appear to have this independent practice model (Larson & Maxcy, 2011), have also not been the subject of any published economic inquiry. The relevance (or lack thereof) of each of these previously exercised coaching research areas speaks to the need for a generalized theory of coaching practice in sports. What does a coach add to the sports product? How are the gains to coaching integrated into team management's objective function? How can differences in the nature or sports settings affect the structure of a sport's coaching industry? We propose a general theory of coaching practice that is not only consistent with the stylized facts about the cycling coaching industry, but could answer these questions for other sports ex ante.

Coaching/Consulting. There are a small number of research works focusing on coaching and consulting in terms of industry structure, and these primarily focus on executive coaching. Many of these papers highlight the ambiguity of coaches' roles and tasks (Hall, Otazo, & Hollenbeck, 1999); and what performance outcomes are present (Schlosser et al., 2006). Some suggest a substantial overlap into psycho-therapeutic methods (Levinson, 1996), and others highlight the risk of coaches' unwitting influences on executives (Berglas, 2002). In nearly all of these cases, coaching is examined in terms of leadership and executive performance. The consideration of the effect of coaching of on subordinates, or employee coaching, has yet to be examined. For one thing, separating out specialized task training from coaching services within an organization might be difficult, if not impossible. The definition of a coach is up for debate at that point. The difficulties of observing employee performance and internal operations in a traditional organization, and determining where coaching is or isn't taking place for "non-leaders", can make data-collection and analysis very difficult. However, we suggest that these issues may be largely side stepped by studying training and coaching within sports settings. While some sports structures may be more analogous than others to any one industry, there could potentially be uses for sports findings that cross-over to extensively similar industrial conditions. This is a mainstay contention for most economic inquiry in sports (Kahn, 2000; Zimbalist, 2001; Seaman, 2003; Szymanski, 2003a; Fizel, 2006). In the case of coaching in sports, employee (athlete) performance is clearly observable, tasks and production are clearly defined, and coaches are explicitly named and/or defined by the client. A coach is a coach because an athlete accepts or states that he/she is. Additionally, the structure of cycling competition in particular would seem to have much in common with many industrial contexts such as legal teams, design teams, financial management teams (Candelon & Dupuy, 2010).

The remainder this paper will be organized to (a) propose a theoretical model for the industrial organization of sport coaches; examine existing stylized facts about professional cyclist coaches and highlight the unique industrial features of the cycling coaching industry that are consistent with this theoretical framework; and (c) conclude with remarks about limitations and future empirical opportunities.

Model

A general theoretical framework will be presented next to potentially explain coaching arrangements in various sports. A coach-athlete matching model is presented, and a specific mathematical model incorporating the unique labor structure of cycling is explored.

General Sport Coaching Framework

We begin by considering the activity of coaching in the simplest terms. The basic premise of coaching service is that the activities of a sport coach generate at least some marginal improvements in the performance of an athlete. We will simplify the discussion by assuming these expected performance improvements map to monotonically increasing payoffs (revenue) earned by the athlete. As such, a coach and client will engage in bilateral bargaining to determine compensation for the coach somewhere between the coach's reservation wage and their expected marginal revenue product.[17] Coaches will

[17] Note that in the amateur client cases, these payoffs may be increased utility or some speculative investment for future financial gains, but for the professional athlete cases, we will consider that these

therefore demand a wage (w) that is a function of the ability of their client (z_i), and their coaching effect (c), i.e $w(z_i, c)$.

Sport Practice. One distinguishing characteristic among different sports contexts relevant to coaching is the nature of the preparation for competition, i.e. practice. Coaches are employed for designing and directing these types of activities in essentially all sports. Sports can vary in not only (1) the specific skills that are practiced, but also (2) the level of physiological conditioning required, (3) the level of integrated action (plays), (4) the physical characteristics of the competitive facility (field of play), and (5) the dispersion of athlete residences (whether there is actually a "home" area). For example, a basketball team has a high emphasis on skill practice, some degree of cardiovascular conditioning, a high degree of planned team interaction (set plays), has a clearly defined field of play (the court dimensions), and a "home" city in which the players reside and host about half of their competitions. In contrast, a professional golfer has high emphasis on skills practice, a lower importance to cardiovascular conditioning, no team strategy or plays, a vastly heterogeneous field of play (courses, surfaces, weather, etc.), and no regular "home court"[18]. Examples of sport practice characteristics are shown in Table 3.1.

The implications for coaching practice are that some of these characteristics can alter the *efficiency gains* possible for different coaching employment arrangements. Straight away, we can see that individual sport athletes will choose to directly contract

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individuals are "fully developed" in the sense that they only realize present period gains from hiring coaching and their future income streams are not changed by current period coaching.

[18] Although golfers may have a "home" course near their residence, their competition there is at best infrequent, and practicing on a single non-standardized home site does not seem to offer any advantage to their preparation. If anything, experiencing a variety of conditions (courses) and/or standardized "range" practices would be preferred.

with their coach because there is no team entity or team interaction required for their competition, i.e. each individual athlete essentially operates as his/her own "firm". At best, from these characteristics we might predict that individual sports that require extensive fine motor practice, e.g. tennis, golf, would seek coaching from local or "in person" coaches to economize on travel, while the gross physiological conditioning sports such as distance running, and triathlon could be effectively conducted remotely.

In team sports however, there may be potential gains to a team hiring a coach rather than the individual athletes hiring them directly. Returning to the example of a basketball team, a coach that focuses heavily on skill development can exploit economies of scale by observing and directing the entire team during designed skills practices, e.g. shooting, passing, lay-ups. Additionally, there are efficiencies gained during coordinated practice and the rehearsal of specific planned plays. It seems illogical to think of basketball players learning a variety of team plays independently from one another, with separate coaches, and even potentially in separate locations.[19] The losses incurred from coordination errors, communication costs, and reintegration time of the team members would likely far outweigh the benefits to any individualized attention. Therefore, the more important and varied integrated team skills are, the more efficient an "in-team" coach can be.

Cardiovascular conditioning on the other hand, more often requires specific prescriptions of exercise tailored to an individual athlete's physical strengths, weaknesses, and levels of health and fatigue. In this way, physiological training is ambiguous as to how it could influence coaching employment efficiencies. One way to consider this effect is to examine how much physiological training manifests in

[19] Or in series from the same coach

competitive outcomes. In most team sports, reaching peak cardiovascular performance is not a direct determinant of the sporting outcomes. Instead, athletes in these sports simply must have some adequate level of cardiovascular ability to compete in other primary ways (motor skills, strategy). In these cases, there could be savings in search and contracting costs if a team manager could select a coach who would work adequately with multiple team athletes in terms of physiological conditioning secondarily to their skills practice. However, when individual *peak* physiological performance is critical and primary to a sport's outcome, e.g. distance running, swimming, and cycling, the individuality and specificity of coaching is increased in order to capture those marginal physiological and psychological benefits that can be the difference in winning and losing. The determination of hiring arrangements on this dimension (physiological preparation) would therefore hinge on how important matching is to effective coaching. If the athlete-coach match is very specific and incorrect matches costly in terms of performance losses, they may easily outweigh any savings to be had from having the team do the hiring of a team coach.

The standardization of the playing field is one area where nearly all team sports enjoy a benefit for training and preparation. While there may be subtle variations across playing fields, athletes essentially face a standardized environment that can be replicated in many locations. Additionally, there is no real benefit to practicing with non-standard equipment or in alternative environments. There is specificity in training. Athletes that face heterogeneous playing environments, such as golfers, road racing runners, and cyclists, cannot capitalize on this type of standardization for practice sessions.

Having all players in one place, i.e. a hometown, allows for some savings as well. When the calendar of a sports competition requires more than half of a player's work days to be completed at or near a "home" site, the players will most often choose to reside somewhere near that location to economize on travel cost.[20] In these ways, a basketball team can subsequently economize on the labor input of the coach. If a teams members and their competitions are widely dispersed geographically, they will not only face the coordination problems in practicing team plays, but the team would also either suffer the costs of transporting coaches around, or hiring more local individual coaches for the athletes, which again undermines any potential economies of scale.

While all of these elements that offer efficiencies to traditional teams sports clearly predict a policy of centralized hiring of coaches by sport team organizations, and predicts that individual sports will do the opposite because these efficiencies are not present there, the sport of cycling produces a more difficult case to fit within this general framework. Cycling is a hybrid of these two sport models; it is an individual sport conducted in teams, perhaps very similar to the corporate examples described above. If cycling were clearly an individual sport model, we would expect the athletes to hire their coaches themselves. If the team elements were primary, we might expect that there would be efficiency gains from the teams hiring the needed coaching. After closing this section with a discussion of some of the sport of cycling's general practice characteristics, the following section will present a formal sport coaching model that can incorporate the peculiarities of the cycling's production functions and how the conditions and

[20] Professional athletes travel is arranged and paid for by teams for away games, but remote residence introduces the personal cost of traveling for home matches, both the time and money for conveyance.

characteristics of the sport lead to the prediction that the coaches will be hired directly by the athletes.

Cycling practice. The specific skills that are practiced for cycling are in many ways easily learned and maintained. As most individuals learn to ride and balance on a bicycle as children, and have little degradation of those skills, i.e. “it’s like riding a bike [you don’t forget]”, there is little emphasis, particularly at advanced levels, on practicing motor skills. Additionally, cyclists’ physical conditioning is integrated with any skill practice as it all takes place while riding. One could contrast this with team sports that more often separate drills (repeats) from conditioning (running laps). These other sports also rely heavily on precision for their main forms of production (scoring). Cycling has no such analog. Performance is based on finishing times alone and there are no needles to be thread. In this way, any efficiency gains from skills coaching in groups would be gains in an area that is not typically in deficit or a major determinant of final performance.

In terms of integrated team skills and plays, we can consider the actions competing cyclists execute as a team. These would involve performing extra work by leading the racing group, sheltering a leader from wind resistance, ferrying food and water to teammates, and offering mechanical assistance to one another. None of these activities require the complicated integration and timing that is often seen in other team sports’ set plays. When examining the structure of the sport of cycling, which will be outlined at length below, it becomes clear that the importance of team work is more about strategic resource allocation rather than orchestrated maneuvers. Again, set “plays” are not something practiced or emphasized in cyclist preparation, and this avenue of efficiency gain for coaching seems absent in cycling. There is a critical coordination of roles that can be differentially influenced by internal vs. external coaches. In particular, the optimal assignment of the leader and helper roles among the riders could be undermined if the rider coaches are not employees of the teams. In that case, an outside coach may have greater incentive than the team manager for his/her athlete to be assigned a team leadership role.

The physiological training of cyclists is also one area where team efficiencies might seem to be present. It would seem that if a manager could hire even one coach that was sufficient for two or more athletes, there can be transactions cost savings. However, one might suggest that because cycling is still ultimately a test of peak physiological conditioning, the concept of "sufficient" and "peak" are incongruent. Because of the specificity of physiological training in cycling, transactions cost savings could be more than offset by losses due to sub-optimal matching. This counterbalance will be incorporated into the formal model to follow.

The playing field consideration, while somewhat integrated with the gains to group skills practice and team play practice, also does not emerge as relevant to the practice of competitive cyclists. Cyclists compete not only on a wide variety of terrain, road surfaces, and in ever-changing climate conditions, but even annual event *parcours* (routes) change from year to year.[21] In this way, there is little gain from centralized practice in a standardized environment. The variety of conditions the cyclists face would more call for developing adaptability and resilience to obstacles. Without this standard field of play, cycling teams lose the efficiency benefits of collective practice, as well as the opportunity for centralized coaching.

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[21] The Tour de France presents a completely new route each year

Hand-in-hand with these heterogeneous competition venues, cycling teams are not linked with any competition facility or "home" competition. Professional cycling has become a global sport and although teams' business headquarters may be in one location, these are seldom meetings, practices, or competitions at that location. Cycling teams are in fact rarely wholly assembled even for competition. The one or two occasions would be a pre-season team camp, and/or a team presentation. These instances are exceedingly focused on sponsor and media education, team and individual photographs, equipment distribution, and administrative meetings. Team practice, and with it the opportunity for group coaching, essentially does not exist. Additionally, investments in specialized training facilities and facilities for cycling are essentially nil.

Formal model of team coaching

Team labor. The model of team cycling formulated by Candelon & Dupuy (2010) characterizes the major features of the sport of cycling and has several important primitives and predictions that will form the basis of the current discussion of general team production. To begin with, Candelon & Dupuy characterized the individual athletes as having a production ability z_i among a distribution of possible abilities Z $(z_i > 0)$. These athletes' abilities map to velocity (*p,* production), which in turn map monotonically to finishing position and prizes (*v,* payoffs). Because of the unique aerodynamic considerations present in cycling, individual cyclists have the option of using their abilities (selling their labor) to benefit other cyclists as helpers. From among the available cyclists, teams would be formed based on the differential payoffs derived from support, with cyclists eventually choosing to perform their labor as helpers, leaders, or individuals (autarky). More able riders become leaders (z_l), and less able riders become helpers (z_h), i.e. $z_l > z_h$. Candelon & Dupuy's model essentially gives rise to velocity functions for the individual cyclists and a production function for a simple two rider team where α is a proportional cost factor for helping, s is the proportion of time spent helping, and $f(z_h)$ is a continuous monotonic function representing the potential assistance garnered by a leader from a helper's labor:

(1) Helper's velocity: $p(z_h, s) = z_h - s\alpha z_h$

(2) Leader's velocity: $p(z_l, s) = z_l + f(z_h)s$

(3) Team's production: $Y(z_l, z_h, s) = v(z_l + f(z_h)s) + v(z_h(1-\alpha s))$

Their theoretical framework predicts that given an extreme convexity of performance payoffs (which is supported by the stylized facts regarding the competition prizes in cycling) athletes will generally not practice autarky, and will become either a helper or leader. Therefore a cyclist chooses to devote either all or none of their work time to helping ($s = \{1,0\}$). Candelon & Dupuy's model is not only mathematically sound but is also generally supported by the stylized facts about professional cycling competition (discussion to follow).[22] We can also note here that the helping effect, $f(z_h)$ essentially represents how effective helping can be in a sport generally, i.e. the level of independence of the performance between team members is in competition. In other words, in team sports of aggregated performance, such as team swimming or gymnastics, the helping effect is nil, $f(\cdot) = 0$. In these cases, autarky is always the dominant production choice for the athlete, and is also optimal for the team. This model also fits other team sports in that all team members can use this helping function, but in many team sports the proportional cost of helping, α, is minimal, and/or there are complicated cross-dependent

[22] See Candelon & Dupuy (2010) for complete distributional assumptions, proposition proofs, and industry descriptives.

helping functions that feed into their overall team production function. In other words, teammates may enhance each others performance with their actions, but these actions are not always directed toward one team leader (as in cycling) because the collective team outcome is the primary goal.

We can in turn expand this model to incorporate general athlete coaching in the performance (velocity) and production functions, and discuss predictions about coaches' employment within or outside of the sport team organizations with respect to efficiency and total value creation.

Value Maximization. The total value generated by the hiring of coaches can be restricted to the considerations of the primary stakeholders in the process: the coaches, the athletes, and the team managers. Essentially, we will consider the market for professional athlete coaches, the conditions of professional cyclists hiring or not hiring coaches at all, and then finally whether or not it is strictly optimal for either the riders or managers to hire them. Ultimately there are two employment arrangements that must be considered:

A. Team hires one coach to coach all team athletes

B. Athletes hire coaches directly themselves

Coaches. We will consider the coaching market to be competitive and that coaches will prefer coaching as many professional athletes as they can to maximize revenue. This is consistent with the stylized facts about the cycling coaching industry in the U.S. as there are thousands of licensed, practicing cycling coaches, and less than 175 professional athletes (USA cycling, 2009; Larson & Maxcy, 2011).

Athletes. To begin the discussion of hiring, we will assert that using any hired coach has a strictly positive effect ($c \geq 0$) on the performance of an athlete. This is reasonable assumption considering that the athlete and coach relationship is driven by the athlete, i.e. the athlete seeks advice and guidance as often as they feel is useful, and a athlete would clearly not hire (or ignore) a coach that might have a negative influence on their performance. Note: We could also consider athletes who do not use an outside coach to be effectively "self coached". By coupling the original model framework with this first assumption we can consider the introduction of coaching into the production functions of the teams and the individual athletes. To begin, with all of the athletes using some form of coaching, the payoff improvements for leaders are both direct and indirect as they will benefit not only from their own coach, but will also benefit from the improved help of their teammates. The helpers also enjoy a direct benefit and the overall team production function is likewise altered. These functions follow:

(4) Helper: $p(z_h,s)= z_h + cz_h - s\alpha(z_h + cz_h)$

(5) Leader: $p(z_l,s) = z_l + cz_l + f(z_h + cz_h)s$

(6) Team: $Y(z_l,z_h,s)= v(z_l + cz_l + f(z_h + cz_h)s) + v((z_h+ cz_h)(1-\alpha s))$

In this condition we can see that with any coach hired by any party, both the riders' and the team's payoffs are strictly higher with the addition of coaching. Therefore, all parties have incentives to have effective coaching in place provided that the costs of hiring these coaches are less than or equal to these gains.

