Article

Journal of Sports Economics
14(4) 411-439

DOI: 10.1177/1527002513496009
jse.sagepub.com

Second Place Is First of the Losers: An Analysis of Competitive Balance in Formula One

Chris Judde[1], Ross Booth[2], and Robert Brooks[1]

Abstract

This article analyses competitive balance in Formula 1 motor racing 1950-2010. It is shown that regulation change has had a significant positive impact on championship uncertainty but not on race uncertainty or long-term dominance. If television viewer suspense is positively related not only to championship uncertainty but also to absolute quality, then this suggests the purpose of such regulation change is to maximize television broadcasting revenues and gross sponsor exposure. A simple econometric model is employed to analyze competitive balance implications of the Resource Restriction Agreement, designed to restrict team expenditure following the global financial crisis.

Keywords

competitive balance, Formula One, motor racing, resource restriction agreement, television ratings

Introduction and Background

The first Grand Prix motor race was held at Le Mans by the Auto Club de France in 1906 (Hughes, 2004). However, it was not until 1947 that a framework of technical

[1] Faculty of Business and Economics, Monash University, Victoria, Australia
[2] Department of Economics, Monash University, Victoria, Australia

Corresponding Author:
Ross Booth, Department of Economics, Monash University, Clayton, Victoria, Australia 3800.
Email: ross.booth@monash.edu

regulations known as Formula 1 (F1) was devised, and until 1950 that the first Drivers' Championship—comprising events in Britain, Monaco, Switzerland, Belgium, France, and Italy, as well as the Indianapolis 500—was contested (Bekker & Lotz, 2009; Jenkins & Floyd, 2001).

In the immediate postwar era, F1 was "an uncoordinated, almost informal sport" populated by "works" cars of teams reliant on the resources of their parent company (e.g., Ferrari, Alfa Romeo, Maserati) as well as privateer entries "raced by individuals who were either independently wealthy or had a wealthy benefactor" (Henry, 2003, p. 38; Jenkins, 2010, p. 889). Teams raced in their national colors—predominantly the red of Italy, silver of Germany, and green of Britain—received modest appearance and prize monies and derived sponsorship only from trade backers, with "small stickers for tire, fuel, oil or brake brands in exchange for a free supply" (Hughes, 2004, p. 42). F1 became wholly independent when the Indianapolis 500 was removed from the 1961 schedule, and the introduction of a revised regulatory framework in 1966 coupled with Ford's decision to make its double four valve (DFV) engine widely available led to an influx of new entrants (Jenkins, 2010).

National colors faded from 1968, when 3 years after tobacco advertising was banned on British television, Imperial Tobacco branding appeared on the cars of Team Lotus (Henry, 1998). Reinforcing the commercial sponsorship revolution, Renault entered F1 with a turbocharged engine in 1977. Its performance encouraged other manufacturers such as Honda and BMW to follow suit, and significantly, these companies would remain a fixture of F1 even after turbocharged engines were banned in 1989 (Jenkins, 2010).

Almost concurrently, it was in 1978 that television broadcasting—hitherto fragmented with viewers "defined by the nationality of successful drivers"—proliferated globally (F1 Racing, 1997b, p. 46). Consistent with the observation of Leeds and von Allmen (2008, p. 85) that few events "changed the finances of professional sports as much as the advent of television," these developments culminated in an arms race that saw the budget of the world champion team increase from US$5 million in 1980 to US$40 million in 1990, before reaching US$300 million in 2000 (F1 Racing, 1997a, 1997b, 2002a).

Today, F1 is a multibillion dollar annual industry, ranking behind only the 4-yearly Football World Cup and Summer Olympic Games in terms of live television audience (Benson, 2011; Jenkins, 2010). The cars, which have effectively become mobile advertising billboards, race fortnightly in front of a global audience of motor sport fans—527 million across 187 countries in 2010—who are "up to three times more brand loyal than fans of other sports" (Autosport, 2011b; Donahay & Rosenberger, 2007, p. 2).

It was the appeal of racing in front of this audience that saw manufacturer teams begin to displace independents—teams that exist only to race in F1, and must therefore comply with a long-run break-even constraint to be viable—from the early 21st century. In 2000, Renault acquired the Benetton team, and Honda and BMW purchased British American Racing and Sauber, respectively, in 2006 (Jenkins, 2010). The scope for positive externalities to be realized by manufacturers is undisputed. For example, accompanying a 100% increase in Mercedes-Benz road car sales between 1995 and 2006 was an increase in the proportion of cars sold in silver (from 22% to 47%), attributed in part to their association with the "Silver Arrows" McLaren-Mercedes F1 cars (F1 Racing, 2006d).

As this potential to realize positive externalities exists, manufacturer teams often benefit from substantial parent company funding. For example, of the Ferrari road car division profit of US$203 million in 2002, US$184 million was diverted to their F1 team (F1 Racing, 2003a). The somewhat inevitable outcome of revenue imbalance between manufacturers and independents would emerge in the late 20th century (Table 1), the consequences of which are succinctly captured by Fort (2006, p. 3); "teams that spend the most tend to win the most." F1 would not be immune in this regard, as a dominant Ferrari won eight Constructors' Championships between 1999 and 2008 (Budzinski & Feddersen, 2011).

Contributing to this outcome, the revenues that teams share—47% of the previous years' television broadcasting revenues, or around 23% of the value of the commercial rights (Figure 1)—represent only a minor proportion of the overall budget of each team (Henry, 2003). Moreover, as Table 1 shows, the distribution is skewed such that ignoring the 4% annual payment Ferrari receives in recognition of their historical contribution to the sport, the team that wins the world championship—relative to the team that is last in the standings—"receives roughly double the amount of money" (Henry, 2003, p. 20).

The purpose of Figure 1 is to show that the primary revenue source of F1 teams—in addition to parent company contributions in the case of manufacturers—is sponsorship (Solitander & Solitander, 2010). However, as all F1 teams compete on the same track at the same time, it is inevitable that sponsorship revenues flow more easily toward successful teams, which as Table 2 indicates, dominate media coverage "to a much greater extent" than do their less successful counterparts (Alexander & Kern, 2004; Bekker & Lotz, 2009, p. 952; Cygan, 2007). Providing further insight into the nature of this relationship, the championship-winning Renault team attracted US$136 million in cash-paying sponsors for the 2006 season, whereas Midland F1 could only generate US$43.5 million, US$32 million of which was derived from personal sponsorships from their drivers (F1 Racing, 2006a).

By 2010, Red Bull—the world champion team owned by the Austrian energy drinks company of the same name—was the most visible brand in F1, attracting a quarter of all television coverage (Sylt & Reid, 2011). Their "advertising value equivalent"—or price of purchasing a comparable quantity of exposure—was estimated at £219.9 million, representing a more than 100% return on Red Bull's total 2010 expenditure of £106.8 million (Sylt & Reid, 2011). Conversely, as slower teams attract less coverage and struggle to generate sponsorship, this hampers their ability to develop a competitive car "creating a potential downward spiral" (Donahay & Rosenberger, 2007, p. 10). Exacerbated by the financial arms race among manufacturer teams intent on improving their relative standing, this competitive

Table 1. Team Budget Data and Prize Money Distribution.

Team/Budget	2002	2003	2004	2005	2006	Team	Prize Money[a] (2004)
Ferrari	US$443.8m	US$418.23m	US$426.24m	US$432.98m	US$406.5m	Ferrari	US$35.5m
Williams	US$353.3m	US$359.04m	US$355.59m	US$360.12m	US$195.5m	B.A.R.	US$33.5m
McLaren	US$304.6m	US$359.22m	US$359.33m	US$419.95m	US$402m	Renault	US$29.5m
Toyota	US$290.4m	US$368.51m	US$397.21m	US$499.05m	US$418.5m	Williams	US$27.5m
BAR/Honda	US$225.1m	US$309.87m	US$343.59m	US$360.16m	US$380.5m	McLaren	US$24.5m
Renault	US$206.8m	US$255.23m	US$258.54m	US$287.21m	US$324m	Sauber	US$23.5m
Sauber/BMW	US$119.5m	US$154.57m	US$146.44m	US$161.32m	US$355m	Red Bull	US$21.5m
Jordan/Midland	US$79.2m	US$79.92m	US$67.78m	US$104.2m	US$120m	Toyota	US$20.5m
Jaguar/Red Bull	US$78.8m	US$141.93m	US$143.04m	US$139.22m	US$252m	Jordan	US$19.5m
Minardi/STR	US$39.6m	US$46.58m	US$39.25m	US$50.58m	US$75m	Minardi	US$18.5m
Super Aguri	–	–	–	–	US$57m		
Total	US$2,141.1m	US$2,493.10m	US$2,537.01m	US$2,814.79m	US$2,986m		

Note. Adapted from F1 Racing, Various. M= million. Adapted from F1 Racing, 2000, 2003b, 2004, 2005 and 2006c.
[a]Awarded in order of team position in the Constructors' Championship.