Matching. In order to incorporate the matching process of athletes with coaches and the potential for inappropriate or sub-optimal matches, we use a modified version of a "characteristic" labor matching model common in the labor matching literature. This type of model, articulated by Dagsvik, J. et al. (1985), and a more complete explanation of its modification and application here, is included as an appendix (Appendix A). In summary, athletes will have superior information about their ideal coach than outside parties, particularly their own cycling team management, who will do incrementally worse at choosing the correct coach to hire. To capture the potential inefficiency of coach matching, we include a factor that represents the reduction of the match effectiveness in production. We will call this factor θ_i, $0 \leq \theta_i \leq 1$ for all i, and characterize c as an athletes' potential coaching gains. θ is therefore a factor reducing this potential effectiveness of hiring coaching because the coach was chosen by someone else (*m)*. For example, for any person (*m*) choosing an athletes coach, the resulting match can range from almost completely ineffective ($\theta_m = 0$) to identical to the athletes choice ($\theta_m = \theta_i = 1$). And from our matching model assertions, we can further state that:

(7) $c\theta_i z_i \geq c\theta_m z_i$ for any $i \neq m$

This matching factor can subsequently be incorporated into the velocity/production functions as follows:

(8) Helper: $p(z_h,s) = z_h + c\theta_m z_h - s\alpha(z_h + c\theta_m z_h)$

(9) Leader: $p(z_l,s) = z_l + c\theta_m z_l + f(z_h + c\theta_m z_h)s$

(10) Team: $Y(z_l, z_h,s) = v(z_l + c\theta_m z_l + f(z_h + c\theta_m z_h)) + v((z_h + c\theta_m z_h)(1-\alpha s))$

Transactions costs. When comparing the possible outcomes or team hired coaches or athlete hired coaches, there is still the possibility in practice that team management might reach the same match selection as the athlete, i.e. $\theta_m=1$ (due to the discrete choice of a coach), so it is not entirely clear that athletes hiring coaches is strictly dominant. However, we suggest that transactions costs might be the proverbial nail-in-the-coffin in predicting the employment arrangements between teams, individual athletes, and coaches. After all, we have considered the added value of using coaching, but not yet the cost of acquiring coaching. Coaches could simply be hired by the team management or hired by the individual athletes, and both employers could presumably pay identical wages up to the marginal product of the coaching services.

While it might be safe to assume the wage costs of hiring coaches is likely not different between individual athletes and team managers, the transaction costs may be much different. Primarily, an athlete that has a better understanding of the type of coach they require (see Appendix A) will be able to more efficiently screen potential coaches and determine their best choice more quickly. As alluded to before, this can arise simply because of the location and costs of information gathering. If an athlete is searching for a coach match, he/she already possesses the specific information about themselves and the exact requirements of the job, and must singularly gather information about potential coaches. The manager on the other hand, would essentially be introduced as an intermediary step to the process, and would need to gather information not only about potential coaches, but also all of the information about their cyclist's specific needs. Relating back to the matching model, these "search" and information gathering investments would be imperfectly returned through improvements to θ_m. When considering this factor, a manager's efforts to find and hire a coach will be strictly more costly. This translates into asserting greater transaction costs of hiring coaches for managers relative to individual cyclists, i.e $T_m > T_i$, for all $m \neq i$. We can specifically suggest that the difference in these search costs will be an increasing function of the specificity required of a coach, i.e. how personalized the work is. The parameter, $\omega > 0$, will represent this specificity, such that $T_m = (1 + \omega)\, T_i$.

To see how this affects the team decision, we can consider the payoffs for both the helper and leader if they were to hire their own coaches, as well as the payoff for the team if they were to hire coaches for their athletes. This requires that the management incurs independent transaction costs for hiring each coach. Additionally, we will use a standard wage w. With these costs considered, we have the following payoffs of each party if they hire their needed coaching (note that helper and leader functions are now payoff functions, not performance functions):

(11) Helper: $h(z_h,s) = v(z_h + c\theta_m z_h - s\alpha\, c\theta_m z_h) - w - T_h$

(12) Leader: $l(z_l, s) = v(z_l + c\theta_m z_l + f(z_h + c\theta_m z_h)s) - w - T_l$

(13) Team: $Y(z_l\, z_h,s)= v(z_l + c\theta_m z_l +f(z_h + c\theta_m z_h)s)+v((z_h + c\theta_m z_h)(1 -\alpha s))-2(w+T_m)$

It is clear from these expressions that if the team management were to transfer the coach acquisition task to athlete, i.e. "buy", they would be willing to transfer as much as $w + T_m$ to each athlete through their salary or extra payments, and each athlete would take on their coach hiring process for as little as $w + T_i$. Regardless of where they end up in this range following bilateral bargaining, it will still be superior to the "make" option of the team assuredly paying $w + T_m$. This analysis still assumes the team payoff gains to coaching (the difference between Equation 10 and Equation 3) are greater than $2w + \sum(1+\omega_i)T_i$. Even if the collective team payoff gains do not exceed this however, at least some of the individual athletes might still hire coaches if the potential gains exceeded $2w + T_l + T_h$ and the athletes could bargain with each other over these coaching costs. It is important to note that at this point benefits of teams hiring coaches are not yet incorporated.

Team coordination. We also add a parameter (γ) that represents the probability for misallocation of team roles by team managers which arises again because of an information asymmetry ($0 \leq \gamma \leq 1$). As coaches that are not employees of a team will have information about their athletes that they may not share freely with the team, the team may make more errors in role assignment with outside coaches than with an internal employee. In particular, an outside coach may have greater incentive than the team manager for his/her athlete to be assigned a team leadership role. This is because the coach is likely to be judged on the performance of his/her athlete, not on the joint payoffs the teams and athletes care about. Conversely an internal coach will be judged based on the team performance. In this way, an outside coach would refrain from honestly reporting the weaknesses of their athlete for their own interests. This asymmetry would adversely affect the coordination of the team, i.e. assignment of leader and helper roles, if the coaches are not employees of the team. So with γ probability, the team will make the correct (optimal) allocation. The more able team members will be assigned the leadership role, and the less able team members will be assigned helper roles. With the probability ($1-\gamma$), the better athletes will sub-optimally be allocated as helpers and less able athletes will be assigned to leadership roles. So the payoffs for the team are $\gamma(Y(z_l, z_h))$ where z_l is assigned leadership, or $(1-\gamma)(Y(z_l, z_h))$ where z_h is assigned leadership.

"Home" facilities. Finally, we incorporate an additive parameter that represents the potential efficiency gains from having team-owned central facilities, ψ. This

parameter can be interpreted as an increasing function of the capital investments in facilities and necessity of specialized equipment for a sport's training.

By adding this final parameter, we can consider the structure of any team sport to determine where practice coaches are likely to be employed, i.e. by teams or individuals. The complete general model for the team decision with all parameters is:

$$Y(z_l, z_h, s, f(\cdot), \alpha, \theta, \gamma, \omega, \psi) = \gamma\, [v(\, (z_l + c\theta_i z_l + f(z_h + c\theta_i z_h)s)) + v((z_h + c\theta_i z_h)(1 - \alpha s))] +$$

$$(1-\gamma)\, [v((z_h + c\theta_i z_h + f(z_l + c\theta_i z_l)s)) + v((z_l + c\theta_i z_l)(1 - \alpha s))] -$$

$$[2w + (1+\omega)(T_l + T_h)] + \psi$$

Model predictions: Cycling

Taking all of this into consideration, we can subsequently compare a cycling team's expected payoffs associated with a more continuous range of coach hiring policy decisions. Specifically, we can consider the team deciding what proportion of the total team coaching they will hire (ξ) and what proportion they will leave to athletes to buy (1-ξ). We know that $0 \leq \xi \leq 1$. For simplicity, we will consider two-athlete teams in a winner take all competition, with any number of teams competing, e.g. $N \geq 2$. Note that under this winner take all condition, s^* is taken to equal 1. This restriction eliminates the practice of autarky, and all athletes are either a helper or a leader. In this scenario, the payoffs is a positive increasing function of velocity, i.e. $Y'(p(z_l), p(z_h)) > 0$, and we note that $h(z_h, \theta_m) = 0$, so the team payoff equals the chosen team leader's payoff. The team manager would therefore solely seek to maximize the velocity performance of their lead rider and would only consider policy choices according the lead rider's production.

Restricting ourselves to the lead rider's production, we can consider the range of policy choices using the general model. The manager's policy decision (ξ) is therefore chosen to maximize according to these payoffs:

$$(14)\ \max_{\xi}\ Y(z_l, z_h) = \begin{cases} v\left(z_l + c\theta_m z_l + f\left(z_h + c\theta_m z_h\right)\right) - 2w - (1+\omega)(T_h + T_l), if \xi = 1 \\ v\left(z_l + cz_l + f\left(z_h + cz_h\right)\right) - 2w - T_h - T_l, if \xi = 0 \\ v\left(z_l + c\theta_m z_l + f\left(z_h + cz_h\right)\right) - 2w - T_h - T_l(1+\omega), if \xi = 1/2 \\ v\left(z_l + cz_l + f\left(z_h + c\theta_m z_h\right)\right) - 2w - T_l - T_h(1+\omega), if \xi = 1/2 \end{cases}$$

We also note here that for the sport of cycling, facility efficiencies are essentially non-existent, $\psi = 0$.

By directly comparing the terms in these expressions, we see that the hiring of coaches by athletes provides the largest expected payoff for the team. The internal coaching case, ξ = 1, will have strictly higher transactions costs than the ξ = 0 case, equal to $\omega(T_l + T_h)$, and concurrently, the performance payoffs for the team with externally hired coaches will exceed those of the team with internal coaching because $cz_l \geq c\theta_m z_l$ and $cz_h \geq c\theta_m z_h$. As such, the fully external coaching gain in the *correct* athlete role allocation will be:

$$(15)\ cz_l - c\theta_m z_l + f(cz_h - c\theta_m z_h) + \omega(T_l + T_h)$$

The reason this is specifically stated as the "correct" allocation is that we still need to include an accounting for the gains from team coordination, i.e. the possibility that athletes may not be assigned to the optimal role, leader or helper based on how coaches are employed. Adding the coordination consideration we know that it is a decreasing function of this policy choice $\gamma(\xi)$, and $\gamma'(\xi) < 0$. We assume here that teams with all internally employed coaches will attain perfect coordination, $\gamma(1) = 1$, and deviations from that hiring policy will reduce the likelihood of perfect coordination, i.e. for $0 \leq \xi < 1$, $0 < \gamma(\xi) < 1$.[23]

For the first special case, if a team chooses to hire a single coach to coach all of its athletes, $\xi = 1$, then the team's payoff function will be:

(16) $Y(z_l, z_h) = v[(z_l + c\theta_m z_l + f(z_h + c\theta_m z_h))] - (2w + (1+\omega)(T_l + T_h))$

If in the other extreme case, the management chooses not to hire its coaching internally, and the riders are free to choose and hire their own coaches, $\xi = 0$, we introduce the probability of misallocating the athletes $(1-\gamma)$:

(17) $Y(z_l, z_h) = v[\gamma(z_l + cz_l + f(z_h + cz_h)) + (1-\gamma)(z_h + cz_h + f(z_l + cz_l))] - 2w - (T_h + T_l)$

As we consider the coordination losses associated with less internal coaching ($\gamma < 1$), we must compare the allocation losses to the potential external coaching gains. In order for the management to instead prefer choice $\xi = 1$ to choice $\xi = 0$, the following must be true,

(18) $v[(z_l + c\theta_m z_l + f(z_h + c\theta_m z_h))] - (2w + (1+\omega)(T_l + T_h))) >$
$v[\gamma(z_l + cz_l + f(z_h + cz_h) + (1-\gamma)(z_h + cz_h + f(z_l + cz_l)] - 2w - (T_h + T_l)$

This reduces algebraically to the condition on γ:

(19) $$\gamma < \frac{z_l - z_h + c\theta_m z_l - cz_h + f(z_h + c\theta_m z_h) - f(z_l - cz_l) - (\omega)(T_l + T_h)/v}{z_l - z_h + cz_l - cz_h + f(z_h + cz_h) - f(z_l + cz_l)} \equiv \gamma^*$$

Where $\gamma^*(z_l, z_h, \theta_m, \omega)$ represents the cutoff value between hiring coaches entirely internally, and leaving the coaches to be hired externally. We can consider the effects of changes to the parameters on this cutoff value. For example:

$$\frac{\partial \gamma^*}{\partial \omega} = -\frac{(T_l + T_h)}{\underset{+}{(\cdot)}v}; \qquad \frac{\partial \gamma^*}{\partial \theta_m} = \frac{cz_l + cz_h}{\underset{+}{(\cdot)}}$$

[23] We will also still assume that s = 1. Riders will not forgo assigned roles, and the decision is irreversible.

The comparative effect of increasing athlete-coach specificity (ω) on γ^* is negative, i.e. the more specific the matching (the higher the transactions costs for teams are), the more severe the allocation problem would need to be (lower cutoff γ^*) to warrant switching to internally hired coaches. Additionally, the comparative effect of a positive change in matching quality θ_m corresponds to an increase in the cutoff γ^*, meaning the less you lose from having the managers match the coaches to athletes, the more likely you are to hire them internally. Overall, if γ^* is sufficiently small, then $\xi = 1$ will be preferred.[24]

Provided the key assumptions hold: (1) that payoffs are sufficiently convex, (2) athletes possess at least some private information relevant to coach matching, and (3) there are minimal economies of scale to hiring *peak* physiological coaching (i.e. highly personalized coaches), and (4) the team's coordination gains from internalized coaching are sufficiently small; $\xi = 0$ will be the optimal policy choice for team management. Athletes will be left to hire their own coaches, and team managers will essentially "buy" their coached athlete inputs. The following section will outline some empirical evidence from the sport of cycling that shows that it is consistent with these conditions and predicted employment outcome.

Empirical Data

A few of the necessary characteristics of the sport of cycling were discussed that should be verified empirically. In terms of coach hiring happening outside of cycling teams, we present some background stylized facts about the practice of cycling teams, the

[24] Note that an important assumed condition for this cutoff is that even in the misallocation case, the resulting velocity of the assigned leader (the less-able, helped rider), still exceeds the velocity of the more-able, helping rider. In this way, the team performance is still that of the assigned leader

structure of the sport, and a consequential verification of the coaching industry model prediction.

Stylized Facts: Cycling Practice

To begin, we will address the main assumptions the model of cycling coaching presumes and their likelihood of accuracy: (1) cycling competition payoffs are sufficiently convex, (2) cyclists possess private information about optimal coaching, (3) cycling performance is heavily dependent on *peak* physiological coaching, and (4) cyclists do not generally "practice" together.

In terms of the common structure of cycling payoffs, there have been a few relevant studies incorporating data reflecting its convexity. Most recently Candelon and Dupuy (2010) included time series representations of the prize distributions for the Tour de France winner that are reproduced in Figure 3.1. The convexity of rewards has increased over time, and now the winner takes home a larger proportion of the prize list. While this table illustrates the change in the winners share, examining the distribution of prizes for any particular placing drives home the point. Figures 3.2 and 3.3 illustrate the convexity in the overall and stage finishing positions for the Tour de France respectively, (*le Tour*, 2009). Despite starting over 190 competitors, the overall prize award falls below 1% of the total purse by the 8th place finisher! Additionally, the cycling governing body regulations themselves sometimes grapple with this move to convexity. For example, in outlining the regulations for prize structures, USA Cycling rulebook mandates:

> **Rule 1L3…**
>
> **b.** For each race with over $2,000 in prizes there must be prizes to at least 20 places and the values for second and following places must be at least the

> following fractions of the first place prize: 1/2, 1/3, 1/4, 1/5, 1/6, etc. for the first twenty places. Larger fractions are recommended. (USA Cycling, 2011)

Stefan Szysmanksi (2003b), in his discussion of the design of sport contests, also addressed prize features for individualistic events. Although he did not delve into the complication of shared prizes and team cycling, it was cataloged that the prize structures for individually classified races are often convex and increasing the "spread" of payoffs can improve performances.

One of the more critical assumptions to the cycling coaching industry prediction is that athletes have specific information about their individual characteristics. This limitation in the quality of an outside party's estimate may arise due to a confounding relationship between athletes and this "choosing" individual, specifically, an employee-employer relationship. As athletes are hired employees of team managers, and they are party to a bilateral bargaining process over wages, there are incentives for the athletes to maintain at least some asymmetric information relative to a manager. For example, assuming that athletes seek to maximize their earnings, these earnings depend on expected production, and presuming they have at least some private information about their own type that might adversely affect their earnings, e.g. known but unobservable weaknesses or imperfections in their skills and abilities, they would have direct incentives to conceal or not reveal this information to any potential employer (manager). However, this type of information would be especially relevant for selecting an optimal coach that might target these shortcomings for improvement. Therefore, a manager may not possess or acquire all of the information about an athlete's type(s) and/or coaching needs before hiring. Additionally, athletes on short term contracts will have incentives to maintain concealment of this information so as to not undermine future labor negotiations.[25] We do find some evidence that supports this short-term contracting scenario. In an unpublished data set gathered from U.S. professional cyclist contracts for another forthcoming study (see Table 3.2), we find that almost all (91-98%) of these athletes are contracted on an annual basis. This incentive to conceal information about weaknesses is coupled with the fact that much of the production of cyclists is difficult to observe, and performance data is lacking, especially for team support riders. Unlike other team sports where individual performance statistics are abundant, cycling competitions take place over many hours on open roads, often out of the view of management (and TV), and are not conducive to this type "play by play" scrutiny. Because the manager's information set is potentially limited by this information asymmetry, their estimates of the cyclists coaching needs (characteristics) could stray more often and more severely away from the true mean.

In terms of the specificity of coaching for the sport of cycling, we can look to studies in exercise science that characterize the demands and determinants of performance in cycling compared to other sports. Lucia, Hoyos, and Chicharro (2001) reviewed the physiological characteristics and demands of professional cycling and highlighted the requirements of performing at > 90% of maximal oxygen uptake for prolonged periods. In contrast, Sallet, et al. (2005) studied the physiological characteristics of professional basketball players and found homogeneity in general aerobic capacity across positions and levels of play. Previously, Wilmore and Haskell (1972) had highlighted the relatively low (and homogeneous) endurance capacity of NFL

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[25] As an aside, if a manager is choosing a coach to hire before he/she knows any information about their athlete, i.e. before hiring, he can do no better than a random coach selection.

players and how this characteristic was not likely to impact their sport performance. While Bloomfield, Polman, and O'Donoghue (2007) studied the physical demands of premier league soccer players and found more heterogeneity in activity based on playing position, they found them spending a small portion (4.9-6.6%) of their playing time in "high or very high intensity activity" and emphasized the importance of strength and coordination above aerobic endurance. These suggest that the physiological preparation for these sports is much more for general conditioning than for *peak* physiological performance (endurance). In terms of what we see in the practice of cycling coaches, the distribution of their athletes may be telling in this regard. If we consider that the coach-athlete relationship is very specialized because of these unique physiological/psychological tasks, we would expect any given coach to not "match" with many athletes. This bears out, as the U.S. coaches that report coaching professional athletes only report coaching about 2.1 professional clients on average, with a median of 1 client (Larson & Maxcy, 2011; see Figures 3.3-3.4).