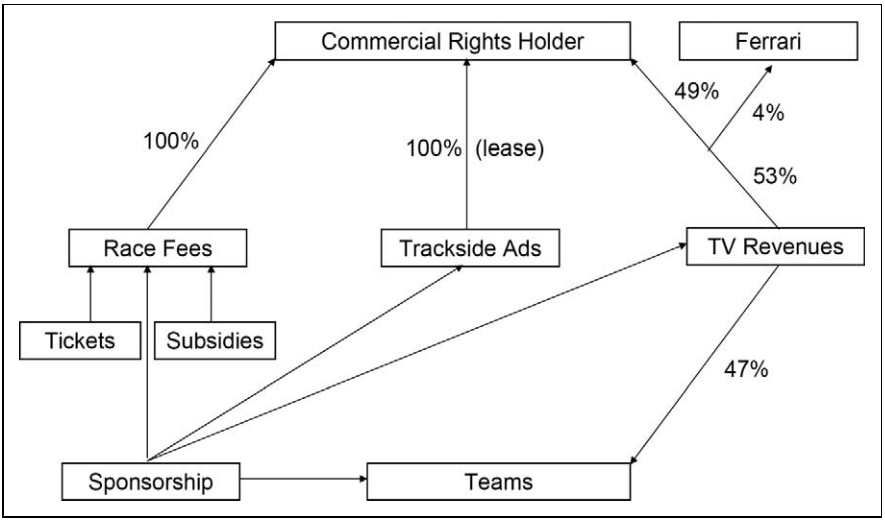

Figure 1. Distribution of commercial rights revenues: 1995-2007.
Source: Henry, 2003.

Table 2. TV Exposure Shares 2006.

Team	Type	Race Exposure Share, %	Points, %
Renault	Manufacturer	29.8	29.34
Ferrari	Manufacturer	22.5	28.63
McLaren	Independent	13.1	15.67
Honda	Manufacturer	9.1	12.25
Williams	Independent	5.0	1.57
BMW	Manufacturer	5.0	5.13
Toyota	Manufacturer	4.6	4.99
Red Bull Racing	Independent	4.5	2.28
Toro Rosso	Independent	3.2	0.14
Midland F1	Independent	1.8	0.00
Super Aguri	Independent	1.3	0.00

Note. Adapted from Sports Marketing Systems in F1 Racing, 2006b.

environment contributed to the failure of the Prost (in 2001), Arrows (2002), and Super Aguri (2008) independent teams (Sanderson, 2002).

In 2005, when tobacco advertising was banned in Europe, the car manufacturers further entrenched their position as F1's "dominant commercial force" (F1 Racing, 2009a, p. 37). However, it had long been argued by former Fédération Internationale de l'Automobile (FIA) president Max Mosley that manufacturers—who are answerable to shareholders as opposed to the sport—"can, and will, leave whenever it suits them" (Henry, 2003, p. 30). The implications of this became clear when Honda, BMW, and Toyota—half of F1's manufacturer base—withdrew from the sport in the wake of the Global Financial Crisis, raising concerns about the viability of Formula 1 (Henderson, Foo, Lim, & Yip, 2010).

In response, the FIA proposed an unprecedented £40m/US$70 million budget cap for the 2010 season. The rationale for the proposal was described by Mosley in the following terms: "If we are to reduce the risk of the F1 world championship collapsing, we have to allow new teams in. We also have to reduce costs drastically. The matter is therefore extremely urgent" (Allen, 2009, p. 77). Unsurprisingly, the cap was resisted by manufacturer teams "loath to cede their entrenched financial advantages," which hitherto allowed them to spend their way to success, or out of uncompetitive situations (F1 Racing, 2009b, p. 36).

However, concerns were also raised by several independent teams that were nervous about the reaction of sponsors to a cap that would make it attractive for them to own teams outright (Allen, 2009). Ultimately, a compromise was reached with the teams agreeing to implement a Resource Restriction Agreement (RRA). This mechanism would see maximum budgets progressively reduce to 50% of their 2008 level—a season in which Toyota spent US$445.6 million—and workforces would decline from a maximum of 700 to approximately 350 by the end of 2011 (Allen, 2010; Budzinski & Feddersen, 2011).

Although the compromise resulted in no 13th franchise for the 2010 season—the proposal of the budget cap led to eighteen applications for the thirteen available slots—three independent teams (Lotus, Virgin, and HRT) nevertheless entered F1 in 2010, each operating on a budget in the region of £50 million (Allen, 2010). With the terms of the RRA extended to the end of 2017, this study aims to complement the existing literature by evaluating the implications of the RRA for competitive balance in Formula 1.

Literature Review

Among the most important contributions to the sports economics literature is the uncertainty of outcome hypothesis. Proposed by Rottenberg (1956), the hypothesis posits that spectators derive greater utility from observing contests with an uncertain outcome, and that the more evenly talent is distributed among teams, the less certain the outcome of those contests will be (Berkowitz, Depken, & Wilson, 2011; Cain & Haddock, 2006; Dawson & Downward, 2005). Competitive balance—defined by Quirk and Fort (1992, p. 243) in terms of the equality of talent distribution among teams "so that uncertainty of outcome is preserved"—is therefore a key determinant of the financial health of a sport, as perennially unbalanced contests would "eventually cause fan interest to wane and industry revenues to fall" (Késenne, 2000, p. 56; Sanderson & Siegfried, 2003).

The issue of competitive balance in F1 has had only limited attention. Unlike many league sports, but like most categories of motorsport, F1 is a hybrid team–individual contest, in which the individual associated with success—the driver—depends on the rest of their team to do everything from optimizing the setup of the car to changing its tires in pit stops (Krauskopf, Langen, & Bunger, 2010; Sanderson, 2002; von Allmen, 2001). However, F1 cannot be directly compared with "spec" categories such as National Association for Stock Car Auto Racing (NASCAR)—which feature standardized chassis, gearbox, and engine packages—given the contrast between the technical freedom conducive to disparate car performance in F1 and categories in which regulators "go to extensive lengths to promote equal competition" (Leeds & von Allmen, 2008, p. 151). In NASCAR, for example, "cars must meet shape requirements based on [eighteen] different templates to ensure that aerodynamically, no car has an advantage over another" (von Allmen, 2001, p. 64).

What differentiates F1 from "spec" categories is that teams—referred to as constructors—are responsible for the design and manufacture of their own cars, gearboxes, and in some cases their engines (Jenkins & Floyd, 2001). With no restriction on team budgets or the distribution of talent prior to the implementation of the RRA, the consequence of different cars powered by different engines driven by individuals of differing ability has necessarily been significant variation in the potential of car–driver combinations (Bekker & Lotz, 2009; Krauskopf et al., 2010). The popularity of such an inherently unbalanced contest therefore raises the question of whether optimal competitive balance in F1 may in fact correspond to less than absolute team equality (Késenne, 2001; Vrooman, 2009).

In a recent econometric study, Krauskopf, Langen, and Bunger (2010) analyze television ratings in an effort to determine the optimal level of competitive balance in F1. Their analysis is based on Kipker's (2002) premise that the dimensions of competitive balance pertinent to viewer's suspense relate to "uncertainty of race outcome, uncertainty of championship outcome, and the absence of long-term dominance," analogous to the game, championship, and dynasty elements associated with league sports (Sloane, 1971).

Although this study is limited in that it utilizes German television ratings alone as a proxy for viewer interest, Krauskopf et al. (2010) conclude that too high a level of competitive balance is as undesirable as too low a level and that viewer interest and by implication television broadcasting revenues and gross sponsor exposure are maximized by a season-long "duel" between superstar drivers, with the occasional race won by a noncontender. Hence, it can be implied that the point of the season at which the Drivers' Championship is decided is a key indicator of the level of competitive balance in F1. Also recognized is the importance of preserving absolute quality, as the championship may be devalued and fan interest may decline if the title is won by a perceived also-ran.

Another recent study by Mastromarco and Runkel (2009) investigates the relationship between regulation change and the level of competitive balance in F1. Published by the governing body FIA prior to each championship season,

Table 3. Examples of Formula 1 Regulation Change.