Finally, there is also evidence that cycling teams do not practice together and typically do not have a geographical "center" as other team sports do. To begin with, the top professional cycling teams are spread around the globe and infrequently have competitions where their business offices are located. For instance, the Radio Shack team is sponsored by a U.S. company and has its business office in Austin, TX, but they compete in over 60 major international events, none of which are within 500 miles of Austin (Team Radioshack, 2011). In terms of nationality, the top 3 finishers in the 2010 Tour de France were a Spaniard on a Kazakhstan team, a Luxembourgian on a Danish Team, a Russian on a Dutch team (*le Tour,* 2011). As the extreme example, the Radio

Shack team features 29 cyclists from 18 nationalities and in addition to this multi-national composition, the cyclists' residences are spread far and wide. On that team, not a single rider resides in the same city, and very seldom are they living in the same country (Team Radioshack, 2011). The other ProTour teams have substantial diversity as well (see Table 3.3). The lack of importance for a central practice site for cycling is also emphasized by the fact that despite the geographic regularity of the Tour de France and the other monumental competitions, e.g. the Tour of Flanders, Paris-Roubaix, team cyclists generally do not reside collectively in or near those locations. More often, they make haven in Southern Spain, Portugal, California, and other dispersed locations with temperate climates. Cycling training, i.e. practice, is essentially considered a solitary vocation. Professional cyclists often have training partners but these are very often not teammates, e.g. when the Belgian rider Wouter Weylandt died in an accident in the 2011 Giro d'Italia, one of the most profoundly affected cyclist turned out to be Tyler Farrar, his training partner from a completely separate squad (Cyclingnews, 2011).

With these parameters established that are predictive of coaches working outside of cycling teams, we can consider some empirical evidence of that very outcome.

Stylized Facts: U.S. Coaching Data

Existing secondary data was analyzed, and new primary data was collected and analyzed to compare the available empirical evidence about the U.S. cycling coaching industry and the predictions of the theoretical model. Cycling coaches in the United States are most often members of USA Cycling, the national governing body for cycling and in order to practice the profession with a USA Cycling license, coaches are required to meet specified coaching education criteria and participate in continuing education activities in order to maintain their license. Virtually all competitive and formal participant bicycling activities in the U.S. are housed in this governing organization and licensed competitors naturally look to USA Cycling as the primary accreditation for cycling coaches. It is this population that we were able to examine.

2008 USA Cycling data. The original secondary data that surfaced to begin to describe the cycling coach industry was acquired directly from USA Cycling after they had conducted an internal survey of licensed cycling coaches. The raw data was coded and used to derive pilot descriptives and analysis. This original survey used a questionnaire of 36 items distributed to the approximately 1450 currently licensed coaches. They received 260 compete responses (17.9% response rate), 208 were male (80%), with and average age of about 44.5 years (SD = 9.7). Most telling of the industry practice, a majority of the coaches said they operated their business as a sole proprietorship or partnership (70.3%), while the remainder indicated that they were employees of another business or government agency (29.7%) (see Table 3.4). Understanding how many of this 29.7% actually worked within or for professional cycling teams was one of the key goals for the following primary data collection.

2010 Comprehensive Survey. An independent survey of cycling coaches was conducted in the summer of 2010. Institutional Review Board (IRB) approval was acquired for human subject research before any data was collected. In addition to access to the licensed coaches, access to the general cycling membership database of USA Cycling was granted, but more specifically, professional and elite (Pro-am) level competitors. USA Cycling executives and the coaching education manager agreed to allow a survey both groups using their email database. No specific provisions or restrictions were included. The survey was again an online questionnaire format. Participant coaches were asked to complete a 40 item questionnaire and participating athletes completed a 40 item questionnaire. The design aimed to limit average completion time to less than 15 minutes in order to assure an adequate response rate and limit participant attrition. The respondent who completed the questionnaire in its entirety took between 7 and 8 minutes on average to complete it. In all, 2207 coaches were solicited for participation and 565 (25.6%) completed the questionnaire. Of these, only coaches that were active, i.e. "currently coaching at least one road cyclist", were included in the industry analysis (N = 386). Of the 1178 athletes contacted, 351 (29.8%) completed the questionnaire sufficiently. Some of the descriptives collected are shown in Table 3.5.[26]

The new survey instrument contained items that focused on the quality *distribution of athletes* for an individual coach. Items were added to address several related questions: Do the best athletes match with the best coaches? Do coaches specialize to particular levels of athletes? This data helped address the falsifiable contention that perhaps coaches choose to coach outside of teams just to have the freedom to contract with all the best clients, i.e. the best coaches capturing the best clients. Specifically, if a top coach was an employee of a team, he/she would likely be restricted in recruiting top clients because of cross-team conflicts of interest. If coaches were escaping team integration for this purpose, then we would expect to see the best coaches serving many professional clients and very few lower level clients. However, this is not what we observe in practice. Individual coaches do not typically coach many

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[26] Some of these statistics are not immediately relevant to this discussion, but were used to characterize clientele composition of practicing coaches in Larson & Maxcy (2011).

professional clients, and they often build a pyramidal stable of clients across many competitive levels (see Figure 3.5). Coaches who report coaching professional clients still maintain an overall average clientele of 15.8 athletes (SD = 11.8). This supports the other empirical evidence for the assertion that professional cycling coaching is extremely individual in nature.

The most important findings arising from the new data source was presented previously in discussion by Larson & Maxcy's (2011) analysis of cycling coaches. Although that research focused on describing the industry to inform a discussion of the human capital of cycling coaches, some relevant stylized facts were established. Specifically, of the 113 responding coaches who reported coaching at least one Pro-am client, only one (0.9%) reported actually working for a professional team, and of all coaches 0.29% (see Table 3.6). This was also confirmed from the opposite side of the relationship as only four (8.5%) the 47 Professionals cyclists responding to the survey reported that their current coach works for their professional cycling team (see Table 3.7). Strangely, even three of those four who reported that their coach was an employee of their current cycling team also reported that they paid those coaches personally for coaching. This suggests that actually only one (2.1%) of the 47 athletes effectively had a coach that was employed by the team with the purpose of actually providing them with coaching.

Discussion

Other Examples

While this model is consistent with the stylized facts in cycling, it bears discussing other examples that might shed light on the usefulness of these critical parameters. After all, it might just be said that individual sports are coached by individual coaches, and team sports by sport coaches, so because cycling is ultimately an individual contest, it follows this taxonomy. There are however, a few special cases that we might see these parameters playing out contrary to this simple dichotomy. A few we will briefly discuss are strength and conditioning coaches supplemental to team sports, gymnastics coaches, and swimming coaches. In these cases their predicted industrial hiring arrangements might be primarily determined by the location parameter (ψ).

In the model of cycling, the two parameters that drive the employment arrangement prediction are related to the specificity of the coach- athlete relationship, (θ_m, ω). In team sports, the strength and conditioning coach's relationship with the athlete might also be very specialized and personalized, but they not be hired by the individual athletes because ψ is sufficiently high enough to outweigh any of the expected sub-optimal matching costs. The strength coach position might also abstract us from the coordination problem, i.e. assume $\gamma \rightarrow 1$, because a strength coach is not likely to add information change the athletes' role allocation.

In gymnastics and swimming, we similarly have extremely high investments in equipment and facilities that allow for higher location-based coaching efficiencies to be sought for an *individual sport*. For this reason, athletes may pool themselves together to form clubs and/or teams despite the lack of any integrated action within their competitions, $f(\cdot)=0$. This would be particularly true at the developmental level where the coaching gains are probably more frequently found in non-individualized skills and training, i.e. $\theta_m \rightarrow \theta_i$, $\omega \rightarrow 0$. Anecdotally, in gymnastics and swimming we see the highest level athletes sometimes hiring individual coaches, and developmental athletes more often working within a club or team that hires the coach. If these individual sports happen to be competing as teams, the athletes' performances are still distinctly separable in team production, i.e. $f(\cdot)=0$. As such, there is not the possibility of misallocating roles because there are no gains to assigning leaders and helpers.

Table 3.8 illustrates the anecdotally evident parameters and predictions of each of these three sports. Future empirical investigations could attempt to more thoroughly test this general coaching model within these contexts.

The role of knowledge

The role of specific knowledge and expertise may play a major role when working on theoretical representations of coaching industrial organization. We have considered how the characteristics of different sports might affect the basic make or buy considerations of sporting organizations. In the cases of traditional team sports, the organizations hire staff and assistant coaches that only work with limited numbers of the athletes in specific preparations, e.g. offensive, defensive, position coaches. This might be characterized as capitalizing on specialized knowledge that particular coaches possess, however the model presented above suggests that these team sport coaches might also be either directing a general form of physical conditioning, and/or economizing on working with athletes in a central location. So if we consider that competitive cyclists need some specialized knowledge, skills, and preparation from their individual coach, why is there not a place for specialty coaches within cycling organizations? Perhaps it is because the cyclists just do not have a "place" at all. The top cycling teams are headquartered all over the globe, and their athlete rosters have never been more internationalized (Thompson, 2008). Team members convene for racing events, but training and preparation is seldom collective. The lack of a home arena, stadium, city, can go a long way to undermining the normal efficiency benefits of group coaching.

Additionally, the actions a cyclist performs can be boiled down to either (a) trying to lead the group, (b) following within the group. When we compare this to the complex plays and finite skills of other team sports, it is clear there is much less “practice” coaching to be performed in cycling. Most of what a cyclist does to prepare for competition falls in the realm of physiological conditioning. So as football players have a need to specialize as required by their skill set and the level complex team plays, cyclists may need more personal assessments, testing, consultation, and carefully tailored training plans.

This whole question also reflects back on the nature of the sport of cycling being an individual sport practiced in teams with drafting as a dominant consideration. In cycling there are unique *opportunity costs* associated with team production, i.e. in order to support a team leader in cycling, a supporting team member must specifically sacrifice his/her performance for the direct benefit of the team leader.

Coaches palmares. A related consideration that is not incorporated in this model is that cycling coaches may have interests that conflict with cycling team management. For example, introducing specialized coaches into traditional team sports does not give rise to any negative consequence for the individual coach (or the athlete) as the success of one specialist footballer does not negatively impact the coach of another player on the team. However, the coach of a cycling team member at some point may be judged on his individual rider’s results, which may be precluded by others on the team because of his role within the team. The mere selection of team “leaders” for cycling teams (by team managers), from arguably comparable individuals essentially disadvantages one rider's coach relative to another's. Also, in other team sports contexts, coaches are not subject to the individual athlete level evaluations; a team's collective performance is what matters (to owners/managers). To add to this problem, the performance output of *domestiques* is not readily evaluated and performance differences can be subtle. In fact, a *domestique* crossing the finish line higher than 20th place may be frowned upon because it reflects that he/she did not "give it all" in support of the team leader, particularly if the team leader did not win the race! Measurement of their direct effects on the outcome of a competition is even troublesome due to the direct interaction with opposing team strategies, accidents, changing weather conditions, and inability to reliably observe their effort. Traditional team sport on the other had are loaded with performance statistics, and the brevity of the competitions allow for extensive "play-by-play" analysis. Cycling competitions taking place over many hours and periods of weeks are not conducive to this type of scrutiny.

We might further consider the market of potential coaches and their influence on the matching process. Even though there are thousands of licensed, practicing cycling coaches in the United States and less than 175 professional athletes (USA cycling, 2009; Larson & Maxcy, 2011), there may be scarcity in specific coaching skills, abilities, experience, and/or talent. In this scenario, we simply consider the coaching firms to be operating in a perfectly competitive supply market for professional clientele. Additionally, we assume that payments for services from athletes and team managers are viewed equivalently by the coaches, i.e. athletes' dollars are as good as managers' dollars. In doing so, we have limited our discussion of the coach-athlete hiring to only the parties with decision power, the athletes (or agents hiring coaches for them). A further discussion should address how coach bargaining power and objectives might affect these predictions.

Finally, understanding the industrial organization of cycling coaches could also potentially contribute to knowledge of other industrial contexts where large numbers of very small firms/individuals provide support services through instruction, coaching, mentoring, and consulting. Specifically, the way that cycling coaches conduct their industry, i.e. specialized, individualized consulting, is likely to have much more in common with the provision of these types of services in the broader corporate world than with that of typical team sport coaches or managers. This would be of particular importance in cases where corporate team members take the role of helpers and execute performances that are difficult to evaluate externally (as in cycling) and come at some steep personal opportunity cost. Additionally, in these contexts where performance is the result of complex individual preparation, especially in cognitive and psychological domains, the resulting industrial structure might be extremely similar. Future research should explore these questions and comparisons.

Conclusion

The prevailing idea behind the general model of coaching industry presented here is that the structure of the sport competitions and their unique practice features determine the equilibrium state of coaches' employment; in the case of cycling, predominantly having them employed outside of cycling teams by the athletes. The overview of practicing coaches above establishes some key characteristics of cycling coaching that lead us to the prediction that cycling coaches will not be hired by cycling teams. Specifically, these are:

(1) Cycling is not heavily focused on fine motor skill development and practice

(2) Cycling team tasks are simple and divisible

(3) Peak physical conditioning is primary to performance in cycling and is highly individualized

(4) Cycling competitions take place in extremely heterogeneous settings

(5) Cycling teams do not have a well defined "home" facility or competitions to economize on facility investments

Using the general model, these sport conditions predict the following: *Coaches are not typically employed by professional cycling teams directly and cycling athletes will hire and pay coaches individually and directly for their services.*

This prediction is entirely consistent with the stylized facts derived from the U.S. coaching data. Ultimately, this can be viewed as a "make or buy" decision for the team management's perspective, i.e. does the team buy their labor component that has been prepared (coached) outside of the company, or does the team purchase "raw" labor and then invest in the extra steps of production (coaching) themselves.

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Tables

Table 3.1
Sport practice characteristics

Sport	Team or Individual	(1) Importance of Fine Motor Skills	(2) Importance of Physiological Limits	(3) Team "set" play integration required	(4) Field of play	(5) "Home" facility
Soccer	Team	High	Moderate	High	Homogeneous	Yes
Baseball	Team	High	Low	Moderate	Homogeneous	Yes
Basketball	Team	High	Moderate	High	Homogeneous	Yes
Football (American)	Team	Moderate	Moderate	High	Homogeneous	Yes
Tennis (singles)	Individual	High	Moderate	None	Homogeneous	None
Golf	Individual	High	Low	None	Heterogeneous	None
Distance running	Individual	Low	High	None	Heterogeneous	None
Cycling	Hybrid	Low	High	Low	Heterogeneous	None

Table 3.2
U.S. Professional cyclist contracts

	2008		2009		2010	
Contract length	n	%	n	%	n	%
3 years or more	1	0.5%	1	0.6%	0	0.0%
2 year	16	8.4%	4	2.5%	3	2.1%
1 year	173	91.1%	154	96.9%	139	97.9%

Table 3.3
Team international diversity

Team	Home Nation	Rider Nationalities	Roster Riders
Omega-Pharma-Lotto	Belgium	6	27
QuickStep	Belgium	8	27
Saxobank	Denmark	11	27
Euskaltel - Euskadi	Spain	2	24
Movistar	Spain	8	26
AG2R La Mondiale	France	6	27
Vaconsoleil	France	9	28
Sky	Great Britain	14	30
Lampre	Italy	8	28
Liquigas	Italy	8	29
Astana	Kasakstan	14	28
Leopard-Trek	Luxembourg	10	26
Rabobank	Netherlands	6	27
Katusha	Russia	7	30
BMC	USA	9	27
HTC-High Road	USA	14	25
Garmin	USA	13	29
Radioshack	USA	18	29
Average		9.5	27.4

Table 3.4
2008 Practice mode responses

Which of the following best describes your business model or how you work as a coach?	Frequency	%	Cum. %
I run my own coaching business.	176	62.2	62.2
I run my own coaching business and have coaches working for me	23	8.1	70.3
I work in a business with other coaches.	32	11.3	81.6
I work through a club exclusively.	44	15.6	97.2
I work through a governmental agency (school, parks dept, et	8	2.8	100
Total	283	100	

Table 3.5
Coach summary statistics (2010)

Variables	*Minimum*	*Maximum*	*Mean*	*SD*	*N*
Age	19	80	44.57	10.15	386
Male	0	1	0.80	0.40	386
Some college education	0	1	0.92	0.27	386
Have some education in Exercise	0	1	0.29	0.46	386
Graduate or Professional Degree	0	1	0.41	0.49	386
Grad. or Prof. Degree in Exercise	0	1	0.17	0.37	386
Coach Full Time	0	1	0.29	0.46	386
# of Recreational Clients	0	88	4.43	10.62	386
# of Category 2-4 Clients	0	53	5.56	7.00	386
# of Pro and Category 1 Clients	0	12	0.71	1.69	386
# of Total Clients	1	100*	10.66	13.18	386
USAC1 Certification	0	1	0.14	0.34	386
USAC2 Certification	0	1	0.47	0.50	386
USAC3 Certification	0	1	0.83	0.38	386
Still competes in cycling.	0	1	0.72	0.45	386
Past Championships won	0	29	0.30	1.89	386
Years coach was category 1 or better (Proam)	0	20	1.42	3.51	386
Years coach has been practicing as a coach	0	39	6.20	6.43	386
Years coach ever spent racing	0	45	12.04	9.27	386

** Maximum response: "100 or more athletes"*

Table 3.6
2010 Practice mode responses

Which of the following best describes how you practice your coaching?	*Frequency*	*%*	*Cum. %*
I coach as an individual coach (independent)	271	70.21	70.21
I coach as an employee of someone else's coaching firm	42	10.88	81.09
I own a coaching firm with some employee coaches	27	6.99	88.08
I coach in a partnership (equal with no employees)	14	3.63	91.71
I coach as a volunteer or club coach	12	3.11	94.82
I coach for charity organizations/rides	8	2.07	96.89
I coach a college team	7	1.81	98.70
I coach as an employee of a gov't agency	4	1.04	99.74
I coach as an employee of a professional cycling team	**1**	**0.26**	100.00
Total	386	100.00	

Table 3.7

Athlete TEAM_COACH responses (For pro cyclists, n = 47)	Frequency	Valid %	Cumulative %
My coach IS a director or manager of my team	1	2.1	2.1
My coach is employed by my cycling team but is usually not my director/manager for competitions	3	6.4	8.5
My coach is independent of my team but works very closely with my director/manager on decisions about my preparations and competitions	8	17	25.5
My coach and director/manager interact infrequently about my preparations and competitions	8	17	42.6
My coach and director/manager almost never interact	26	55.3	97.9
I have no director or manager for competitions	1	2.1	100
Total	47	100.0	

Table 3.8
Sport parameters

Sport	θ_m	ω	$f(\cdot)$	γ	ψ	Expected Optimal ξ
Team sport strength coach (football, basketball, baseball, etc.)	$\theta_m \approx \theta_i$	$\omega \to 0$	$f(\cdot)>0$	$\gamma \to 1$	High	Internal
Gymnastics Elite	$\theta_m > \theta_i$	$\omega > 0$	$f(\cdot)=0$	*N/A*	High	External
Gymnastics Development	$\theta_m \approx \theta_i$	$\omega \to 0$	$f(\cdot)=0$	*N/A*	High	Internal
Swimming Elite	$\theta_m > \theta_i$	$\omega > 0$	$f(\cdot)=0$	*N/A*	High	External
Swimming Development	$\theta_m \approx \theta_i$	$\omega \to 0$	$f(\cdot)=0$	*N/A*	High	Internal
Cycling	$\theta_m > \theta_i$	$\omega > 0$	$f(\cdot)>0$	$\gamma \to 1$	$\psi \to 0$	External

Figures

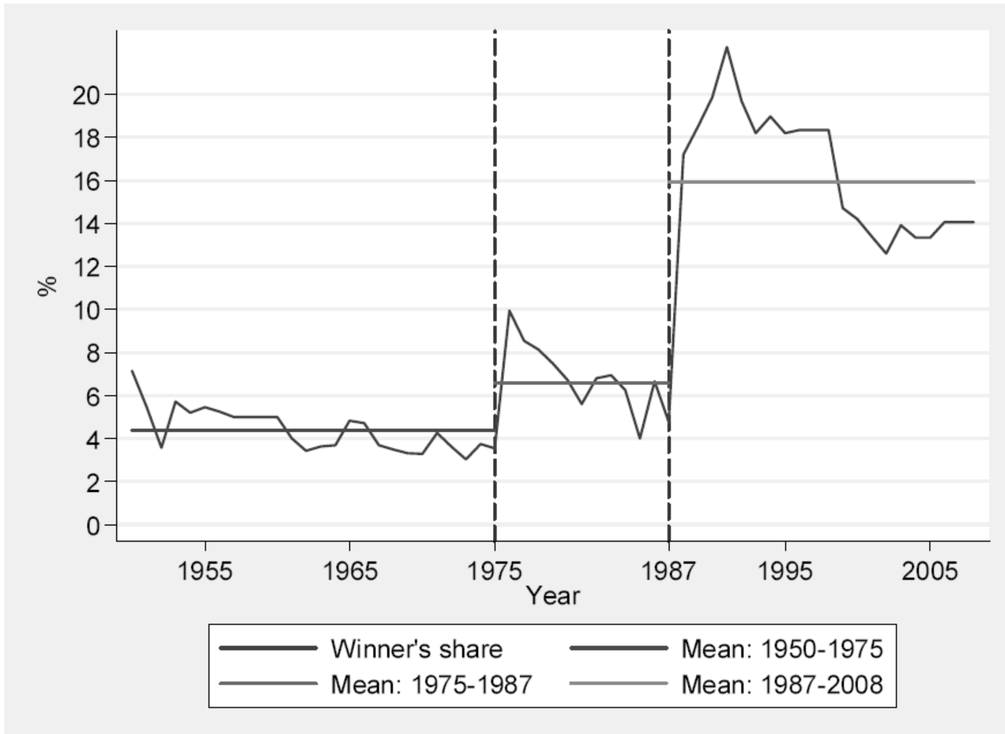

Figure 3.1 Distribution of Tour de France prizes to the winner. From Candelon & Dupuy (2010).

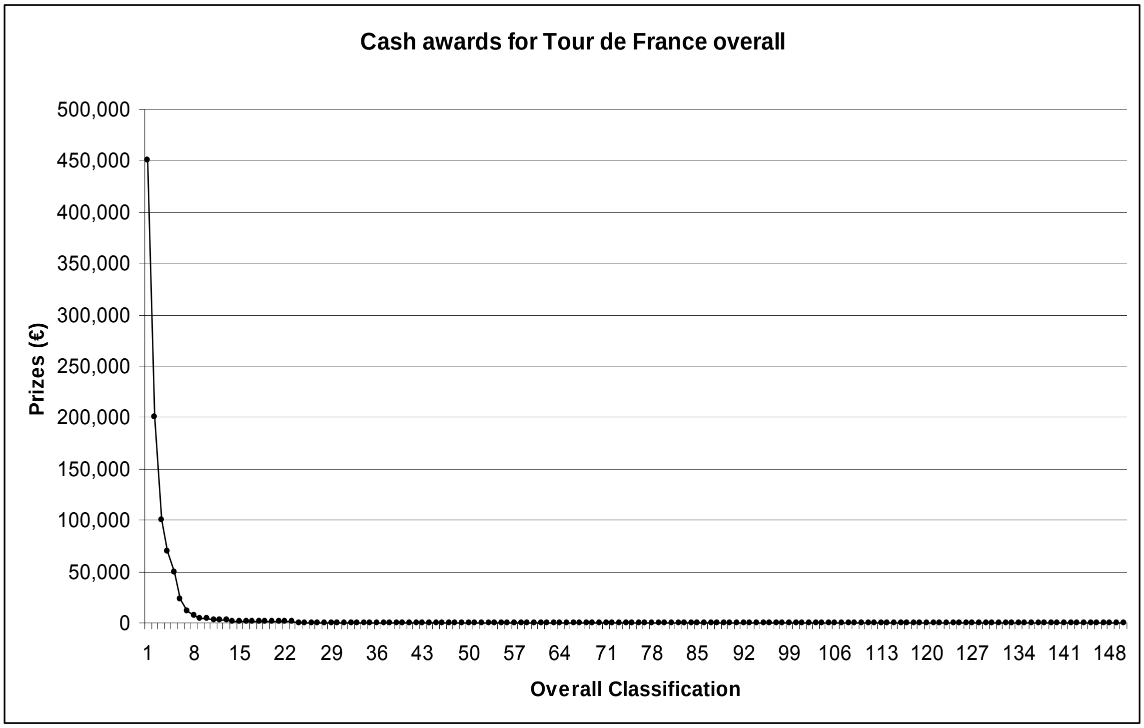

Figure 3.2 Prize payment based on the final standings in the Tour de France display extreme convexity. (Le Tour, 2010)

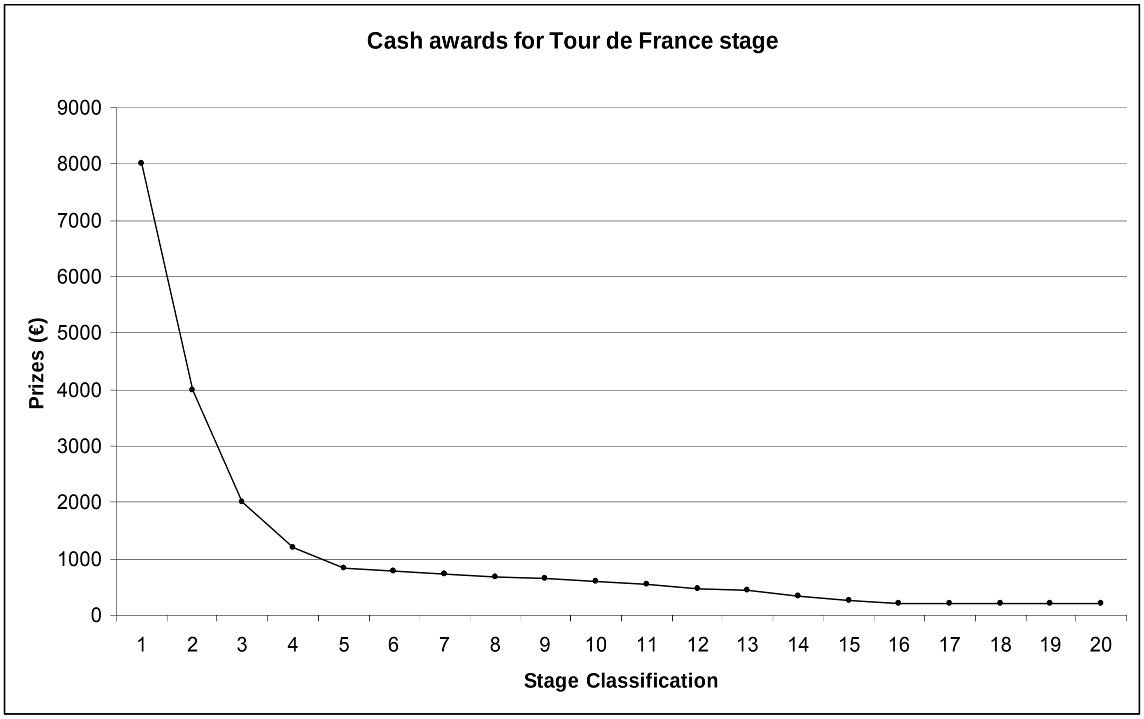

Figure 3.3 Stage placing payoffs display similar convexity to those of the overall competition. (Le Tour, 2010)

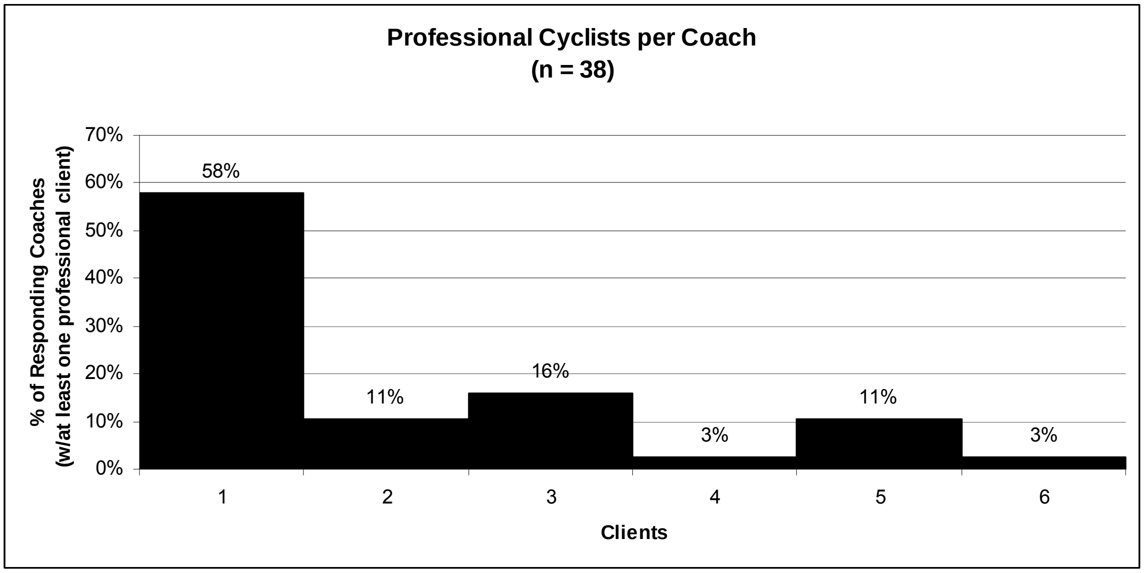

Figure 3.4 Most coaches reporting coaching professional clients typically coach just one.

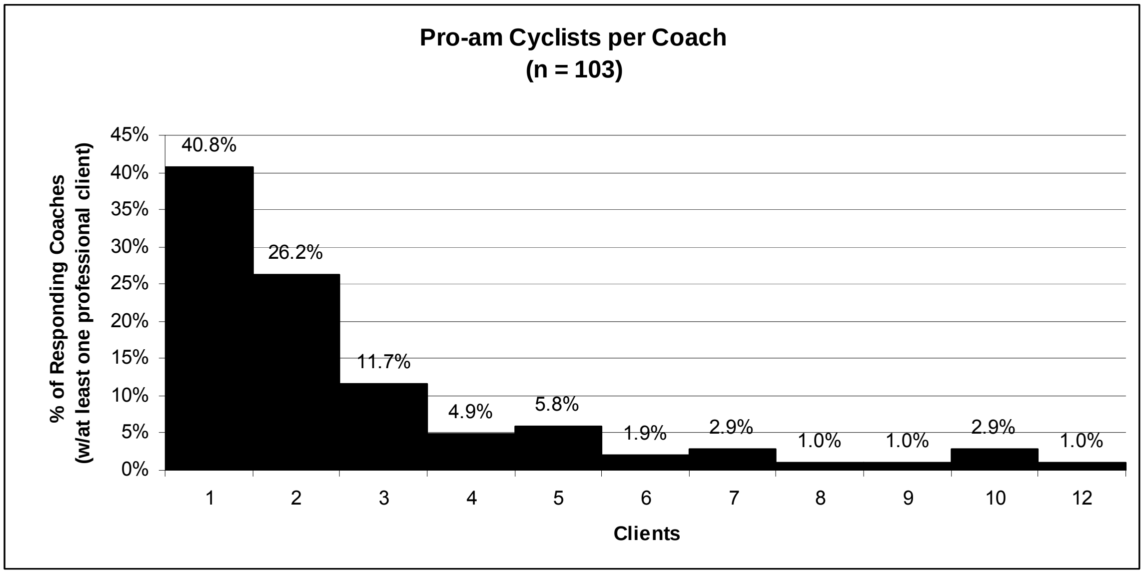

Figure 3.5 Coaches of professional and elite amateur cyclists generally have very few professional clients

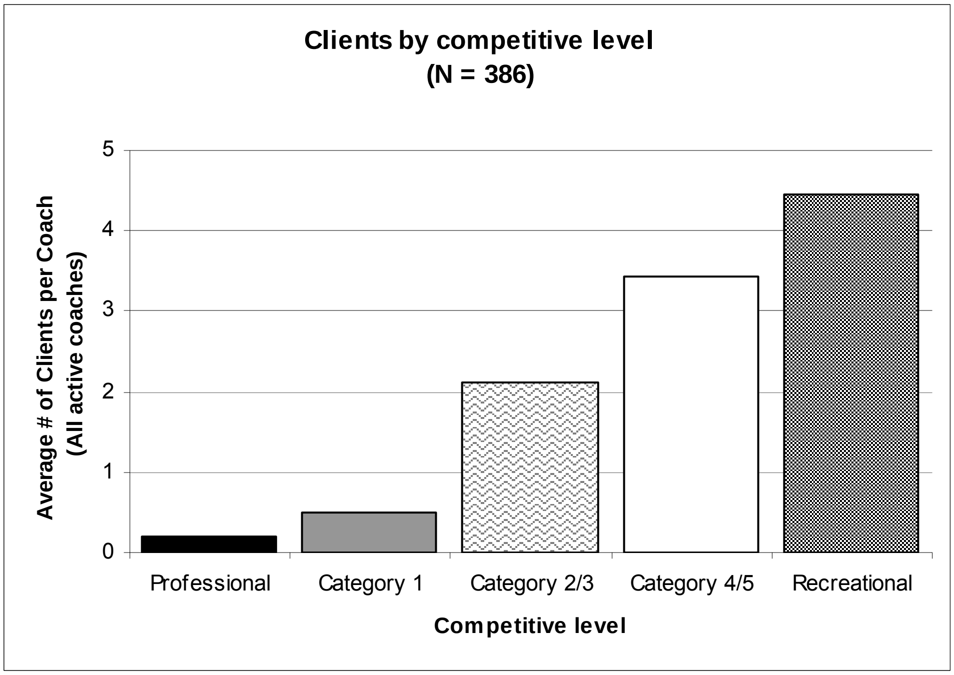

Figure 3.6 The clientele for cycling coaches displays a pyramidal structure with very few Professional/elite clients, and increasing numbers of lower level clients.

CHAPTER 4

UNCERTAINTY OF OUTCOME AND RADIO POLICY IN PRO CYCLING[27]

[27] Larson, D.L., and Maxcy, J. To be submitted to *Sport Management Review*

Abstract

The importance of "contest closeness" or uncertainty of outcome is a topic that has been broached frequently by sports economists. However, its discussion is almost always in conjunction with analysis of competitive balance in team sports. Professional competitive cycling is one particular context where competitive balance may have less importance, but the uncertainty of outcome is likely still critical for consumer demand. This empirical analysis considers the conceptualization of uncertainty of outcome in professional cycling and creates the likelihood of breakaway success (*LBS*) measure to represent it. The *LBS* is then analyzed in 1436 bicycle races between 1985-2010 to examine potential changes in outcomes associated with changes in competitive technology, specifically the introduction of two-way radios for competitors and their team directors. The data suggests that the introduction of radio technology did not have a significant impact on flat event outcomes in terms of the *LBS*, but there was a significant negative association observed with the *LBS* for the hilly terrain competitions ($\alpha = 0.05$). In addition to the differences in the *LBS* across terrain types, there were statistically significant differences among the three "Grand Tours", and across races with different strategic importance. A closing discussion also illustrates the radio-policy topic's relevance to current research in industrial organizational theory.