Season Regulation Introduced	Nature of Changes (Main Reasons)
1961	Maximum engine size reduced from 2.5 to 1.5 L. Supercharging now banned. Weight limit introduced (for the first time) of 450 kg (increase competition and provide more tightly defined regulations)
1966	Maximum engine size increased from 1.5 to 3.0 L (keep F1 in line with market trend to larger capacity engines)
1981	Use of ground effect "skirts" banned (safety)
1989	Use of turbo chargers banned. All engines required to be normally aspirated (cost reduction)
1994	Removal of automated driver aids (cost reduction and responding to public demand for increased driver input)
1998	Car maximum width reduced (from 200 to 180 cm) and use of slick (untreaded) tires made illegal. Grooved tires introduced (safety—reduce size and speed of cars)

Note. Adapted from Jenkins, 2010, p. 888.

regulation changes (Table 3) have traditionally been implemented for reasons such as reducing costs, improving safety, maintaining relevance with external market trends and/or increasing competition (Jenkins, 2010). Given (i) that no driver has suffered a fatal accident since 1994, (ii) the desire to maximize the value of the commercial rights, and (iii) recent growth in ratings and sponsorship revenues, it is perhaps unsurprising that competitive balance has become a more prominent motivation for regulation change since the mid-1990s (Appendix A).

Mastromarco and Runkel (2009, p. 3013) conclude that competitive balance regulation change exerts a "significant positive impact" on uncertainty of championship outcome that is quantified using the standard deviation of championship points. However, this measure is potentially misleading, as it is possible for the championship to be decided relatively early in the season, only for the points standings to subsequently close, thereby distorting the true level of competitiveness. Given Krauskopf et al.'s (2010) conclusions and "anecdotal evidence that fan interest is stimulated by a close title race"—one example being a pronounced decline in ratings after Michael Schumacher secured the 2002 title in race 11 of 17—it would therefore seem to be more appropriate to model this relationship using the Drivers' Championship decision point as the dependent variable (F1 Racing, 2003c).

Another limitation relates to the assumption that increased competitive balance leads always to heightened viewer suspense, hence Mastromarco and Runkel (2009) fail to acknowledge the importance of absolute quality as identified by Krauskopf et al. (2010). Moreover, in conflict with the wider literature, the authors assume that teams behave as profit maximizers. This article investigates whether the assumption of

F1 teams' profit or points maximizing is more appropriate to evaluate the implications of the RRA on competitive balance.

Research Aims

The objectives of this article are therefore (i) to establish whether F1 teams behave as profit or points maximizers, (ii) to econometrically investigate the impact of competitive balance regulation change with respect to all three pertinent dimensions of competitive balance, and (iii) to evaluate the implications of the RRA for competitive balance using an evolution of Fort and Quirk's (1995) two-team model developed by Booth (2000).

Method

Statistical data detailing race and championship performance from 1950-2010 (Appendix B) were obtained from secondary sources, predominately Griffiths (1997) and www.race-database.com/f1/. Additional information, such as team budget data (reproducing details of team accounts on public view at Companies House), sponsor exposure data, and race day weather, for example, were obtained from periodicals and specialist publications.

To ensure consistency and comparability, several revisions were made to the statistical data. For example, as all results did not count toward the championship prior to 1991, drivers' points were aggregated for the 1950-1990 seasons as were constructors' points for the 1950-1978 seasons. Moreover, as the first Constructors' Championship was not awarded until 1958, results are implied for the 1950-1957 seasons. To remove a possible source of bias, points awarded for the driver setting fastest race lap were removed from the 1950-1959 data as were the results of the Indianapolis 500 from 1950-1960 for the reason that few F1 drivers participated in this event. Race reliability statistics for the period 1950-1965 were also manually recalculated to incorporate the current 90% classification regulation. Finally, the points system structure of F1's numerous eras were normalized using a ratio of Herfindahl-Hirschman Indices (HHIs; refer to Appendix C).

Econometric Modeling

The data were then utilized to perform an ordinary least squares (OLS) regression to model uncertainty of championship outcome, the dependent variable the point of the season (percentage of total races) that the Drivers' Championship was decided (Figure 2).

In recognition of the fact that the points standings potentially influence driver behavior, the data in Figure 2 correspond to the raw (rather than the revised) values.

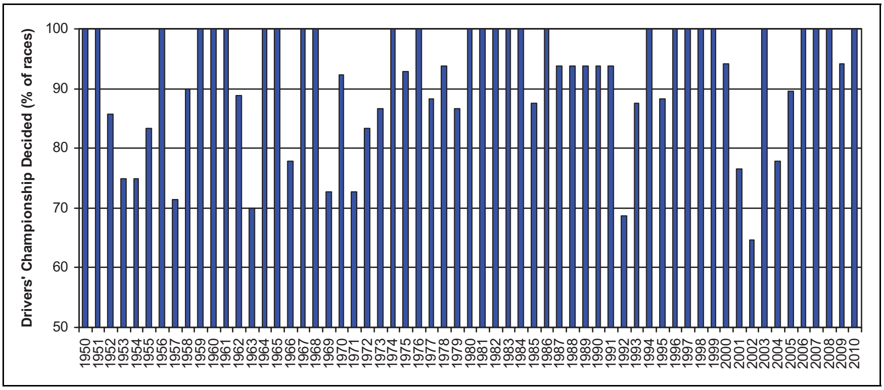

Figure 2. Drivers' championship decision point (% of races).
Source: Authors' Calculations.

Hence, a dummy variable for whether all points scored counted toward the championship is included in the model. A competitive balance regulation change dummy variable is also incorporated. The effects of unreliability and inclement weather are controlled for, as cars often retire from races due to technical problems or accidents, and the difference in grip and visibility between a dry and a wet track can suit different cars and/or drivers (Bekker & Lotz, 2009). For similar reasons, a dummy variable is included to recognize years in which more than one company supplied tires to F1 teams (i.e., a "tire war"). Additional explanatory variables capture the proportion of manufacturer teams to proxy for revenue imbalance and changes in the points system structure through the value of the HHI ratio.

A final independent variable is included as a proxy for relative driver competitiveness. The literature provides many measures suitable for this purpose. Given that many drivers fail to score points—let alone wins—in F1, the HHI was again employed to compare the realized distribution of wins to the "balanced" outcome of each race being won by a different driver (Equation 1).

$$\text{Win HHI Ratio}_{YrX} = \frac{\sum_{i=1}^{\text{No. of drivers}_{YrX}} (\text{Win\%}_i)^2}{\text{No. of Races}_{YrX} \times (100/\text{No. of Races}_{YrX})^2} \qquad (1)$$

Values of this ratio are presented in Figure 3.

An OLS regression was also utilized to evaluate uncertainty of race outcome. However, in this case, the dependent variable is the season average number of lead changes per Grand Prix. This was selected in preference to the adjusted churn measure commonly applied in the NASCAR literature, because a lead change—like overtaking in general—is far less frequent in F1, with an average of 3.12 lead changes per race from 1950-2010 (Figure 4), compared with the NASCAR average

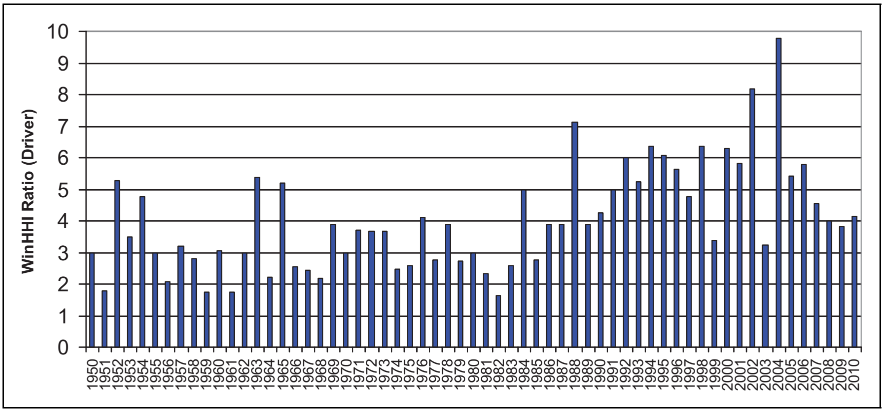

Figure 3. Value of Win HHI Ratio (Driver) 1950-2010.

Source: Authors' Calculations. HHI = Herfindahl-Hirschman Index.

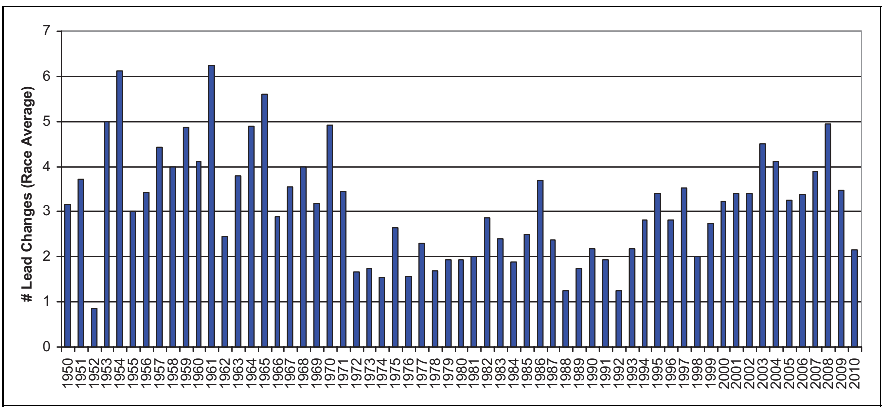

Figure 4. Average Formula 1 Race Lead Changes 1950-2010.

Source: Author.

of 10.27 per race from 2000-2008 (Berkowitz, Depken, & Wilson, 2011). The lead change measure adequately reflects the different nature of the racing between the two categories—where F1 lead changes are the exception rather than the rule—thereby representing a robust indicator of race uncertainty.

This model also required revisions to the included explanatory variables. For example, a dummy variable for aerodynamic wings is incorporated. These devices, introduced to F1 in 1968, create a region of turbulence behind the car, greatly increasing the difficulty of overtaking on road courses. Dummy variables are also included for years refueling pit stops during races were permitted (1982-1983, 1994-2009) as well as years F1 raced at the oval-esque prechicane Monza circuit configuration (1962-1971). An interaction term comprising the Monza and aerodynamic wings dummies completes the model. The inclusion of this term will provide an insight into whether the level of overtaking in F1 is an aerodynamic phenomenon, related to circuit design, or a combination of both.

To evaluate the long-term dominance dimension of competitive balance, a binary probit model—incorporating pertinent explanatory variables from the preceding OLS models—was employed to identify the factors contributing to a driver becoming a back-to-back world champion. The sample data were amended for this model, as there have been six F1 seasons without a defending champion present. To elaborate, in addition to the first championship in 1950, there have been two fatalities (1959 and 1971) and three retirements (1974, 1993-1994) of champions who were not subsequently present to defend their title.

The Two-Team Model

To evaluate the theoretical implications of the RRA, a version of the well-known Fort and Quirk (1995) two-team model developed by many authors including, among others, Booth (2000), Késenne (2000, 2001, 2002, 2007), and Szymanski (2003), is employed. Confining the analysis to a two-team contest is necessary to invoke the principal assumption of the model "that there is an asymmetry in the revenue generating function for each team" (Szymanski, 2003, p.14). Reflecting the likelihood that one team enjoys parent company's support is more attractive to sponsors, and/or has a larger fan base, it will be later established that the "large" revenue F1 team is a manufacturer and the "small" revenue team an independent.

Total revenue is assumed to be a positive function of accumulated points percentage, exhibiting diminishing marginal returns, ceteris paribus (Crooker & Fenn, 2007; Késenne, 2002). Talent (driver, engineering, etc.) is the critical input used to generate the desired output of points percentage. The suitability of this approach is captured in Jenkins and Floyd's (2001, p. 950) statement that "the accumulation of championship points is unambiguously accepted within [F1] as a key competitive outcome." F1 teams compete for the (100 units) of points percentage available each season. Moreover, the model allows for one individual (i.e., an elite driver or ingenious engineer) to account for more talent units than another (Fort & Quirk, 1995; Késenne, 2000). The model predicts that the team accumulating the greater talent share scores the higher points percentage, thus winning the championship (Hall, Szymanski, & Zimbalist, 2002).

Each team can be classified based on their primary objective, broadly described as either (i) maximizing their accumulated points percentage subject to the breakeven constraint or (ii) accumulating a specific points percentage so as to maximize their profit (Késenne, 2007).

In the absence of equalization mechanisms, manufacturers have the capacity to outbid independents for talent; hence, there is "potential for ... parity to be underprovided" (Crooker & Fenn, 2007, p. 157). A well-known result of the two-team

Table 4. Tyrrell Team Financial Data 1991-1995.

Year	Budget	Profit
1991	US$25,852,882	US$3,156,200
1992	≅ US$13,000,000	−US$2,702,120
1993	≅ US$16,000,000	US$150,410
1994	US$14,184,036	−US$2,539,054
1995	US$21,446,924	US$1,849,056
Overall	≅ US$90,484,000	−US$85,508

Note. Adapted from F1 Racing, 1997a.

model applied to F1 is that competitive balance decreases if the teams behave as points maximizers (win maximizers). In the profit-maximizing case, the wealthier manufacturer team records the higher profit, but when points percentage maximization is assumed, the manufacturer team acquires talent at the expense of the independent, and wages increase as the two teams compete for talent. Thus, a points-maximizing contest is characterized by a greater payroll imbalance and a less even distribution of talent (Késenne, 2000). Team behavior is therefore a key determinant of the level of competitive balance, and it is this issue that will be addressed first.

Results and Discussion

The results and analysis are presented in the following three sections, structured to ensure that each objective of the study is clearly and adequately addressed.

Team Behavior

The literature overwhelmingly supports the notion that Formula 1 teams behave as points maximizers. This philosophy is captured in the famous quote "second place is first of the losers" attributed to Ron Dennis, former managing director of the McLaren International team "whose stated aim is to go to every race to win" (Allen, 2010, p. 200).

Supporting evidence relates to financial data spanning the past three decades, which reveal that long-run team profits have been modest at best throughout this period. One example relates to the independent Tyrrell team, which recorded an almost negligible loss of US$85,000 on revenues of nearly US$90.5 million between 1991 and 1995 (Table 4).

The data in Table 4 also indicate that even if teams register profits, they are "ploughed back into the business," leading to the "inescapable fact [that] teams simply spend what they generate" (F1 Racing, 1997b, p. 45; 1999, p. 88). Further examples of this relate to the Williams team, which registered a US$13.2 million profit from revenues of US$72.6 million in 1995, financing a new US$13.5 million

Table 5. Ordinary Least Squares (OLS) Regression Model.

Variable	Coefficient (*t*-Statistic)	*p* Value (Significance)
Constant	108.002 (6.045)	.0000
All Points Count Dummy	5.683 (1.317)	.1938
Competitive Balance Dummy	6.938 (2.755)	.0082[a]
Manufacturer Representation (%)	−0.086 (−1.501)	.1397
Points System HHI Ratio	−10.460 (−0.825)	.4134
Tire War Dummy	−0.619 (−0.183)	.8558
Unreliability (%)	0.066 (0.257)	.7980
Wet Races (%)	−0.027 (−0.235)	.8155
Win HHI Ratio (D)	−3.538 (−4.004)	.0002[a]
Drivers' Champ. Decided (−1; %)	−0.900 (−7.719)	.0000[b]
Adjusted R^2	.586	
Durbin-Watson STATISTIC	2.246	
Sample	1951-2010	

Note. Adapted from Authors' Calculations. HHI = Herfindahl-Hirschman Index. Dependent Variable = Δ Drivers' Championship Decision Point (% of races).
[a]1% significance level. [b]0.1% significance level.

factory (F1 Racing, 1997b). Similarly, profits of US$28.6 million and US$27.5 million recorded in 2000 and 2001, respectively, underwrote the construction of a US$44 million wind tunnel facility (F1 Racing, 2002b). Given such examples, it is not unreasonable to conclude that F1 teams—at least prior to the introduction of the RRA—behaved in a points-maximizing manner.

Econometric Analysis of Competitive Balance

The results of the uncertainty of championship outcome OLS regressions are presented in Tables D1 and D2 in Appendix D. Two models are presented, as revisions were necessary to verify the statistical and practical significance of the competitive balance dummy variable and address the relatively modest R^2 value associated with the initial model. To achieve this, the dependent variable in the revised model (Table 5) is defined as the change in the Drivers' Championship decision point between successive seasons and a lag of the initial dependent variable is included to correct for autocorrelation.

In addition to the competitive balance dummy retaining its statistical and practical significance, it is noted that no changes in the sign or significance associated with any other explanatory variables were observed as a result of the change in specification of the OLS model.

The results of the regression indicate that the implementation of competitive balance regulation change contributes to the Drivers' Championship being decided 6.9% later in the season, after taking into account changes in relative driver competitiveness. Referenced to an average championship decision point of 91.5% of the

Table 6. Ordinary Least Squares (OLS) Regression Model.