Introduction

Professional cycling teams are threatening to boycott the 2011 Tour of Beijing (AIGCP, 2011). The event is one of the only events on the professional cycling calendar that is wholly owned and operated by the Union Cycliste Internationale (UCI), the world governing body for cycling.[28] This significance of choosing this event for a boycott lies in an escalating grievance between the UCI and the professional teams and cyclists. In 2009, the UCI began to phase in a ban on the use of radio communications in road cycling races, and by 2011, the first tier of professional cyclists are feeling the impact. The ban is scheduled to be complete in 2012.[29] This rule change is being instituted following nearly 20 years of allowing the technology to be used by cycling teams in their competitions. In that time, cycling team managers had developed entrenched centers of control (the team support car) for carefully directing their cyclists' actions within races (Dzierzak, 2007), and they were not obliged to surrender this technological advancement. In some ways this became an issue of industrial governance between and among cycling's main stakeholders that is not going to be resolved before this manuscript is complete. But while that dispute is not our primary focus, the circumstances and original rationale for this contentious policy shift is worth further examination in several other respects. In particular, what is the basis for the change, and will the change ultimately bring about desired effects for the sport consumers?

The original rationale for the radio ban stems from critical opinions about the characteristics of the cycling sport product being presented to spectators and TV viewers.

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[28] The only other main events they own and operate are the World Championships in all of the various cycling disciplines.
[29] The world's top events, the Tour de France, Giro d'Italia., Vuelta a Espana, and a handful of "monument" events are the last to be included in 2012.

The UCI president Pat McQuaid points directly to this original motivation in the beginning of a recent open letter to the professional cyclists McQuaid (2011):

> I begin by informing you that in 2008 I was convened to a meeting with the biggest producer of television images of cycling, France Television, and was told by senior executives clearly that if radios were retained in cycling and used as they were being used that the coverage of cycling on television would be reduced.

The primary complaints from the media and viewers appeared to be that there was a shift toward “predictable” and “boring” event outcomes (Hood, 2011). The use of radios was a convenient suspect and an apparent crusade to eliminate them was undertaken. While their was purportedly a “working group” assembled of cycling stakeholders examining this policy change during a period of “deep reflection” (McQuaid, 2011), it has never been made clear what kind of information was available during that time to effectively reflect upon the causes and effects of the lost product appeal. No specific evidence was ever disclosed.

This essentially outlines the research questions considered in this manuscript: Have professional cycling event outcomes changed? And if so, is the use of radio technology associated with these changes? This chapter frames this discussion in terms of competitive balance, outcome uncertainty, and consumer demand for sport. It defines a new measure of uncertainty of outcome specific to the sport of cycling and the structure of its competitions. Using this measure, the results of this particular policy decision by the UCI will be analyzed and discussed relative to its stated purpose.

Literature Review/Rationale

Professional cycling can be a brutal endeavor that demands participants to subject themselves to some of the world's toughest physical challenges. The earliest cycling races, such as the Paris-Brest-Paris (1891), Bordeaux-Paris (1891) were tests of pure endurance over great distances still rarely tackled in modern cycling events: 1196km, and 560km respectively (Armstrong, 2003).[30] The Tour de France, upped the ante on these one day affairs in 1903 by creating the first ever "stage race" in cycling (Wheatcroft, 2004).[31] A cycling stage race consists of multiple-segment race taking place over the course of several days or weeks with individual stage completion times being aggregated into an overall time which determines the overall champion (riders start each stage en masse). As the most famous and well known cycling competition to this day, the Tour de France's roots were steeped in a philosophy of attrition that had no rival. Before being "humanized" after 1930, the event frequently had consecutive 260-470km stages running into the night, with the longest total tour (5745km) occurring in 1926 (Wheatcroft, 2004). Modern editions are typically around 3500km (Tour-giro-vuelta.net, 2011). It was in these earliest versions though that supplemental rider support efforts originated. The "support car", appeared early in professional cycling's history; even if it was sometimes under somewhat covert circumstances, such as when riders in the early editions of the Tour de France were caught cheating by taking rides in motorcars during the dark of night (Wheatcroft, 2004).[32] For most of the sport's development, the support car followed right along, offering at first medicinal and nutritional rations, then later mechanical

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[30] The first Bordeaux-Paris was won in 26hours 36minutes (International Cycle Sport, n.d.)
[31] Auto racing had begun to use the format by this time
[32] First with the "broom wagon" picking up riders abandoning the race along the course (p. 28, Wheatcroft, 2004)

assistance, and then finally, a platform for strategic professional team managers to access and direct the race outcomes (McGurn, 1987; Wheatcroft, 2004).

Team cars to this day are forbidden from taking a position in front of racing cyclists such that they could receive the advantage of aerodynamic assistance from the vehicle, and they are strictly kept at a safe distance behind the racing action in a regimented order set by the race referees (UCI, 2011). Until recently, the managers and support vehicles were essentially relegated to following the action, serving as spectators, and at best, serving as infrequent advisors to team cyclists that chose to drop back into the caravan to chat.

Beginning in the 1990s, things began to change in terms of how connected managers were to the action. Some cycling team managers began to experiment with the use direct two-way-radio communications between themselves and their team's riders. The new ability to communicate course conditions, race information, strategic instructions, and tactical direction created a quick competitive advantage. Lance Armstrong's team, at the time sponsored by the Motorola electronics company led this charge (Dzierzak 2007). As with any legal, imitable advantage, it was replicated quickly, and soon became the industry standard (Dzierzak, 2007; Hood, 2011). Furthermore, improved satellite television broadcasting, GPS tracking, and compact televisions allowed for real time viewing of all race events from a moving team support vehicle (Tan, n.d; Dzierzak 2007). The availability of information for all of the team directors allowed for more precise observation, and specific direction of a team's players. Team support cars were transformed from simple assistance vehicles into technologically sophisticated "war rooms" (Tan, n.d.; Reynolds, 2008).

With this new availability of information, access to managerial analysis, and tighter communication links between team directors and riders, some close observers, particularly race commentators, broadcasters, and fans, proposed that an unintended consequence emerged (Hill, 2011). They charged that team directors were developing formulas for strategic behavior to precisely calculate the pace and timing of all of their racers' actions (Hood, 2011). Events were beginning to display specific patterns and predictable outcomes. The suggested pattern generally consists of: a) a small group of riders is allowed to breakaway and is given a manageable lead, and b) a calculated, methodical, and coordinated chase is timed for the inevitable catch of the escapees to happen within a mile or two of the race finish line. This pattern is mainly observed in flatter races because the inclusion of heavy climbing obstacles minimizes the effective use of drafting for chasing breakaways (Olds, 1998) and because body mass plays a larger role than aerodynamics when ascending steep climbs (Prinz, 2005).

Interestingly, this new prototype outcome has potentially undermined one of the key components driving consumer demand for sport consumption, the uncertainty of outcome. The intuitive contention that sport spectators require an uncertain outcome to maintain interest in a contest is a repeated topic of study (Neale, 1964; Knowles, 1992; Madrigal, 1995; Czarnitzki, 2002; Boreland & MacDonald, 2003; Paul & Weinbach, 2007; Buraimo, 2009), and is often recited in policy stances surrounding sports (e.g. Noll, 1974; Levin, Mitchell, Volcker & Will, 2000).

It was to this effect that the world governing body for cycling, the Union Cycliste Internationale (UCI) targeted a new policy change to its competitive rules to include a blanket radio ban. In responding to current resistance to this change, the UCI president Pat McQuaid reiterates the policy rationale in an open letter to the professional cyclists:

> As for the reasons that pushed the UCI towards the progressive banning of earpieces, they are fairly obvious and above all well-known, so I will simply summarize them: return the rider to the centre of action, make him fully responsible for his strategy and evaluation of the situation during each phase of the race in order to avoid all outside control, which considerably reduces the unpredictable character of an event and therefore the thrill that our sport can offer to its millions of fans. Our sport is one of intelligence and physical ability with elements of chance thrown in.
>
> The support of the media – particularly television – for this readjustment is a demonstration of the necessity to intervene on this point: the course of too many races is now a foregone conclusion, and this limits enormously the large scale visibility of cycling. (McQuaid, 2011)

In 2009, radios were banned in all U23 competitions, and for 2010-2011, radios are prohibited in all but the very largest professional events. In 2010, USA Cycling followed suit with the international governing body and issued a ban on radios in all of its events as well. The aim is to transition to a complete ban by 2012 (Weislo, 2010).

Competitive Balance and Outcome Uncertainty.

A wide variety of measures have been used in economic studies of competitive balance in professional team sports (Humphreys, 2002; Fort 2006). For example, Scully (1989) and Quirk and Fort (1997) used the dispersion (standard deviation) of win percent, which was useful for single season comparisons. Eckard (1998) added the consideration of balance fluctuations over time with his *VAR*, which incorporated variance in win percent over any time period *T*. Schmidt & Berri (2001) and Fort & Quirk (1995) used a conventional economic measure of inequality, the *Gini* coefficient to assess competitive balance. Depken (1999) made use of another conventional industrial organization measure, the *Hirfindahl-Hirschman Index* (*HHI*), to represent the competitiveness of the industry (on the field). While each of these measures has its own strengths, weaknesses, and best practical applications, there are ultimately two primary motivations for concerning ourselves with competitive balance.

The first argument is that balance must be maintained among sports teams to ensure the economic stability of a sports league. This is a unique feature of sports in that the survival and strength of ones adversaries is required in order to produce the highest quality final product, the sports competition (Kesenne 2007). Neale (1964) first called this sport peculiarity an "inverted joint product" and it represents the inherent requirement to have some reasonably able adversary in order to produce an economically viable sport match.

The second main argument is based on consumer demand and outcome uncertainty. A series of comments in the sports economics literature between Fort & Maxcy (2003), and Zimbalist (2003) is particularly informative to this discussion. As a result of the exchange, Fort and Maxcy (2003) made the distinction between competitive balance research that analyzes competitive balance for the purposes of examining the effects of, "changes in the business practices of pro sport leagues" (Analysis of Competitive Balance, ACB), and analysis of competitive balance used to test the outcome uncertainty hypothesis (UOH), i.e. that changes in the uncertainty of outcomes have a functional relationship with consumer demand (fan interest). In analyzing changes in the cycling event characteristics based on the technology used in competition, we are certainly concentrating on the latter. The new contribution made by considering the sport of cycling is that previous studies examining the UOH were almost all in team sports leagues where the uncertain outcome was derived from standard competitive balance measures—an overall measure of the dispersion of wins, championships, or othe measure of success across a team-sport league—like those discussed above (e.g., Schmidt & Berri, 2001; Humphreys, 2002; Borland & Macdonald, 2003). In cycling, we consider a direct measure of the race "outcomes" that can serve as a proxy for the *sequence of events* taking place within the contest (the story the consumer experiences).

Many league policy interventions in sports are specifically aimed to move competitive balance in more desirable directions, and the consumer demand argument is the basis for nearly all of them. In fact, when Major League Baseball commissioned an economic study of baseball economics, the *Blue Ribbon Panel Report* (Levin et al., 2000), part of the resulting analysis read, "…The presence in the game of clubs, perhaps a majority, that are chronically uncompetitive, alongside clubs that routinely dominate the postseason, undermines the public interest and confidence in the sport (p.42)." It is this optimal joint product, and consumer's desire for a "close match" that economists see as a benchmark and motivation for study of competitive balance and outcome uncertainty. Pat McQuaid clearly evokes both of these sentiments, consumer demand and economic viability, as he continued in his diatribe to the cyclists,

> We just want to make cycling more attractive to the general public, which in turn will increase its popularity and hopefully improve your working

> conditions. Keeping cycling attractive is also necessary for cyclist to be able to remain cyclists and for giving others the opportunity to become cyclists later. (McQuaid, 2011)

In the U.S. many imbalances in team sport leagues may simply be brought about by the underlying structure of the team sport industry, i.e. the closed league. Closed leagues have a comprehensive collective policy of market territory protection, which maintains markets with great variance in size and fosters imbalance. Rather than address this issue of disparate market size, team owners argue for player mobility restrictions, often citing competitive balance arguments and the UOH. While these policies do have significant effects on their profits and payrolls, the effects on competitive balance are arguable. Most of the subsequent economic studies have been couched and mired in the intricacies of labor collective bargaining agreements within the closed league systems of the U.S. Thankfully, in the case of professional cycling we can effectively abstract from these issues because professional cycling operates as an open league, with no territorial considerations, and an unrestricted free-agent labor market.

Nevertheless, the characteristics of the sports products themselves (games, matches) clearly must matter for sport consumers. These characteristics are not only the win or loss of a match, but an entire unscripted story. This is where the discussion of competitive balance and outcome uncertainty for professional cycling diverges from traditional team sports. The sport of cycling offers a context where the win-loss record can fade to the background while a new concept of outcome uncertainty takes the forefront. In professional cycling, competitive balance has much less meaning. The balance between the different teams' wins (which are almost never analyzed) is not as important as the individual winners of the races. Additionally, those individual race victories are spread among a much larger pool of potential winners than you typically see in team sport matches. One could go so far as to say that all 198 riders starting the Tour de France stand some chance (although for some miniscule) of winning the race or individual stage personally.[33]

Therefore, outcome uncertainty and competitive balance in the race results may not be tightly linked to one another, or of much significance to cycling consumers. For example, in their study of the industry of professional cycling, Rebeggiani & Tondani (2008) presented empirical evidence that the top professional cycling teams appeared to differentiate their efforts (talent allocations) based on events that had more meaning to their team sponsors (geographic proximity) with the exception of the Tour de France, clearly indicating a sorting based on optimal allocation of resources and not necessarily in the direction of a balance in team wins. However, this does not say much at all about the outcome uncertainty that these cycling events may or may not still possess (simply by featuring 150-200 competitors). There may be a breakaway or a sprint, but the mass of individuals will employ their team strategies to aim for one outcome or the other.

In an alternative view, this chapter will explore how outcome uncertainty in cycling races' may be more broadly interpreted to include the entire sequence of events or recurring narratives present in a cycling competition. It may be that these perceived differences in the quality of the spectacle i.e. the story, are what matters to the professional cycling consumer (fan). A new measure designed to gauge outcome uncertainty for the sport of cycling is introduced below.

[33] Conservatively there are probably 10-15 potential winners of the Tour each year.

Competitive balance and outcome uncertainty measures

None of the methods for measuring competitive balance/uncertainty of outcome discussed above are sufficiently relevant to the policy considerations in professional cycling. The product quality argument made by the world governing body for cycling, while clearly an "uncertainty of outcome" concern, it is not directly related to any of the current measures of competitive balance. It is not a problem of *who* is winning, as much as *how* they are winning. As Philip Dine (2007) discusses this concept, he quotes the French scholar Georges Vigarello (1992):

> The Tour [de France] promotes sport as a popular serial or soap opera, an approach that is certainly encouraged by the tactics of cycling: the riders break away, they catch each other up. …, they help each other, they do the unexpected. All of which provides an anecdotal framework…More obviously than in other sporting competitions, the event relies for its continued existence on storytelling. (p. 915)

One enjoyable feature of watching a professional bicycle racing is witnessing a story unfold of an enterprising individual, or a collaborative small group of racers, attempting to outpace the main group of racers to a heroic welcome at a finish line. Popular press and broadcast coverage are littered with references to "the escape", "surviving out front", "outfoxing the bunch", "riding across the line alone in triumph", evoking emotional responses in fans for the resourceful, persevering underdog that overcame the overwhelming odds of success (Hood, 2011). Horatio Alger would be proud.

This narrative is most often and effectively played out on flat courses where strategy and timing can often win out against brute physical ability. While not always requiring final success (crossing the finish line first), the uncertainty of not knowing whether or not a breakaway will survive to the finish line must pay off periodically. Whether breakaways succeed too rarely or too often, we can assume that the underlying suspense is gone and interest in the events will wane. It is this supposedly lost narrative that the recent UCI policy aims to recover.

Therefore when considering this uncertainty of outcome measure, we begin with the assumption that cycling fans wish to see some optimal level of breakaway successes and failures. Assuming that cycling officials are reacting to a deviation from this preferred level, we can investigate whether our measure varied significantly with the use of two-way radios.

The new contribution to sports economics research that this uncertainty of outcome measure brings is that it can clearly be distinguished from competitive balance. In other sports contexts, these terms are often used interchangeably and are very tightly linked concepts. In cycling however, the appeal, and essentially the revenue generating potential arises largely from the "show" and not necessarily the end result. In this way, their may be more or less competitive balance in cycling, but the revenue generating appeal might be more tightly linked with the product narrative and dramatic structure. It might be impossible to separate these concepts out in other sports, but this paper points to an instance where the introduction of technology has potentially to display drastic effects on the core product on only the dimension of outcome uncertainty while leaving competitive balance untouched.

It is important to note that this is not the first time, nor will it be the last, that a sport's governance has sought to guard against its narratives or improve its core product appeal. Were it not so, we would still be able to catch a baseball player "out" after his hit ball first bounces off the ground (Goldstein, 1991) and observe the lethal "flying V" formation in football (Watterson, 2002). There are examples across many sports.

Specific Aims. This study aims to make three specific contributions:

1. Introduce new measure to represent uncertainty of outcome for competitive cycling
2. Empirically test for changes in uncertainty of outcome as a result of a specific competition rule condition
3. Discuss this rule change as a manipulation of bounded rationality (increased communication costs) and suggest an empirical test for subsequent effects on the hierarchy within the organization (potential re-emergence of team captain role)

Eventually, this new spontaneous policy change will allow for a natural experiment of sorts. In fact, coupled with archived data, it can provide us with something analogous to a repeat measures experimental design. Changes will not only be observed after the present policy change, but also retroactively and in time series from the onset of radio communication usage (popular press and archived media suggest that radios first appeared around 1992 (Weislo, 2010)). Therefore, analysis of data from 1985 through present competition seasons should be able to shed even more light on all of these questions. Previous to 1985, the events had significantly more variation in the number of teams, the number of stages, and total participants (tour-giro-vuelta.net, 2011).

Testable hypotheses. With this measure of uncertainty of outcome in hand, it is only left to use this assessment tool for our relevant testable hypothesis. In the case of this policy change and its intent, we propose the following hypothesis:

> H1: Professional cycling races before the adoption of two-way radios (before 1992) will have a higher probability of ending in a *breakaway* than in a *sprint* compared to races after radios were first introduced (1992).