Variable	Coefficient (*t*-Statistic)	*p* Value (Significance)
Constant	6.711 (6.580)	.0000
Competitive Balance Dummy	−0.088 (−0.250)	.8040
Monza Dummy	−0.355(−0.596)	.5537
Points System HHI Ratio	−1.113 (−0.967)	.3382
Race Time Dummy	0.428 (2.592)	.0125[a]
Refueling Dummy	1.065 (4.615)	.0000[c]
Tire War Dummy	−0.004 (−0.014)	.9889
Unreliability (%)	−0.013 (−0.488)	.6274
Wet Races (%)	−0.005 (−0.258)	.7971
Wings Dummy	−2.657 (−5.385)	.0000[c]
Monza Dummy × Wings Dummy	2.658 (3.459)	.0011[b]
Adjusted R^2	.437	
Durbin-Watson Statistic	2.207	
Sample	1950-2010	

Note. Adapted from Authors' Calculations. HHI = Herfindahl-Hirschman Index. Dependent Variable = Average Race Lead Changes.
[a]5% significance level. [b]1% significance level. [c]0.1% significance level.

season between 1950 and 2010, this result is practically significant, as it implies that the championship is decided on an average of between one and two races later based on the maximum of 20 Grands Prix permitted under the current regulations. That competitive balance regulation change is significant at the 1% level in a model with an adjusted R^2 of 58.6% supports Mastromarco and Runkel's (2009) conclusion that regulation change contributes to increased uncertainty of championship outcome. However, in this case, the measure is more practically significant, given the previously detailed relationship between the championship decision point, television broadcasting revenues, and sponsor exposure.

The results of the uncertainty of race outcome OLS regression are presented in Table 6 (refer also to Table D3 in Appendix D). Multiple unsuccessful attempts were made to remove the heteroscedasticity in the residuals, including the use of weighted and generalized least squares techniques. In order to rectify this issue, White's (1980) heteroscedastic consistent covariance matrix estimation procedure was employed.

It is evident that competitive balance regulation change is statistically and practically insignificant in this model. Indeed, the results indicate that lead changes are to a greater extent dependent on (i) the frequency of pit stops, as the refueling dummy is significant at the 0.1% level and indicates that an average of 1.07 more lead changes per race have occurred when refueling has been permitted, (ii) aerodynamics, as the wings dummy is significant at the 1% level and suggests that there have been an average of 2.66 fewer lead changes, since F1 cars have sported wings, and (iii) circuit characteristics, given that the interaction term is significant at the 1% level and implies that even after the advent of wings, the oval-like nature of the

Table 7. Binary Probit Regression Model [Dependent Variable = Probability of Back to Back Drivers' World Champion].

Variable	Coefficient (z-Statistic)	*p*-Value (Significance)	Marginal Effects (Evaluated at Means)
Constant	−8.454 (−1.852)	.0640[a]	
All Points Count Dummy	6.975 (3.074)	.0021[c]	0.393
Competitive Balance Dummy	−0.961 (−1.248)	.2121	−0.054
Manufacturer Representation (%)	0.039 (2.847)	.0183[b]	0.002
Points System HHI Ratio	−7.899 (−2.096)	.0361[b]	−0.445
Tire War Dummy	1.469 (1.379)	.1679	0.083
Unreliability (%)	0.349 (2.847)	.0044[c]	0.020
Wet Races (%)	−0.115 (−2.191)	.0285[b]	−0.006
Observations with Dep. Var. = 1	14		
Observations with Dep. Var. = 0	41		
Model Correct Evaluation	85.45%		
Sample	1951-2010 (except 1959, 1971, 1974, 1993, 1994)		

Note. Adapted from Authors' Calculations. HHI = Herfindahl-Hirschman Index. Dependent Variable = Average Race Lead Changes.
[a]10% significance level. [b]5% significance level. [c]1% significance level.

Monza circuit completely offset the negative effect of aerodynamics at all other circuits. This result is consistent with aerodynamic wings enhancing the slipstream effect, which paradoxically assists overtaking on oval courses.

It is noted, however, that the maximum race time dummy is positive and significant at the 5% level, contrary to the expectation that the introduction of a 2-hr race time limit would reduce the average number of lead changes. This suggests that there is some uncertainty in the model, reflected in the relatively modest adjusted R^2 of 43.7%. Thus, although competitive balance regulation change appears to have no discernible effect on uncertainty of race outcome, such a conclusion must necessarily be made with caution.

Finally, the results of the binary probit regression are presented in Table 7. Again, competitive balance regulation change appears to be statistically and practically insignificant, in this case with respect to the probability of a driver becoming a back-to-back world champion. Given a successful evaluation "strike rate" of 85.5%, the model indicates that this outcome depends to a greater extent on (i) whether all points count toward the championship, the positive coefficient consistent with the intuitive concept that champions are consistent drivers; (ii) the nature of the points system, the negative coefficient also supporting the notion that a champion driver benefits from a flatter points distribution which places a higher premium on consistency; (iii) the proportion of manufacturer teams, the positive coefficient indicating that big budget manufacturers have been better able to provide a championship-contending car in consecutive seasons; (iv) unreliability, the negative coefficient suggesting that nonclassifications have traditionally been concentrated

Table 8. OLS Regression Data: Performance Versus Budget.

Team Type	Budget (2000-2006, Average)	Points Percentage (Average)
Manufacturer	US$333.67m	14.35%
Independent	US$183.88m	6.25%

Note. Adapted from Authors' Calculations.

among teams and drivers taking risks to challenge the champion team and driver who in turn are less likely to make race-ending errors; and (v) weather, the negative coefficient reflecting the often unpredictable outcome of wet races.

Coupled with Mastromarco and Runkel's (2009) observation that the FIA has tended to implement competitive balance regulation change after particularly unbalanced seasons, the preceding analysis is consistent with Krauskopf et al.'s (2010) discussion on the importance of preserving absolute quality. In other words, competitive balance regulation changes are ostensibly introduced to promote a season-long contest without compromising the quality of drivers contesting the championship thereby maximizing television broadcast revenues and gross sponsor exposure. It is this implied "desired" outcome that will guide the analysis of the competitive balance implications of the RRA.

The Resource Restriction Agreement: Theoretical Analysis

To establish an initial equilibrium, team budget data for 2000-2006—an era in which all championships were won by manufacturer teams (Ferrari from 2000-2004, Renault from 2005-2006)—revealed that the average independent team budget was US$184 million, while the average manufacturer team budget was US$334 million (both expressed in 2006 USD). Substituting these values into a regression of points percentage on budget (Appendix D) yielded the average independent and manufacturer team scoring 6.25% and 14.35% of the available points, respectively (Table 8).

Hence, a baseline has been established from which to evaluate the implications of the RRA, a mechanism that will progressively reduce the maximum expenditure—and talent accumulation capacity—of large revenue teams. On this theme, Mercedes-Benz is spending 65% less in 2011 than it was in 2006 as a consequence of the RRA (Autosport, 2011a). The competitive balance implications of the RRA will ultimately depend on the value of the maximum budget permitted. In the limiting case of the maximum budget being affordable to the smallest revenue team, the payroll imbalance between manufacturer and independent teams is eliminated, thereby yielding equal points percentage distribution, and implying increased uncertainty of championship outcome.

Improvements in the terms of distribution of the commercial rights revenues—which from US$341 million in 1998 had reached US$1.5 billion in 2010—may contribute toward the realization of this outcome (Allen, 2011b; F1 Racing, 1999).

Recent amendments saw the teams' share rise to US$658 million in 2010; an average of US$54 million each, with world champions Red Bull receiving US$87 million. Forecasted ongoing growth in the value of the commercial rights highlights the potential for convergence between minimum team budgets and the maximum RRA-permitted expenditure (Allen, 2011c; Hotten, 2011).

However, the implications of this outcome require careful consideration. In particular, a progressively reducing maximum budget is necessarily associated with a concurrent reduction in the price of talent. This raises the prospect of a reduction in absolute quality as a consequence. To elaborate, drivers would face stronger incentives to move to categories such as NASCAR, in which drivers derive a substantial proportion of their income from prize money and endorsements. Given the importance of absolute quality to F1's credibility, this issue is clearly worthy of further consideration.

A related issue can be implied from Solitander and Solitander's (2010) observation that only about 5% of the thousands of components comprising an F1 car carry over from one year to the next. That is, the equal points percentage distribution is predicated on the annual expenditure of each team being allocated to their efforts for that season alone, and of teams who have a poor start to a season not diverting their resources mid-year to their car for the following campaign (as is currently the case), which could yield an advantage over teams who continue to develop their current car. This raises the prospect of increased turnover of championship contending teams between the seasons. The implications for absolute quality would be compounded if teams no longer have the financial capacity to buy out driver contracts, creating an environment in which it would be less certain that the best drivers would contest the championship in consecutive years.

A final issue necessarily relates to that of policing expenditure, given (i) the relationship between budget and performance and (ii) that fan interest turns on the "assumption that the contest is an above-board display" (Sanderson, 2002, p. 214). In addition to the implementation of an independently devised audit methodology, powerful deterrents relate to precedent (Allen, 2009). For example, McLaren was disqualified from the 2007 Constructors' Championship and fined US$100 million for possessing Ferrari's intellectual property. And in 2009, negative publicity led to major sponsors terminating their contracts with Renault after it was revealed that team management had conspired to fix the result of the 2008 Singapore Grand Prix by instructing one driver to crash his car to enable his team mate to win (Henderson et al., 2010). It is not unreasonable to assume that such examples will (in part) contribute to deterring systematic breaches of the RRA.

Limitations of Study

The major limitation of the two-team model is that in reality points percentage is a function not only of talent, thus there is inherent uncertainty associated with the preceding analysis (Késenne, 2007). Moreover, while it was concluded that on average

Table 9. F1 Relative Competitiveness Statistics.

	2010/2011[a]	1950-2010 Average
Win % HHI Ratio (Driver)	4.158/5.489	4.027
Adjusted Points % HHI Ratio (Driver)	2.466/3.047	2.087
Championship Decision Point (Driver)	100/78.9	91.5
Average Number of Race Lead Changes	2.16/5.13	3.12

Note. Adapted from Authors' Calculations. HHI = Herfindahl-Hirschman Index.
[a]As at conclusion of 2011 Japanese Grand Prix (October 10, 2011).

independent and manufacturer teams would have equal probabilities of winning the championship, there are no mechanisms to prevent certain teams dominating particular seasons. Indeed, 2011—the first complete season subject to the RRA (i.e. as 2010 F1 cars were designed using resources from pre-RRA 2009)—saw the Drivers' Championship decided after 15 (78.9%) of the 19 races and greater imbalance in relation to the distribution of both points and wins (Table 9). Importantly, absolute quality was preserved, with 2011 crowning the first back-to-back world champion since 2006 (and notably, the first for an independent team since 1999). However, with an average of 5.15 lead changes per Grand Prix, uncertainty of race outcome appreciably increased. Hence, it is probable that only the passage of time will reveal the ultimate competitive balance implications of the RRA.

Another limitation of this study is that it does not explore the possibility of changes in team behavior. In March 2011, 23.39% of the independent Williams team was floated on the Frankfurt Stock Exchange, raising the possibility of an F1 team for the first time behaving as a profit maximizer (Allen, 2011a). Although Késenne (2002, p. 184) notes that such teams may elect to maximize their points percentage subject to a "constraint of a given profit rate to satisfy their shareholders," this issue is clearly worthy of further investigation, raising as it does the possibility of a contest between not only independent and manufacturer teams but also profit- and points-maximizing independents.

Conclusions

Having established that Formula 1 teams behave in a manner consistent with points maximization, an econometric analysis of competitive balance in F1 was undertaken. This identified the key roles uncertainty of championship outcome and absolute quality play with respect to the introduction of competitive balance regulation change. The desire to maximize the value of the commercial broadcast rights and gross sponsor exposure were also considered, bringing together several interrelated elements of the existing literature. It was then determined that the introduction of the RRA has the potential to promote a more balanced contest between F1's independent and manufacturer teams. Although this outcome is necessarily predicated on reality conforming to a framework of highly restrictive assumptions, a range of associated issues were nevertheless identified and discussed, culminating in the proposal of several avenues for future research in this field.

Appendix A

Competitive Balance Regulation Changes

Table A1. F1 Competitive Balance Regulation Changes.

Year	Nature of Regulation Change
1952	Accommodation of cars conforming to Formula 2 regulations
1958	Formula 1 cars to be run on commercially available fuels only
1961	Introduction of minimum dry car weight (450 kg)
1978	Movable aerodynamic devices banned
1981	Twin-chassis banned
1982	Gas turbine engines banned
	Rotary engines banned
1983	Six-wheel cars banned
	Four wheel drive banned
1984	Maximum (race) fuel allowance capped at 220 L
1986	Maximum (race) fuel allowance reduced to 195 L
1987	Maximum boost of turbocharged engines limited to 4.0 bar
1988	Maximum boost of turbocharged engines limited to 2.5 bar
	Maximum (race) fuel allowance of turbocharged cars reduced to 155 L
1989	Turbocharged engines banned
1993	Formula 1 cars to run on “pump” fuel only, policed using a “fingerprint” system
	Continuously variable transmission (CVT) banned
1994	Launch control banned
	Traction control banned
1996	107% qualifying regulation introduced
1998	Torque-steer systems banned
2001	Beryllium alloys banned
2003	Team orders banned
	Single-lap qualifying system introduced
	Parc-ferme conditions now apply between qualifying and the race
	Tire suppliers permitted to customize Tires for each team
2006	Engine configuration standardized: 2.4 L 90° V8 weighing no less than 95kg
2007	Engine specification frozen as at conclusion of 2006 championship season
	Annual per-team testing limit of 30,000 km introduced
2008	Standard electronic control unit introduced (ECU)
	Traction control banned
	Restrictions on aerodynamic testing (circuit and wind-tunnel) limited
2010	In-season testing banned
	Resource Restriction Agreement enforced

Appendix B

Formula One Statistics: 1950-2011

Table B1. Summarized Formula 1 Competitive Balance Statistics.

	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010/2011[a]	Avg
Number of world champions (D)	5	7	7	6	7	5	1	-
Number of world champions (C)[b]	5	7	3	3	4	3	1	-
Championship distribution (D)	5-2-1-1-1	2-2-2-1-1-1-1	2-2-2-1-1-1-1	3-3-1-1-1-1	2-2-2-1-1-1-1	5-2-1-1-1	2	-
Championship distribution (C)[b]	5-2-1-1-1	2-2-2-1-1-1-1	6-3-1	4-4-2	5-3-1-1	7-2-1	2	-
Championship decided (D)[c]	87.1/89.0	91.8/90.1	87.0/92.3	100.0/93.8	88.8/97.7	82.6/96.7	100.0/78.9	91.5
Number Lead changes[c]	3.77/3.95	4.30/3.84	2.66/2.02	2.22/2.31	2.08/2.90	3.73/4.60	2.16/5.13	3.12
Number back to back	4	1	0	1	3	5	0/1	-
Win % HHI ratio (D)[c]	3.664/2.567	3.082/3.257	3.305/3.214	2.912/4.300	5.375/5.240	6.664/4.713	4.158/5.489	4.027
Win % HHI ratio (C)[c]	4.396/2.488	3.121/2.611	3.112/3.936	4.190/7.071	6.049/5.074	5.781/4.414	4.353/5.703	4.354
Adjusted[d] points % HHI ratio (D)[c]	3.160/2.049	2.133/1.571	1.885/1.835	1.757/2.219	2.396/1.814	2.116/2.033	2.466/3.047	2.087
Adjusted[d] points % HHI ratio (C)[c]	1.634/1.024	1.102/0.972	1.101/1.458	1.519/2.049	2.007/1.559	1.910/1.920	2.259/2.765	1.533

Note. Adapted from Authors' Calculations. Avg = average; D = Driver; C = Constructor; HHI = Herfindahl-Hirschman Index.
[a]2011 data correct as a conclusion of Japanese Grand Prix (October 10, 2011). [b]Constructors' Championship first awarded in 1958. Results for 1950-1957 implied from championship standings. [c]Presented as averages per half-decade (e.g., in form 1950-1954 (average)/1955-1959 (average)). [d]Adjusted for changes in the points system structure by dividing by the relevant ratio from Appendix C.

Appendix C

Points System Comparison Table

Table C1. Comparison of Points Systems Using Herfindahl-Hirschman Index Ratio (Authors' Calculations).

Position[a]\Era	'50-'59	%	'60	%	'61-'90	%	'91-'02	%	'03-'09	%	'10-'11	%
First	8	34.78	8	33.33	9	36	10	38.46	10	25.64	25	24.75
Second	6	26.09	6	25.00	6	24	6	23.08	8	20.51	18	17.82
Third	4	17.39	4	16.67	4	16	4	15.38	6	15.38	15	14.85
Fourth	3	13.04	3	12.50	3	12	3	11.54	5	12.82	12	11.88
Fifth	2	8.70	2	8.33	2	8	2	7.69	4	10.26	10	9.90
Sixth	0	0	1	4.17	1	4	1	3.85	3	7.69	8	7.92
Seventh	0	0	0	0	0	0	0	0	2	5.13	6	5.94
Eighth	0	0	0	0	0	0	0	0	1	2.56	4	3.96
Ninth	0	0	0	0	0	0	0	0	0	0	2	1.98
Tenth	0	0	0	0	0	0	0	0	0	0	1	0.99
Other	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23	100	24	100	25	100	26	100	39	100	101	100
Points % HHI		2438.6		2256.9		2352.0		2455.6		1676.5		1508.7
Ratio[b]		1.616		1.496		1.559		1.628		1.111		1.000

Note. Adapted from Authors' Calculations. Points systems adapted from Hughes (2004). HHI = Herfindahl-Hirschman Index.
[a]Half points awarded for races in which less than 75% of the intended laps completed. [b]Referenced to 2010/2011 points system.