Methods

Uncertainty of Outcome Measure. We will consider an aggregation of all types of races, flat and mountainous, in the analysis because although climbing terrain may minimize the effect of team strategy, radio communications might still factor into the outcomes of these races as well. However, it can be noted that the wildly popular mountain climbing stages in the sports biggest events (Tour de France, Giro d'Italia, Vuelta a Espana) nearly always feature some kind of breakaway winner (Van Reeth, 2011), which anecdotally supports the notion that more breakaway outcomes are preferred to less. Scrutiny of the flatter stages is also important to attempt to focus on the margin at which consumer demand might suffers as breakaway successes are reduced beyond an optimal level (As the UCI would argue). The extent to which these changes actually translate into differential consumer demand is a valid discussion for another time, but this paper will focus only on measuring the effects of technological change in production and the new policy effects on outcomes, i.e. the increase in predictable outcomes and the potential effects of intervention respectively.

This leads to defining the measure of uncertainty of outcome we propose for flat cycling races, the *likelihood of breakaway success* (*LBS*). Ideally, the most valid and reliable measurement of this probability of breakaway success would be direct observations of events and recordings of the actions that transpired. Delineation of when a breakaway began, how time gaps changes, how opponent teams behaved, and observation of the failure/success could be observed, recorded, and analyzed. This would be the most complete picture of the “narrative”. Unfortunately, because cycling events take place over hundreds of miles of open roads, often outside the view of television cameras, and because this researcher is not omniscient (although that would make “research” superfluous), we must suffer with the next best choice for available data. The data available for this measure will be collected from final event classifications (finish line results) of “grand tour” cycling events. These results will be drawn from event accounts commonly distributed in public media.

In order to parse the available event results to reflect outcome uncertainty related to breakaway outcomes, we classified a *breakaway* outcome as when the first 25 riders finish a race with more than a 10 second spread among one another. We alternatively classified a race finish as a *sprint* if the first 25 finishers in a race finish within 10 seconds of the race winner. While ten seconds may seem arbitrary, it is based on conservative, historical, finishing speeds and durations of a normal group *sprint* of a road cycling event. As a typical full effort sprint to the finish line might last maximally between 20 and 30 seconds based on human physiological limits for individual sprinting (Friel (2003) actually suggests 12 seconds), a rider contesting a field sprint would have to be at least 50% faster than his/her top competitors in the sprinting group to finish with such a lead. At the professional level, where differences in ability are very small, the probability of any rider sprinting at such a comparative rate is so infinitesimally small that we can accept that if a rider finishes with such a lead ahead of a substantial group of riders, they must have previously established their lead, i.e. via a pre-sprint *breakaway*. Therefore, a 10 second lead requirement is defensible, if not conservative to define this dichotomy, i.e. breakaway = 1; sprint = 0.

So with this simple classification system that can be constructed from a large sample of archived cycling event results, we attempted to encapsulate the essence of this policy target, improvements in uncertainty of outcome: *breakaway* outcomes improving the desirable uncertainty of the event and the *sprints* representing the less desirable outcome.

Model/variables

The data were analyzed using a logit regression with the binary dependent variable, likelihood of breakaway success (*LBS*).[34] The primary explanatory variable coefficient of interest is whether or not radio use was present (dummy). We also incorporated several potential control variables to account for expected confounding associations. These included variations in terrain, i.e. Flat, Hilly, and Mountain stages, dummy variables for which annual event the data was drawn from, as well as variables related to overall race strategy. Table 4.1 lists each variable included in the model and the expected sign of its coefficient.

The terrain dummy variables reflected the effect we might terrain to have on the race outcomes because the effects of drafting are of decreasing benefit as the race routes

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[34] In examining our available dataset, we suggest future consideration of time-series analysis. While we assumed a model that was represented by cross-sectional data with independent observations, there may by underlying correlations in the error terms. These might be able to account for different historical eras (1980s to 2010s comparisons), and the particular composition of the racing field (as prominent riders' careers clearly span several data points). The available data did not include data about the individual competitors and teams.

become hillier, i.e. Flat < Hilly < Mountain. Gravity quickly overcomes aerodynamic resistance as the most oppositional force to the cyclists on long steep climbs (such as those featured in Grand Tour routes) so cyclists are more severely “selected out” based on their maximal aerobic capacity as the climbing challenges become greater. This selection should create a “shattered” pattern at the finish line akin to a running road race. Coded as dummy variables, we use the most mountainous stages (*mountains*) as the reference condition and would expect the remaining variably coefficients to be negative, i.e. less and less likely to have a breakaway outcome. *Radio*flat* and *radio*hilly* were also included to see if radios had a differential effect on flat stages and hilly stages vs. mountainous terrain.

The strategy variables accounted for changes in the overall competition of a grand tour that would affect how some teams were likely to treat breakaways. For example, before the first time trial (*b4TT*) in a grand tour, all of the competitors are often very close in the overall standings (time differences very small), so any breakaway winner could easily take the coveted overall lead in the race at any stage. After this time trial, the main contenders in the competition have begun to distance themselves from the bulk of the field with their individual performance. Having this “spread” allows the “non-contenders” more freedom to breakaway because the overall contenders team’s have less incentive to chase breakaways all the way down because their overall lead is not threatened as long as the gap at the finish is small enough. Stages following the first mountain stage (*afterfirstmtn*) will have the same feature and we would expect more leeway for breakaways following that selective juncture. A dummy variable for the final stage was also included because the final stage of the grand tours by tradition are nearly always conducted as a parade in the early going with a short bit of racing to close the end of the event. As such, they are significantly distinct from a normal stage and nearly always are expected to end in a sprint finish. We would expect this coefficient to be negative, i.e. more likely to be a sprint outcome (non-breakaway).

In order to account for the possibility of a time and/or a trend of gradual adoption interaction variables were included for the year, *radios*year, flat*year.* Despite considering conducting the analysis using panel data, there was essentially no defensible or appropriate panel configuration in the available data. The primary difficulty was the variability of the racing stages from year to year. Each stage race organizer alters their route and progression of stages from year to year, so stage 1 in one year, may be any other type of stage in a completely different location the next year.

Finally, dummy variables were included for the three grand tours to guard against any fixed effects for any significant time of year, cultural, or competition design differences. If any prediction were to be made, it might be that the Tour de France would feature more breakaways (negative coefficients on *Giro* and *Vuelta*) because it is the most competitive of the three grand tours by virtue of being the most globally significant.

The resulting full logit model was:

1) $$LBS = Pr(breakaway) = \beta_0 + \beta_1 Giro + \beta_2 Vuelta + \beta_3 final\_stage + \beta_4 b4TT + \beta_5 afterfirstmtn + \beta_6 year + \beta_7 radios + \beta_8 radios*year + \beta_9 flat + \beta_{10} hilly + \beta_{11} hilly*radios + \beta_{12} hilly*year + \beta_{13} flat*radios + \beta_{14} flat*year$$

We also estimated second logit regression model, with a subset that only included the flat stages (n = 705). This was to more closely examine just the events that could potentially see the greatest differences because of radio technology, e.g. the coordination and timing of chases.

2) $LBS = Pr(breakaway) = \beta_0 + \beta_1 Giro + \beta_2 Vuelta + \beta_3 final\_stage + \beta_4 b4TT + \beta_5 afterfirstmtn + \beta_6 year + \beta_7 radios + \beta_8 radios*year$

Data/Results

The data for the analysis were acquired from the archive website http://www.tour-giro-vuelta.net/ (2011). This website is one of only a few sources that reports not only the finishing position of all of the top 25 cyclists of the three major tours, but also the relative finish times, and has a complete archive reaching back into the early 1910s. Wherever the results may be less complete, the historical archives of the event promoter, and/or printed press accounts with complete results and times were used. Data were gathered for all mass start stages of the three grand tours from 1985-2010 (N = 1436). The data included characteristics of each mass-start race day (see Table 4.2). There was a substantial mix of race characteristics in the sample data across all of the variables because the grand tour organizers essentially redesign their races each year with varying numbers of mountain stages, hilly stages, and flat stages for each edition. On average, the grand tours in the sample included about 49% flat stages (SD = 0.50), and the remainder were either hilly (mid-mountain), or mountainous with either uphill or flat terrain to the finish lines (see Figure 4.1). Upon visual inspection (see Figure 4.2), the outcomes of the stages in terms of annual averages (*LBS*) appear relatively stable around the sample mean of around 55% (SD = 0.50) of all stages ending in a breakaway. The mean stability of the flat stage outcomes in that same annual figure was a bit more ambiguous, but it appears that it may be trending down slightly during our time frame.

The results were consistent across both estimations and all of the parameter estimates were in agreement. The broader model had a statistically significant Chi-square statistic and pseudo-R^2 of 0.44, and the flat stage subset model had a statistically significant fit with a pseudo-R^2 of 0.16.

In terms of our chosen explanatory variables, all of the *control* variables were statistically significant with expected signs that were consistent with the theory of their inclusion. The estimated coefficients for the stage race dummies were statistically significant and suggested that the stages in the *Giro* d'Italia and *Vuelta* Espana (all else equal) are both less likely to end in a breakaway than stages in the Tour de France (reference condition) (see Table 4.3). The coefficients associated with the closeness of the overall standings, *b4TT* and *afterfirstmtn* were also both statistically significant and in the expected direction, i.e. breakaways were the less probable outcome in the stages taking place before the first time trial, and were more likely following the first mountain stage (p = 0.03, p = 0.013 resp.). The *finalstage* lived up to its tradition and billing and was strongly associated across all of the stage races with sprint finish outcomes (82.7% of the time). In the general model, the terrain characteristics of the races had the expected associations with breakaway likelihood. The more vertical terrain that was included (*hilly, mountains*), the more likely the final outcome would feature a breakaway.

The dummy variable that represented the beginning of radio availability for competition (1992 and onward), *radios*, did not show a significant association with *LBS* either alone or when interacted with the *year* variable (to potentially reflect the increasing adoption of the technology). However, there was a negative association between the likelihood of a breakaway and radio use in hilly stages (*hilly*radios*) borne out in the regression estimate, all else equal.

In terms of the differential effects of each explanatory variable, Table 4.4 presents the odds ratio for a unit change in the statistically significant coefficients. For example, a race on flat terrain is 17.78 times more likely to finish in a sprint (non-breakaway) compared to a mountain terrain race (reference state), all else equal.

Discussion

The regression results suggest that the presence of radios in the grand tour cycling competitions did not have a statistically significant association with whether or not flat races would end in a breakaway. However, it is of interest to note that there was a statistically significant effect of radio use on outcomes in hilly races, so the changes in the outcomes perceived by commentators and fans are not necessarily imagined. We would clearly need to look more closely at other possible causes for these changes that are not included in this model. One immediate suggestion is that perhaps the nature of the competition is evolving to feature more specialized teams. In the past it may have been that sprinters only received incidental support from their teams while more teams may have been more concerned with the overall competition. It might be that the continually increasing TV viewership has increase the value of the highly visible stage win, and some teams are more wholly orienting themselves toward supporting their sprinters. Empirical examination of the payoffs associated with stage victories, not only in prizes but in increased visibility (for sponsorship revenues associated with TV), should be coupled with extra controls for the number of specialist sprinters participating in the races to begin to test that new hypothesis.

The implementation of the radio ban policy in 2012 will again allow for a repeat measure in the future and the results of that analysis and/or the incorporation of more control variables will show whether or not this primary result is stable, i.e. radios have no significant affect on flat race outcomes.

Considerations related to the theoretical framework

Information/Communications. There are clear implications of this policy action regarding the use of information and communication in production, in this case team performance. The use of information and knowledge in organizations has recently been modeled and explored by Garicano (2000) and was discussed previously by Hayek (1945). Garicano and Rossi-Hansberg's (2004) most recent writing addresses organizational hierarchy, knowledge and communications explicitly. Following the lead of this modeling, these policy changes can be interpreted as the radio ban introducing a strict effect of increasing communications costs for cycling teams. The distribution of knowledge among the workers (riders) could be of severe consequence to productivity because the costs of communication are greatly increased. In practical terms, riders can either drop back to a support car, or send a team member back to do so. This costs the team not only the time required to perform this maneuver, but also an inordinate amount of energy that would otherwise be used for more direct sport performance. Additionally, simply communicating strategic imperatives among one another is severely limited by their movements and positions in the race. No longer can a team director broadcast instructions for all team members to receive. Moving further with Garicano's recent work, we would expect to see a change in wages and hierarchy of the cycling team itself. Depending on the severity of communication impairment, one would expect to see the hierarchy moving from two layers (Manager→Rider) to perhaps three or more (Manager→Captain rider→Riders) with more autonomy and knowledge nested in the lead riders. We might eventually expect a measurable differential effect of teams hiring more experienced "lead" riders and/or veterans.

Role of "Captains". Anecdotally, before the implementation of this new technology (two-way radio communication), cycling had previously held a long tradition of valuing on-the-road leadership. This was to such a degree that the designation of a team leader "captain" remained imbedded in the vernacular of the sport (Tan, n.d). It is important to note that the designation of this captain was often independent of which rider the team would support during a race. In some instances, this role was equated to that of a quarterback in American football, one who "called the shots". From this authors perspective this role clearly diminished with the advent of in-race radios, and often if a rider happened to be designated a team leader or captain, it was merely in line with who had the most physical talent regardless of leadership or decision-making ability. One exchange that might provide evidence of this leadership transition was recounted in Matt Rendell's (2008) historical account of the tactical discord over the radio in a 2001 Tour de France stage between Lance Armstrong and his team director, Johan Bruyneel (both instructing teammate Roberto Heras who was pacing Armstrong's group up a mountain climb):

Armstrong to Heras: "Take it easy, take it easy"

Bruyneel to Heras: "Faster, faster."

Armstrong to Heras: "Take it easy, take it easy."

Bruyneel to Heras: "Faster, faster."

Armstrong to Bruyneel: 'Goddammit, Johan, tell him to slow down!" (p. 278)

This exchange not only highlights the use of radios at the time, but also the shifting "locus of control", even for the world's top tour cyclist at the time.[35] Not only was Heras was receiving conflicting instructions, but he ultimately only responded to the team director's instructions.

When considering the implications for the upcoming radio-ban policy on team organizational hierarchy, we hope to eventually formalize and test this expected change as well. Essentially, the policy might bring about a reversion of this shift to where cyclists would again assume a leadership role "on the road".

Appeal of leadership. It might also be possible that some consumer appeal may be gained with the re-introduction of rider leadership into the core sport product. Even if the empirical test shows no effect of the radio technology on uncertainty of outcome, it will remain to be judged whether the implications of this change warrant its continuance. In other words, we may not see any more or less breakaway race finishes, but the change in the process to reach that outcome may have more appeal to the fan, i.e. witnessing the cyclist's themselves formulating strategy, communicating, and coordinating team members. Again, a full treatment of the determinants of consumer demand is warranted and should not neglect the socio-cultural narrative that may be relevant (managed action (employees) v. individual enterprise (entrepreneurship))

Advantage to the chasers? One basic assumption made about the UCI policy effort was that the use of radios is an inherent advantage to the chasing group. However, in order for this to hold, we must conceptualize how this technology offers a differential advantage to chasers over escapees. Both groups similarly have access to more

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[35] This would be Armstrong's 4th Tour de France victory.

information and the ability to use that information for strategic decisions. It may just be (if uncertainty of outcome is truly altered), that with a certain level of information availability, the breakaway effort is simply a less viable option for success at the finish line, and the dominant strategy for more of the cyclists is to concede to a group sprint outcome. In other words, some restriction of information, as may be introduced by this policy change, would allow enough "play" (imperfect information) in the strategic framework for the more occasional breakaway success. In considering that case, a comparative study of the information availability between the chasers and escapees would be warranted.

Conclusion

Through an analysis of data representing cycling race outcomes of stages of the world's three largest cycling events, the purported relationship between two-way radio use and competition outcomes is not statistically apparent in flat competitions. However, there is an association between the likelihood of breakaway finishes and hilly racing stages with radio technology. Future research should incorporate other potentially important variables in their empirical analysis, such as the levels of "sprint-orientation" competing teams have and maintain throughout the course of a stage race (as some sprinters may be eliminated in the mountains), and/or expand the data set to include other important events (including single day contests).