Appendix D
Econometric Models

Uncertainty of Championship Outcome

Table D1. OLS Regression Output: Championship Uncertainty (Model A).

Variable	Coefficient	Std. Error	*t*-Statistic	*p* Value
Constant	116.603	13.710	8.505	.0000
All Points Count Dummy	5.379	4.332	1.242	.2199
Competitive Balance Dummy	6.673	2.544	2.623	.0114
Manufacturer Representation (%)	−0.067	0.055	−1.215	.2298
Points System HHI Ratio	−10.489	12.844	−0.817	.4178
Tire War Dummy	−1.363	3.389	−0.402	.6893
Unreliability (%)	0.088	0.259	0.340	0.7355
Wet Races (%)	−0.023	0.113	−0.201	.8414
Win HHI Ratio (D)	−3.526	0.894	−3.943	.0002
R^2	.352082	Mean/*SD* dependent var		91.5/10.2
Adjusted R^2	.252402	Durbin-Watson stat		1.992081

Note. dependent var = dependent variable; HHI = Herfindahl-Hirschman Index; OLS = ordinary least squares; Std. Error = standard error; *SD* = standard deviation. Dependent Variable: Drivers' Champ. Decided (%), 1950-2010, OLS.

Table D2. OLS Regression Output: Championship Uncertainty (Model B).

Variable	Coefficient	Std. Error	*t*-Statistic	*p* Value
Constant	108.002	17.866	6.045	.0000
All Points Count Dummy	5.683	4.314	1.317	.1938
Competitive Balance Dummy	6.938	2.518	2.755	.0082
Manufacturer Representation (%)	−0.086	0.058	−1.501	.1397
Points System HHI Ratio	−10.460	12.682	−0.825	.4134
Tire War Dummy	−0.619	3.386	−0.183	.8558
Unreliability (%)	0.066	0.257	0.257	.7980
Wet Races (%)	−0.027	0.114	−0.235	.8155
Win HHI Ratio (D)	−3.538	0.884	−4.004	.0002
Drivers' Champ. Decided (−1; %)	−0.900	0.117	−7.719	.0000
R^2	.649040	Mean/SD dependent var		.0/13.6
Adjusted R^2	.585867	Durbin-Watson stat		2.246135

Note. dependent var = dependent variable; HHI = Herfindahl-Hirschman Index; OLS = ordinary least squares; Std. Error = standard error; *SD* = standard deviation. Dependent Variable: Δ Drivers' Champ. Decided (%), 1951-2010, OLS.

Uncertainty of Race Outcome

Table D3. OLS Regression Output: Race Uncertainty.

Variable	Coefficient	Std. Error	*t*-Statistic	p Value
Constant	6.711	1.020	6.580	.0000
Competitive Balance Dummy	−0.088	0.354	−0.250	.8040
Monza Dummy	−0.355	0.596	−0.596	.5537
Points System HHI Ratio	−1.113	1.151	−0.967	.3382
Race Time Dummy	0.428	0.165	2.592	.0125
Refueling Dummy	1.065	0.231	4.615	.0000
Tire War Dummy	−0.004	0.260	−0.014	.9889
Unreliability (%)	−0.013	0.027	−0.488	.6274
Wet Races (%)	−0.005	0.019	−0.258	.7971
Wings Dummy	−2.657	0.493	−5.385	.0000
Monza Dummy × Wings Dummy	2.658	0.769	3.459	.0011
R^2	.531136	Mean/SD dependent var		3.12/1.23
Adjusted R^2	.437363	Durbin-Watson stat		2.207732

Note. dependent var = dependent variable; HHI = Herfindahl-Hirschman Index; OLS = ordinary least squares; Std. Error = standard error; *SD* = standard deviation. Dependent Variable: # Race Lead Changes (average), 1950-2010, OLS. White Heteroscedasticity-Consistent standard errors and covariance.

Long-Term Dominance

Table D4. Binary Probit Regression Output.

Variable	Coefficient	Std. Error	*z*-Statistic	*p* Value
Constant	−8.454	4.565	−1.852	0.0640
All Points Count Dummy	6.975	2.269	3.074	0.0021
Competitive Balance Dummy	−0.961	0.770	−1.248	0.2121
Manufacturer Representation (%)	0.039	0.016	2.360	0.0183
Points System HHI Ratio	−7.899	3.768	−2.096	0.0361
Tire War Dummy	1.469	1.065	1.379	0.1679
Unreliability (%)	0.349	0.123	2.847	0.0044
Wet Races (%)	−0.115	0.053	−2.191	0.0285
Obs with Dep = 0	41	Total obs		55
Obs with Dep = 1	14			

Note. Adapted from Authors' Calculations. Dep = dependent; HHI = Herfindahl-Hirschman Index; Obs = observation; Std. Error = standard error. Dependent Variable: back-to-back champion, binary probit, defending champ = 1.

Table D5. Binary Probit Regression Evaluation Table.

	Prediction Evaluation (success cutoff C = 0.5)					
	Estimated Equation			Constant Probability		
	Dep = 0	Dep = 1	Total	Dep = 0	Dep = 1	Total
P(Dep = 1) ≤C	37	4	41	41	14	55
P(Dep = 1) > C	4	10	14	0	0	0
Total	41	14	55	41	14	55
Correct	37	10	47	41	0	41
% Correct	90.24	71.43	85.45	100.00	0.00	74.55
% Incorrect	9.76	28.57	14.55	0.00	100.00	25.45
Total Gain[a]	−9.76	71.43	10.91			
Percentage Gain[b]	NA	71.43	42.86			

Note. Adapted from Authors' Calculations. Dep = dependent; NA = not available.
[a]Change in "% Correct" from default (constant probability) specification. [b]Percentage of incorrect (default) prediction corrected by equation.

Financial Analysis

Table D6. OLS Regression: Points Percentage Versus Budget.

Variable	Coefficient	Std. Error	*t*-Statistic	*p* Value
Constant	−3.685	1.404	−2.624	.0106
Budget ($m)	0.054	0.008	6.601	.0000
R^2	.436811	Adjusted R^2		.428879

Note. Std. Error = standard error; OLS= =ordinary least squares. Dependent variable: points %, 73 observations. White Heteroscedasticity-Consistent standard errors and covariance.

Table D7. OLS Regression: Team Budget Versus Team Type.

Variable	Coefficient	Std. Error	*t*-Statistic	*p* Value
Constant	183.879	18.004	10.213	.0000
Manufacturer Dummy	149.795	28.085	5.334	.0000
R^2	.286059	Adjusted R^2		.276003

Note. Std. Error = standard error; OLS= =ordinary least squares. Dependent Variable: budget ($m), 73 observations.

Authors' Note

This article was presented at the 87th Annual Conference of the Western Economic Association International, San Francisco, California, June 29–July 3, 2012.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

Alexander, D. L., & Kern, W. (2004). The economic determinants of professional sports franchise values. *Journal of Sports Economics*, *5*, 51–66.

Allen, J. (2009). On F1 – 2009: A revolutionary year (pp. 18, 23, 26–29, 32–34, 38–39, 46–47, 62, 74–76, 105–106, 110, 117–118, 122, 129, 138–139, 154, 160–162, 166–167, 187–188, 196–197, 237–239). Chippenham, England: Wiltshire Speed Merchants.

Allen, J. (2010). On F1 – 2010: Five rivals, one champion (pp. 50, 90, 100–107, 122, 140–147, 158–159, 177–179, 192, 200–205). Chippenham, England: Wiltshire Speed Merchants.

Allen. (2011a). Retrieved March 02 2011, from http://www.jamesallenonf1.com/2011/03/williams-gets-its-flotation-away-shares-fully-subscribed/

Allen. (2011b). Retrieved June 05 2011, from http://www.jamesallenonf1.com/2011/06/bahrain-not-the-only-flashpoint-for-formula-1-teams/

Allen. (2011c). Retrieved April 06 2011, from http://www.jamesallenonf1.com/2011/04/f1-turnover-tops-1-billion-again-as-teams-share-rises/

Autosport. (2011a). Retrieved March 12 2011, from http://live.autosport.com/commentary.php/id/314

Autosport. (2011b). Retrieved January 22 2011, from http://www.autosport.com/news/report.php/id/89033

Bekker, J., & Lotz, W. (2009). Planning formula one race strategies using discrete-event simulation. *Journal of the Operational Research Society*, *60*, 952–961.