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Tables

Table 4.1
Variable definitions

Variable	Definition	Expected Sign
breakaway	Coded 1 if the race ended in a breakaway, 0 otherwise (Sprint)	N/A
radios	Coded 1 if radios were available to use in competition (1992 to present), 0 otherwise	(+/-)
flat	Coded 1 if the race had flat elevation profile, 0 otherwise	(-)
hilly	Coded 1 if the elevation profile included several categorized hills, 0 otherwise	(-)
mountians	Coded 1 if the elevation profile included some categorized mountain climbs, 0 otherwise	(-)
tour	Coded 1 if the race was a stage of the Tour de France, 0 otherwise	(reference)
giro	Coded 1 if the race was a stage of the Giro d'Italia, 0 otherwise	(-)
vuelta	Coded 1 if the race was a stage of Vuelta a Espana, 0 otherwise	(-)
finalstage	Coded 1 if the race was the final mass-start stage of a Grand Tour, 0 otherwise	(-)
b4tt1	Coded 1 if the race was a Grand Tour stage taking place before the first Time Trial of the stage race, 0 otherwise	(-)
afterfirstmtn	Coded 1 if the race was a Grand Tour stage taking place after the first Mountain stage of the stage race, 0 otherwise	(+)
year	The year the competition took place	(+/-)
*hilly*radio*	*hilly* dummy variable * *radios* dummy variable	(+/-)
*hilly*year*	*hilly* dummy variable * The calendar year of the competition	(+/-)
*flat*year*	*flat* dummy variable * The calendar year of the competition	(+/-)
*flat*radios*	*flat* dummy variable * *radios* dummy variable	(+/-)

Table 4.2
Variable descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
breakaway	1436	0.550	0.497	0	1
Radios	1436	0.727	0.445	0	1
Flat	1436	0.491	0.500	0	1
Hilly	1436	0.201	0.401	0	1
mountains	1436	0.308	0.461	0	1
Tour	1436	0.328	0.469	0	1
Giro	1436	0.341	0.474	0	1
Vuelta	1436	0.331	0.472	0	1
finalstage	1436	0.052	0.223	0	1
b4tt1	1436	0.345	0.476	0	1
afterfirstmtn	1436	0.657	0.475	0	1

Table 4.3
Logistic regression results

Dependent variable: *breakaway*	Coefficients (Std. Err.)			
constant	-10.331		-97.39	
	(166.78)		(177.267)	
Giro	-1.198	***	-1.021	***
	(0.249)		(0.197)	
Vuelta	-1.392	***	-1.175	***
	(0.243)		(0.196)	
final_stage	-2.121	***	-1.910	***
	(0.460)		(0.410)	
b4tt1	-1.243	***	-1.265	***
	(0.224)		(0.171)	
afterfirstmtn	0.525	*	0.405	*
	(0.218)		(0.166)	
Year	0.005		0.051	
	(0.083)		(0.089)	
Radios	0.052		1.458	
	(0.383)		(1.054)	
*radio*year*	-0.043		-0.024	
	(0.086)		(0.067)	
Flat			-2.878	***
			(0.469)	
Hilly			-1.544	**
			(0.513)	
*hilly*radio*			-2.127	*
			(1.160)	
*hilly*year*			0.028	
			(0.075)	
*flat*radios*			-1.377	
			(1.104)	
*flat*year*			-0.061	
			(0.072)	
Number of observations	705		1436	
Wald chi2(8,14)	122.91		828.43	
Prob > chi2 =	0.000	***	0.000	***
Pseudo R2 =	0.160		0.438	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 4.4
Differential effects

	Overall		Flat sub-sample	
Variable	Breakaway Exp(B)	Sprint 1/Exp(B)	Breakaway Exp(B)	Sprint 1/Exp(B)
Giro		2.77		3.31
Vuelta		3.24		4.02
final_stage		6.75		8.34
b4tt1		3.54		3.47
afterfirstmtn	1.50		1.69	
Flat		17.78		
Hilly		4.68		
*hilly*radios*		8.39		

Reference condition: Tour de France mountain stage, no radios, after first time trial, before first mountain stage.

Figures

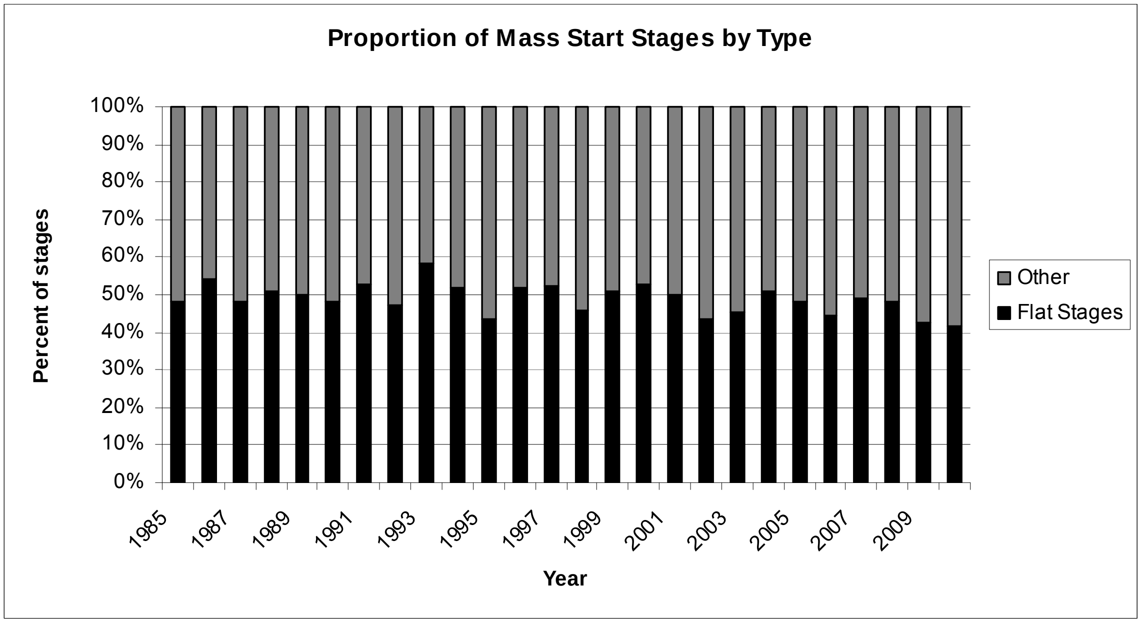

Figure 4.1 The balance of flat and mountain stages fluctuates around or just away from 50-50 split.

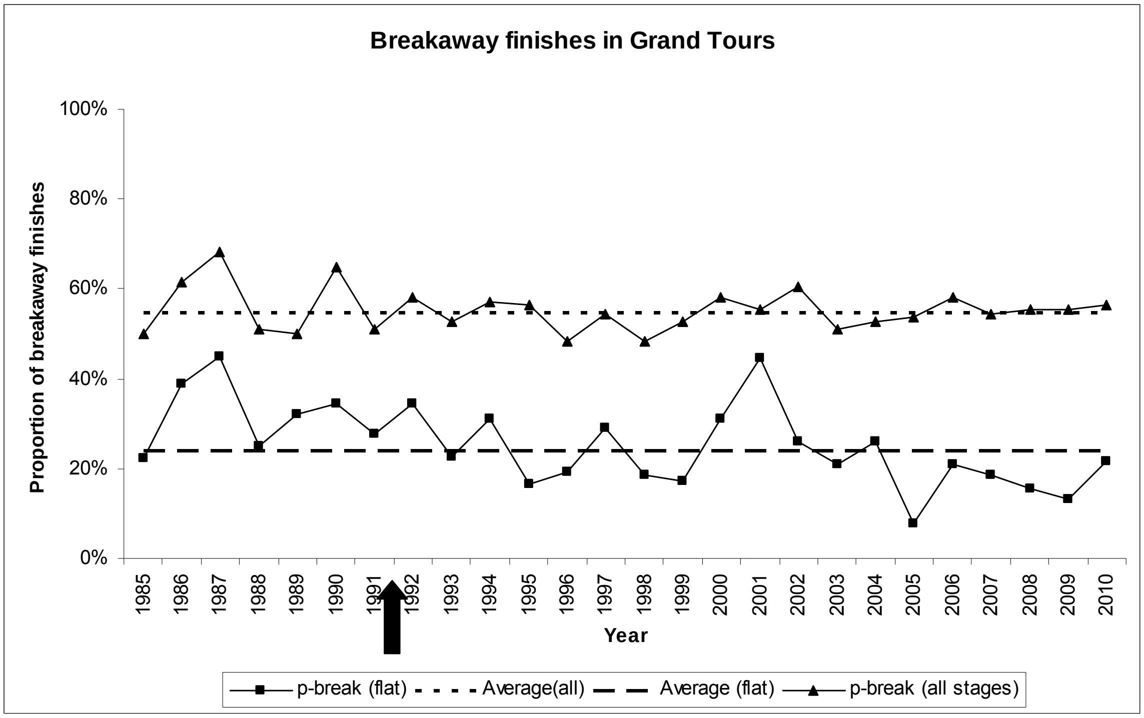

Figure 4.2 The effects of radio use, beginning in 1992, are not clear from initial inspection of race outcome data in series.

CHAPTER 5

CONCLUSION

The purpose of this dissertation was to explore the use of the sport of cycling for economic research. Chapter 1 and 2 summarize the history of thought in sport economics, explore the historical background of competitive cycling, and highlight the structural features and economic phenomena relevant to economic inquiry. Chapters 3 and 4 further examine two of these topics through a theory and empirics respectively.

Chapter 1 and 2's discussions culminate in highlighting potential areas for economic research in competitive cycling. These are summarized in Table 5.1 and include potential work that can be done in the future, particularly in areas such as micro-economic theory and industrial organization.

Chapter 3 formulated a general industry model for sport practice coaching. It specifically discussed features that affect the efficiency of practices, the importance of coach-athlete matching, and the potential coordination benefits available with internal employees. The prevailing idea of the general model of coaching industry was that the structure of the sport competitions and their unique practice features determine the equilibrium state of coaches' employment. The overview of practicing U.S. cycling coaches established some key characteristics that lead the general model to predict that cycling coaches will not be hired by cycling teams. This prediction was entirely consistent with the stylized facts derived from the U.S. coaching data.

The empirical topic in Chapter 4 had a simpler theoretical framework to examine changes in competitive cycling outcomes. Based on evidence that the sport of cycling has unique competitive balance and uncertainty of outcome features, a simple model for measuring a characteristic of these outcomes was created. The new likelihood of breakaway success (*LBS*) measure was used to represent the "breakaway narrative" that consumers of cycling may prefer, and this measure was analyzed in grand tour cycling races over the time period from 1985-2011. In particular, a present policy concern, the UCI's impending rule to ban the use of two-way radios, was a central motivation for the analysis. According to this data, and using the *LBS* measure for logit regression estimation, the presence of the radio technology in competitive cycling has had no statistically discernable association with the likelihood of a breakaway outcome in flat competitions, but a significant negative association with hilly competitions. Other potential reasons for changes in the *LBS* over time were suggested, and future research and policy questions were explored.

In summary, this dissertation explored the potential for economic research in competitive cycling, and exercised this possibility through two full, relevant, independent, research-based manuscripts.

Table 5.1

Research of the economics of cycling

Area	Topic	Study	Notes
Performance	Determinants of success	Prinz (2005)	Highlighted the importance of body mass (BMI)
	Determinants of success	Cherchye & Vermeulen (2006)	Rankings of professional cyclists
	Determinants of success	Torgler (2006)	Considered team position, experience, and country of origin
	Modeling/predicting outcomes	Dilger and Geyer (2009)	Racing dynamics of sprint finishes (historical performance data, natural physics)
	Coaching	?	
Industrial Organization	Organizational forms	Desbordes (2006)	Industry descriptives for France
	Multiple stakeholders	Morrow & Idle (2008)	Regulation changes and the stakeholder relationships
	Financing model	Desbordes (2008)	Case study of Professional Tour
	Organizational forms	Rebeggiani and Tondani (2008)	Cournot framework, product differentiation, and efficiency benchmarks
	CB/Outcome uncertainty	?	
	Unique compensation structures	?	Riders compensate one another(side payments) in addition to receiving salary
Micro-economic theory	Principal-agent	?	Shirking
	Incentive structures	?	Short term contracts
	Team dynamics	Candelon & Dupuy (2010)	Leader, helper, autarky determination

APPENDIX A

Coach matching

As mentioned previously, the effect a coach has on his/her athlete's peak physiological performance, c, would depend heavily on the quality of the match with that given client. In other words, the knowledge of a coach, and how it "fits" with the individual athlete's needs, will determine how effective their efforts are. Furthermore, because the coaching relationship can be very specialized and personal, we will assert below that any individual athlete will do strictly better at choosing their most effective coach than any other person. In short, this is because athletes possess, or develop over time, an asymmetrical tacit knowledge about exactly what they need from a coach. In professional sports, the physical development required to enter the professional ranks typically takes several years, and it is reasonable to assume that athletes have this extended period of time to develop this informational advantage. We would also suggest that athletes early in their development face more general training "problems" and as they became more experienced become more and more limited by specific training "problems".[36]

This matching problem harkens back to the labor matching discussions of Boyan Jovanovic (1979) that accounts for the imperfect information among employees and employers. In his examples, employee tenure and turnover is tightly related to the quality of the match made. To formalize this concept in sport coaching, we can begin from a popular structure used in employee-employer matching models, a circular "characteristic"

[36] In elite cycling coaching, there is commonly an extensive analysis of an athlete's "limiters".

framework. Dagsvik, Javonovic, and Shepard (1985) use this "characteristic" concept to approach matching of employees and firms. They begin with the simplest model that has a single firm and single worker who each possess a single characteristic, the firm φ, and the employee λ. These characteristics lie on a unit circle with the distance between them (y) representing the quality of the match (θ).[37] These types are generated through some stochastic process and the quality of the match determines the worker's productivity, and maintenance and tenure of the employment arrangement. In their standard framework, these types are not initially known to the parties involved.

We can use this model for a single athlete who is considering hiring one of two potential coaches. The rider has his/her characteristic λ, and the two coaches' characteristics are φ_1, and φ_2 respectively, all three stochastically determined (See Figure A.1). In the case of the athlete, although his/her true characteristic λ^* is stochastically determined, we extend the model to suppose the athlete will have at least some imperfect information about exactly where his/her characteristic is located on the circle. For simplicity, we will assume the athlete also has perfect information about the location of his/her two potential coaches' types on the unit circle. The athlete will use his/her private information to make an estimate, or "best guess", about his/her own type, and these guesses will be distributed normally around the true location of their characteristic (λ^*). With this guess, the athlete will then seek to minimize the absolute distance(y) between their estimate λ and the possible coaches φ_i, i.e. the athlete will choose the coach whose known trait is closest to their own trait estimate. Under these conditions and because of their imperfect estimates, the athlete will make a sub-optimal coach match decision with

[37] Dagsvik, Javonovic, and Shepard (1985) use μ but we will use θ to be consistent with our model notation.

some probability based entirely on the quality of their own trait information (according to some variance, σ).

Comparing between athletes choosing their own coach, and someone else (manager) choosing a coach for them, we start by introducing the simplifying assumption that athletes and these others "selectors" have perfect information about any potential coaches' types, i.e. of the available coaches, φ_i is known. This assumption could be relaxed to include some limits on this knowledge, but provided that the available information about coaches is similar across athletes and managers, the primary result will hold. Considering the selection of a coach for an athlete by an outside party we will maintain the assumption that once drawn, the coach types are known to the manager as both athletes and managers will have the same information about the coach types.

In the case of estimating the athlete's type, λ, an outside party will also have imperfect information about the athlete's true type (λ^*). However, here we can also incorporate a mechanism that may produce different results between the athlete's choice and an outside party's choice, i.e. asymmetric information. Essentially, the information set of an outside party will be strictly smaller than the information set of the athlete themselves. Again, in order to consider the optimality of an athlete-coach match among potential coaches, e.g. φ_1, and φ_2 (see Figure A.1), this outside individual will need to make some guess about the true type of the athlete (λ^*). We would expect these estimates could be normally distributed somewhere near the true mean λ^*, but they also may be subject to bias ($\lambda^* \pm$ e) or increased variability (σ + e) around the true value. Both of these effects will increase the probability of a sub-optimal match, i.e. outside parties will make more frequent errors if they were called on to make a coach choice.

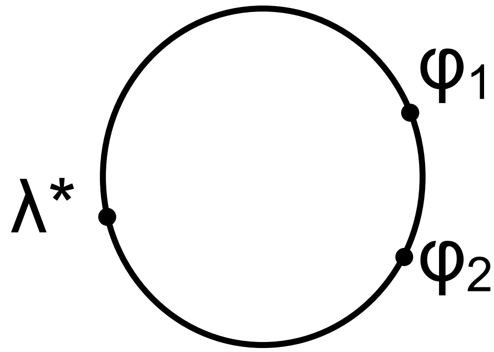

Figure A.1 Coach circular “characteristic” matching model

In this simple case, we can compare the information sets of athletes versus other individuals (managers) in attempting to match coaches and athletes. Despite the fact that athletes may have limited information about an individual coach’s match adequacy, he/she arguably has the most up to date and accurate information about what the job of the coach will be (because it relates directly to their own status and needs). While one might argue that team management could also develop this tacit knowledge of athlete “types” over time working in the industry, we have outlined at least one reason to believe that team management’s knowledge about coach compatibility would remain general or biased in nature, and could never approach the specificity of information an individual athlete possesses. Essentially, managers will not be likely to have the ability to “get inside” each of their athletes to match their own (even if limited) self awareness which is critical for effective coaching.

If we generalize this model to N characteristics of athletes and coaches, we can see that this effect would simply be compounded across the independent characteristics of each. Also, in a practical sense, we could view these athlete characteristics as heterogeneous in terms of specificity. For instance, as alluded to previously, the characteristics that really matter for a coach-athlete relationship arise from the problem solving and advisement an athlete might need. In a sense, these individual "characteristics" are each production "problems" for the athlete, and coaches serve as potential specialists contracted to address them. These services could be general advice and the solving of routine problems, as are common for skill based team sports, but at the professional level of "peak physiological condition" based sports are much more likely to be very specific and targeted at the weaknesses of an athlete's repertoire. The knowledge about these specific weaknesses and needs of the athlete are much more likely to reside with the athlete for the reasons discussed above.

Although we have this prediction that athletes will do a superior job of selecting coaches that will work best for them, these coaches could still be either employees of a sports team, or contracted directly by the athlete. If coaches were to be hired by the team, the athletes could just inform the team of their preferred coach and the team could hire and compensate that coach without directly revealing private information. The following section will delve into the sport of cycling to understand how this ambiguity may be resolved in its specific context.

APPENDIX B

COACH QUESTIONNAIRE

USAC Coach Questionnaire

STUDY TITLE: INDUSTRIAL ORGANIZATION OF PROFESSIONAL CYCLING COACHES

RESEARCHERS: This study is being conducted by Daniel Larson, MS (bshark@uga.edu), 352-262-7601, under the direction of Dr. Maxcy (jmaxcy@uga.edu), 706-542-4420
Department of Kinesiology, the University of Georgia

To current or former USA Cycling Coach:

As a current or former USA Cycling licensed cycling coach in the United States, you are invited to participate in a new research study about the business of cycling coaches. Despite being both key facilitators for the development of young cyclists and valuable service providers to the professional cycling industry, the coaching profession has been vastly understudied. Please consider your participation in this study to be a personal contribution to the knowledge of, and general improvements in, the cycling coaching profession.

Your participation in this study is voluntary. If you refuse to participate, you will not be penalized or lose any benefits to which you are otherwise entitled. The potential benefits of this study to society are an improved understanding of the economic determinants of private organizational team structures. Improved commercial efficiencies and possible public policy considerations can be more informed with an improved understanding of the economic determinants of similar professional practices.

Your requested contribution will be in the form of a short questionnaire about your cycling coaching experiences. This questionnaire should take less than 10 minutes to complete and requires only that you are able to navigate a normal web page environment. There are no anticipated risks associated with your participation in this study, and you may choose to withdraw from the study at any time without penalty or loss of benefits to which you are otherwise entitled.

If you choose to participate, all of your responses will remain confidential. Your identity will be temporarily assigned a numerical code. Coded responses from a separate athlete survey will be linked to your code in order to study athlete and coach matching within the industry. The key to these codes will be strictly confidential and deleted/destroyed by the researchers immediately following the data collection period. Individually identifiable information will never be reported or released to anyone including other coaches, athletes, or study participants. This linked information will only be used by the primary researcher to investigate and analyze the industry as a whole. Again, you are free to discontinue your participation at any time for any reason without penalty or loss of benefits to which you are otherwise entitled.

Please choose one of the following options:

- ○ YES, I have read and understand the risks and benefits of participation in this study and wish to participate.
- ○ NO, I would like to withdraw.

If you have any questions about this questionnaire or research project, please direct them to: Daniel Larson (bshark@uga.edu), 352-262-7601, or Dr. Maxcy (jmaxcy@uga.edu), 706-542-4420
Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Consent

Age Verification

USAC Coach Questionnaire

Thank you for agreeing to take part in this survey. Please confirm the following to begin:

- ◯ I CONFIRM that I am at least 18 years old.
- ◯ I am NOT yet 18 years old

Information about you.

Please remember that all of your responses are strictly confidential and will not be shared with anyone.

What is your gender?

- ◯ Male
- ◯ Female

What is your current age?

What is the highest educational degree you have attained?

- ◯ High School Diploma/GED
- ◯ Associate's Degree
- ◯ Bachelor's Degree
- ◯ Master's Degree
- ◯ Doctoral Degree (or terminal degree such as JD, MD, DDS, DVM, etc)
- ◯ None of the above

If the above highest degree is a college degree, was your academic study closely related to sports, exercise, or coaching?

- ◯ Yes
- ◯ No
- ◯ Don't Know OR No College Degree

About Your Coaching Activity

Please answer the following to tell us some more about your coaching activities.

USAC Coach Questionnaire

What is your CURRENT coaching certification level?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ Don't Know
- ◯ I am not CURRENTLY a certified USA Cycling coach

Which of the following best describes how you practice your coaching?

- ◯ As an individual coach (Independent)
- ◯ In a partnership (roughly equal shares with no employees)
- ◯ I own a coaching firm with at least some employee coaches
- ◯ I coach as an employee of someone else's coaching firm
- ◯ I coach as an employee of a professional cycling team
- ◯ I coach as an employee of a government agency (parks, recreation, NGB, etc.)
- ◯ Other (please specify)

Is your only occupation coaching and/or personal training?

- ◯ Yes
- ◯ No
- ◯ Don't Know

Do you aspire to coach full-time?

- ◯ Yes
- ◯ No
- ◯ Don't Know

Do you presently coach at least one road cyclist?

- ◯ Yes
- ◯ No

More About Your Coaching History

Please answer the following to tell us some more about your coaching activities.

USAC Coach Questionnaire

How many years have you coached cyclists?

[ ]

How many years have you been a USA Cycling certified coach?

[ ]

Have you practiced as a cycling coach without a USA Cycling (or USCF) coaching license in the past 5 years?

○ Yes

○ No

Do you coach at least one Professional or Elite (Category 1) level cyclist?

○ Yes

○ No

About your Professional/Elite level coaching

Please answer the following to tell us some more about your coaching activities.

Of the Professional and Elite (Category 1) level cyclists you personally coach, what is closest to the approximate monthly price they pay you for coaching? (including cash equivalent of any traded goods)

[ ]

Of the Professional and Elite (Category 1) level cyclists you personally coach, do any of them pay you with a specified percentage of their winnings or cycling salary for coaching?

○ Yes

○ No

What is that percentage?

[ ]

About Your Athletes

Please answer the following to tell us about your coaching clients.

Do you sometimes refer potential athletes to other coaches outside of your company?

○ Yes

○ No

USAC Coach Questionnaire

Do you sometimes refer potential athletes to other coaches within your company?

- ◯ Yes
- ◯ No
- ◯ Not applicable, I work alone

More About Your Athletes

For the following questions, consider ONLY the ROAD cyclists that you currently personally coach.

How many total cyclists are you coaching?

How many are Male?

How many are Female?

How many are Masters athletes?

How many are Junior athletes?

How many are U23 athletes?

More About Your Athletes

For the following questions, consider ONLY the ROAD cyclists that you currently personally coach.

USAC Coach Questionnaire

How many athletes that you currently coach are in their...
(select any that apply)

	Number of Athletes
1st year with you?	
2nd year with you?	
3rd year with you?	
4th year with you?	
5th year with you?	
6th year with you?	
7th year with you?	
8th year with you?	
9th year with you?	
10th year with you?	
MORE than 10th year with you?	

How many are UCI Professional athletes?

How many are USA Cycling Category 1 athletes?

How many are USA Cycling category 2 or 3 athletes?

How many are USA Cycling category 4 or 5 athletes?

How many do you know are probably NOT USA Cycling members?

How many of your athletes from last year did NOT continue with your coaching for this year?

More About Your Athletes

USAC Coach Questionnaire

Of your athletes from last year not continuing with your coaching(if any), how many were for each of the following primary reasons?

	Number of cyclists
Price was too high for them	
Loss of job or personal income	
Service expectations not met	
Performance expectations not met	
Moving out of the area	
No longer competing in cycling	
No explanation	

Other (please specify)

About Your Cycling History

Tell us about your own experiences as a cyclist!

How many years were you ever an active competitor?

How many years were you ever a top regional competitor? (Category 2 or better)

How many years were you ever a National level competitor? (Category 1 or better)

How many years were you ever a Professional or International level competitor? (UCI competitions OR paid any salary for cycling)

How many times have you ever participated in the Olympic Games as an Athlete? (Number of Olympics, not individual events)

USAC Coach Questionnaire

How many cycling National Championship, World Championship, or Olympic Games medals have you won as an Athlete?
(Select all applicable, if NONE, leave blank or select "0")

	Gold	Silver	Bronze
Masters National Championships (Road and Track)			
Collegiate National Championships (Road and Track)			
Junior or U23 National Championships (Road and Track)			
Professional or Elite National Championships (Road and Track)			
Road or Track World Championships (any age group)			
Olympic Games (Road and Track)			

Do you still compete as a cyclist?

- ○ Yes
- ○ No

Of all of your cycling history and experience, pick one PRIMARY area of cycling that you feel you were most accomplished in:

- ○ Road sprinter
- ○ Time-trialist (flat or rolling)
- ○ Climber
- ○ Track specialist (sprint or endurance)
- ○ Other (please specify)

Open Response

Tell us your story:

Feel free to offer any additional information or comments about any question that you were asked in this questionnaire:
(not required)

USAC Coach Questionnaire

Feel free to tell us about anything that you feel is significant about your past cycling coaching experiences that is not discussed in previous questions:
(not required)

When satisfied, click "Next" to finish survey.

THANK YOU!

You are finished. Thank you for your time and participation. If you have any questions about this research project, please contact:

Daniel Larson, bshark@uga.edu
OR
Joel Maxcy, jmaxcy@uga.edu

Click "Done" to complete the survey.

APPENDIX C

ATHLETE QUESTIONNAIRE

USAC Athlete Questionnaire

STUDY TITLE: INDUSTRIAL ORGANIZATION OF PROFESSIONAL CYCLING COACHES

RESEARCHERS:
This study is being conducted by Daniel Larson,MS under the direction of Dr. Joel Maxcy
Department of Kinesiology, the University of Georgia,

To UCI/Elite licensed cyclist:

As a current UCI professional or Category 1 cyclist licensed in the United States, you are invited to participate in a new research study about the business of cycling coaches. As top level cyclists are key clientele for practicing coaches, your personal experiences and history of working with cycling coaches is critical in evaluating the coaching industry. Please consider your participation a contribution to the overall improvement of the cycling coaching profession.

We are requesting that you complete a short questionnaire about your past cycling coaching experiences. This questionnaire should take less than 10 minutes to complete and requires only that you are able to navigate a normal web page environment. There are no anticipated risks associated with your participation in this study, and you may choose to withdraw from the study at any time without penalty or loss of benefits to which you are otherwise entitled.

Your participation in this study is voluntary. If you refuse to participate, you will not be penalized or lose any benefits to which you are otherwise entitled. The potential benefits of this study to society are an improved understanding of the economic determinants of private organizational team structures. Improved commercial efficiencies and possible public policy considerations can be more informed with an improved understanding of the economic determinants of similar professional practices.

If you choose to participate, your responses will remain strictly confidential. Your identity will be temporarily assigned a numerical code. Coded responses from a separate coach survey will be linked to your responses in order to study athlete and coach matching within the industry. The key to these codes will also be strictly confidential and immediately deleted/destroyed by the researchers. Individually identifiable information will never be reported or released to anyone. Any information collected through this questionnaire will only be used by the primary researchers to investigate and analyze the coaching industry as a whole. Again, you are free to discontinue your participation at any time for any reason without penalty or loss of benefits to which you are otherwise entitled.

Please choose one of the following:

- ◯ YES, I have read and understand the risks and benefits of participation and want to begin
- ◯ NO, I want to withdraw

If you have any questions about this questionnaire or research project, please direct them to: Daniel Larson (bshark@uga.edu), 352-262-7601, or Dr. Joel Maxcy (jmaxcy@uga.edu), 706-542-4420
Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Consent

Age verification

Thank you for agreeing to take part in this survey. Please confirm the following to begin:

- ◯ I CONFIRM that I am at least 18 years old
- ◯ I am NOT yet 18 years old

USAC Athlete Questionnaire

Basics About You

What is your gender?

- ○ Male
- ○ Female

What is your current age?

[ ]

What is the highest educational degree you have attained?

- ○ High School Diploma/GED
- ○ Associate's Degree
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ Doctoral Degree (or terminal degree such as JD, MD, DDS, DVM, etc)
- ○ None of the above

If the above highest degree is a college degree, was your academic study closely related to sports, exercise, and/or coaching?

- ○ Yes
- ○ No
- ○ Don't know OR No college degree

About Your Cycling

Please answer the following about your cycling history:

How many years have you been an active cycling competitor at any level?

[ ]

How many years have you been a top regional competitor? (Category 2 or better)

[ ]

How many years have you been a National level competitor? (Category 1 or better)

[ ]

USAC Athlete Questionnaire

How many years have you been a Professional or International level competitor? (UCI competitions OR paid any salary for cycling)

How many times have you participated in the Olympic Games as an athlete? (Number of Olympics, not individual events)

How many cycling medals have you won in each of the following? (Leave blank OR Select "0" if NONE)

	Gold	Silver	Bronze
Masters National Championships (Road and Track)			
Collegiate National Championships (Road and Track)			
Junior or U23 National Championships (Road and Track)			
Professional or Elite National Championships (Road and Track)			
Road or Track World Championships (any age group)			
Olympic Games (Road and Track)			

Pick one PRIMARY area of cycling that you feel you have the highest level of ability in?

- Sprinting
- Time-Trialing (flat or rolling)
- Climbing

More About Your Cycling

Please answer these questions about your earnings:
Reminder: responses are strictly confidential

Roughly how much in total payments will you receive for just your cycling salary this year?

As closely as you can estimate, how much will you receive in "take home" prize winnings this year? (after paying and receiving any shared prize money)

As closely as you can estimate, how much do you earn annually in other tangible cycling contract benefits? (Examples: equipment to sell, sellable clothing, performance bonuses, etc.)

USAC Athlete Questionnaire

How much, if anything, do you earn (gross) through ALL other NON-bicycle-racing related sources?
(Examples: full-time work, part-time work, off-season work, family support, student financial aid, investment income, etc.)

Do you personally coach other cyclists?

- ◯ Yes
- ◯ No
- ◯ Don't Know

About Your Coaching

A few more questions about your coaching activity:

As accurately as you can estimate, how much do you earn each YEAR coaching other cyclists?

Do you coach any professional cyclists?

- ◯ Yes
- ◯ No
- ◯ Don't Know

If you do coach other professional cyclists for pay, are ALL of them on your current team?

- ◯ Yes
- ◯ No
- ◯ I do NOT coach other professional cyclists

About Your Coaches

Please answer the following about your coaching experiences:

Have you ever had formal personal coaching for the sport of cycling?

- ◯ Yes
- ◯ No

USAC Athlete Questionnaire

Are you currently being coached by anyone for the sport of cycling?

- ◯ Yes
- ◯ No

More About Your Coaching

Please answer some questions about your coaching costs:

What is closest to the approximate monthly price you currently pay for coaching? (including cash equivalent of any traded goods)

[ ]

Do you pay your current coach a specified percentage of your winnings or cycling salary earnings for coaching services?

- ◯ Yes
- ◯ No

What is that approximate percentage?

[ ]

Your Cycling Team

Tell us about your team organization:

Which of the following best describes your current team:

- ◯ Professional UCI registered team
- ◯ Elite amateur team with support personnel
- ◯ Elite amateur team without support personnel
- ◯ Club or team with very few Elite riders without personnel support
- ◯ I am not currently a part of a team

Your Cycling Team Role

Tell us about yout team contributions:

USAC Athlete Questionnaire

Which of the following best describes your PRIMARY assigned role for your CURRENT team in MOST major team road racing events?

- ◯ Team Leader: Sprinter
- ◯ Team Leader: General Classification/Time-Trialist
- ◯ Team Leader: Climber
- ◯ Support: Sprinter (lead-out)
- ◯ Support: General: Feeding/Mecahnical/Pacing/Chasing
- ◯ Support: Climber

Which of the following roles have you performed in major team road racing events in the past year?
(select all applicable)

- ☐ Team Leader: Sprinter
- ☐ Team Leader: General Classification/Time-Trialist
- ☐ Team Leader: Climber
- ☐ Support: Sprinter (lead-out)
- ☐ Support: General: Feeding/Mecahnical/Pacing/Chasing
- ☐ Support: Climber
- ☐ Captain: On the road directing of team

Your Cycling Team Coaching

Tell us about your team's coaching:

Are you being coached by a manager or director of your current team?
(with no outside coach)

- ◯ Yes
- ◯ No

About what percentage of your other team members are coached by a manager, director, or employee coach of your current team?

[ ]

USAC Athlete Questionnaire

Which of the following best describes your coach's involvement in your current cycling team

- ◯ My coach IS a director or manager of my team
- ◯ My coach is EMPLOYED by my cycling team but is usually not my director/manager for competitions
- ◯ My coach is independent of my team but WORKS VERY CLOSELY with my director/manager on decisions about my preparations and competitions
- ◯ My coach and director/manager INTERACT INFREQUENTLY about my preparations and competitions
- ◯ My coach and Director/manager almost NEVER INTERACT
- ◯ I have NO team director/manager for competitions.

Coach and Management Interactions

Have there ever been any significant conflicts between your team director/manager(s) and any of your cycling coaches?

- ◯ Yes
- ◯ No
- ◯ Don't Know

If YES, please briefly describe the nature of the conflicts and resolution (if applicable):

Have any of your coaches ever suggested you act in a way that was against the instructions of your team director/manager?

- ◯ Yes
- ◯ No
- ◯ Don't Know

If YES, please briefly describe the nature of the conflicting instructions and action taken by you (if applicable):

More About Your Coaches

Please tell more about your coaching history:

USAC Athlete Questionnaire

My CURRENT cycling coach is:
(Reminder: responses are strictly confidential)

Other (please specify Name and Location)

How were you first connected with your CURRENT cycling coach?

- [ ] Coach solicited me on local cycling routes/group rides
- [ ] Was referred to this coach by other cyclist(s)
- [ ] Coach worked with local club or team that I became a member of
- [ ] Found coach through USA Cycling website
- [ ] Found coach through other internet searches or advertisement
- [ ] Coach was already a current friend
- [ ] Coach is a family member
- [ ] Other (please specify)

Does your CURRENT cycling coach live in the same local area that you normally train and prepare for competitions?

- ○ Yes
- ○ No
- ○ Don't Know

About Your Past Coaches

USAC Athlete Questionnaire

Please consider ALL of your past personal cycling coaches beginning with the most recent:
(select only those that apply)

	Years
Coach 1: How many years have you worked with your most recent personal coach?	
Coach 2: How many years did you work with your personal coach before Coach 1?	
Coach 3: How many years did you work with your personal coach before Coach 2?	
Coach 4: How many years did you work with your personal coach before Coach 3?	
Coach 5: How many years did you work with your personal coach before Coach 4?	
Coach 6: How many years did you work with your personal coach before Coach 5?	
Coach 7: How many years did you work with your personal coach before Coach 6?	
Coach 8: How many years did you work with your personal coach before Coach 7?	
Coach 9: How many years did you work with your personal coach before Coach 8?	
Coach 10: How many years did you work with your personal coach before Coach 9?	
If you have had more than 10 personal coaches, what was about the average number of years you worked with each coach?	

Did your FIRST cycling coach live in the same local area that you normally trained and prepared for competitions?

- ○ Yes
- ○ No
- ○ Don't Know

How were you originally connected with your FIRST cycling coach?

- ☐ Coach solicited me on local cycling routes/group rides
- ☐ Was referred to this coach by other cyclist(s)
- ☐ Coach worked with local club or team that I became a member of
- ☐ Found coach through USA Cycling website
- ☐ Found coach through other internet searches or advertisement
- ☐ Coach was already a current friend
- ☐ Coach is a family member
- ☐ Other (please specify)

Open Response

Tell us your story:

USAC Athlete Questionnaire

Feel free to offer any additional information or comments about any question that you were asked in this questionnaire:
(not required)

Feel free to tell us about anything that you feel is significant about your past cycling coach experiences that is not discussed in previous questions:
(not required)

When finished, click "NEXT" to finish survey.

Thank you

You are finished. Thank you for your time and consideration. If you have any questions about this research project, please contact:

Daniel Larson, bshark@uga.edu
OR
Joel Maxcy, jmaxcy@uga.edu

Click "Done" to complete the survey.