Benson. (2011). Retrieved April 21 2011, from http://www.bbc.co.uk/blogs/andrewbenson/2011/04/will_f1_go_pay-per-view.html

Berkowitz, J., Depken, C. A., & Wilson, D. P. (2011). When going in circles is going backward: Outcome uncertainty in NASCAR. *Journal of Sports Economics*, *12*, 253–283.

Booth, R. (2000). *Labour market intervention, revenue sharing and competitive balance in the victorian football league, 1897-1998*. (Unpublished PhD). Monash University, Melbourne.

Budzinski, O., & Feddersen, A. (2011). Measuring competitive balance in Formula One racing (IME Working Paper), University of Southern Denmark, Esbjerg, Denmark.

Cain, L. P., & Haddock, D. D. (2006). Research notes: Measuring parity: Tying into the idealized standard deviation. *Journal of Sports Economics*, *7*, 330–338.

Crooker, J. R., & Fenn, A. J. (2007). Sports leagues and parity when league parity generates fan enthusiasm. *Journal of Sports Economics*, *8*, 139–164.

Cygan, A. (2007). Are all sports special? Legal issues in the regulation of formula one motor racing. *European Business Law Review*, *18*, 1327–1351.

Dawson, A., & Downward, P. (2005). Measuring short-run uncertainty of outcome in sporting leagues: A comment. *Journal of Sports Economics*, *6*, 303–313.

Donahay, B., & Rosenberger, P. J. (2007). Using brand personality to measure the effectiveness of image transfer in formula one. *Marketing Bulletin*, *18*, 1–15.

F1 Racing. (1997a). *F1 Racing Magazine*, April, 30–34.

F1 Racing. (1997b). *F1 Racing Magazine*, May, 45–58.

F1 Racing. (1999). *F1 Racing Magazine*, July, 88.

F1 Racing. (2000). *F1 Racing Magazine*, May, 26.

F1 Racing. (2002a). *F1 Racing Magazine*, April, 26–28.

F1 Racing. (2002b). *F1 Racing Magazine*, December, 24–37.

F1 Racing. (2003a). *F1 Racing Magazine*, March, 22.

F1 Racing. (2003b). *F1 Racing Magazine*, September, 62–72, 87.

F1 Racing. (2003c). *F1 Racing Magazine*, June, 24.

F1 Racing. (2004). *F1 Racing Magazine*, April, 64–72.

F1 Racing. (2005). *F1 Racing Magazine*, February, 82.

F1 Racing. (2006a). *F1 Racing Magazine*, June, 22.

F1 Racing. (2006b). *F1 Racing Magazine*, July, 25.

F1 Racing. (2006c). *F1 Racing Magazine*, September, 25.

F1 Racing. (2006d). *F1 Racing Magazine*, March, 106.

F1 Racing. (2009a). *F1 Racing Magazine*, February, 37.

F1 Racing. (2009b). *F1 Racing Magazine*, May, 34–36.

Fort, R. (2006). *Sports economics* (2nd ed., pp. 3, 15–22). Upper Saddle River, NJ: Pearson Prentice Hall.

Fort, R., & Quirk, J. (2004). Owner objectives and competitive balance. *Journal of Sports Economics*, *5*, 20–32.

Griffiths, T. R. (1997). *Grand prix* (3rd ed.). London, England: Bloomsbury.

Hall, S., Szymanski, S., & Zimbalist, A. S. (2002). Testing causality between team performance and payroll: The cases of major league Baseball and English Soccer. *Journal of Sports Economics*, *3*, 149–168.

Henderson, J. C., Foo, K., Lim, H., & Yip, S. (2010). Sports events and tourism: The Singapore formula one grand prix. *International Journal of Event and Festival Management*, *1*, 60–73.

Henry, A. (1998). *Williams formula 1 racing team* (pp. 50, 68, 79–89). Newbury Park, CA: Haynes.

Henry, A. (2003). *The powerbrokers* (pp. 20–26). Osceola, WI: Motorbooks International.

Hotten, R. (2011). Formula 1 makes bumper profits as bid rumours continue. Retrieved May 18, 2011, from http://www.bbc.co.uk/news/business-13438913

Hughes, M. (2004). *The unofficial formula one history* (p. 14). London, England: Anness.

Jenkins, M. (2010). Technological discontinuities and competitive advantage: A historical perspective on formula 1 motor racing 1950-2006. *Journal of Management Studies*, *47*, 884–908.

Jenkins, M., & Floyd, S. (2001). Trajectories in the evolution of technology: A multi-level study of competition in formula 1 racing. *Organization Studies*, *22*, 945–969.

Késenne, S. (2000). Revenue sharing and competitive balance in professional team sports. *Journal of Sports Economics*, *1*, 56–65.

Késenne, S. (2001). The different impact of different revenue sharing systems on the competitive balance in professional team sports. *European Sport Management Quarterly*, *1*, 210–218.

Késenne, S. (2002). The monopsonistic player labour market in a win-maximising league. *European Sport Management Quarterly*, *2*, 180–187.

Késenne, S. (2007). Does a win bonus help to increase profit or wins in professional team sports? *International Journal of Sport Finance*, *2*, 142–148.

Kipker, I. (2003). *Determinanten der TV-Nachfrage in der Formel 1 - Superstar- vs. Spannungseffekte und Implikationen für die Wettbewerbspolitik*, 85–103. In Dietl, Helmut (ed.), Globalisierung des wirtschaftlichen Wettbewerbs im Sport. Schorndorf: Verlag Karl Hofmann.

Krauskopf, T., Martin, L., & Bünger, B. (2010). *The Search for Optimal Competitive Balance in Formula One* (CAWM Discussion Paper), University of Münster, Münster, Germany, *38*, 1–15.

Leeds, M., & von Allmen, P. (2008). *The economics of sports* (3rd ed., p.151). Boston, MA: Pearson Addison Wesley.

Mastromarco, C., & Runkel, M. (2009). Rule changes and competitive balance in Formula One motor racing. *Applied Economics*, *41*, 3003–3014.

Quirk, J., & Fort, R. (1992). *Pay dirt: The business of professional team sports* (p. 243). Princeton, NJ: Princeton University Press.

Rottenberg, S. (1956). The baseball players labour market. *Journal of Political Economy*, *64*, 242–258.

Sanderson, A. R. (2002). The many dimensions of competitive balance. *Journal of Sports Economics*, *3*, 204–228.

Sanderson, A. R., & Siegfried, J. J. (2003). Thinking about competitive balance *Journal of Sports Economics*, *4*, 255–279.

Sloane, P. (1971). The economics of professional football: the football club as a utility maximiser. *Scottish Journal of Political Economy*, *17*, 121–146.

Solitander, M., & Solitander, N. (2010). The sharing, protection and thievery of intellectual assets: The case of the Formula 1 industry. *Management Decision*, *48*, 37–57.

Sylt, C., & Reid, C. (2011). Retrieved May 30 2011, from http://www.independent.co.uk/news/business/news/cost-of-red-bulls-f1-dominance-tops-163420m-2290900.html

Szymanski, S. (2003). Incentives and competitive balance in team sports. *European Sport Management Quarterly*, *3*, 11–30.

Von Allmen, P. (2001). Is the reward system in NASCAR efficient? *Journal of Sports Economics*, *2*, 62–79.

Vrooman, J. (2009). Theory of the Perfect Game: Competitive Balance in Monopoly Sports Leagues, *Review of Industrial Organization*, *34*, 5–44.
White, H. (1980). A heteroskedasticity-consistent covariance matrix and a direct test for heteroskedasticity. *Econometrica*, *48*, 817–838.

Author Biographies

Chris Judde graduated from Monash University in Melbourne Australia, with both a Bachelor of Commerce/Bachelor of Aerospace Engineering double degree, and a Bachelor of Economics Honours degree. Chris was included on the Faculty of Engineering Dean's Honours List and awarded the Institution Project Award from the Institution of Mechanical Engineers for completing the most outstanding final year research project. For his Economics Honours degree Chris was awarded a University Medal for Undergraduate Academic Excellence and included on the Faculty of Business and Economics Dean's Honours List.

Ross Booth is a Senior Lecturer in the Department of Economics at Monash University in Melbourne, Australia. His main research interest is the economics of professional team sports leagues, especially the Australian Football League. His research has been published in international books *International Sports Economics Comparisons, the Edward Elgar Handbook on the Economics of Sports, Violence and Aggression in Sporting Contests: Economics, History, and Policy and forthcoming in Economics of Sports Leagues: An International Perspective, and in The Games are not the Same: The Political Economy of Football in Australia; as well as journal articles in Australian Economic Review, Economic and Labour Relations Review, Economic Papers, Journal of Sports Economics, Labour and Industry, and Sport Management Review*.

Robert Brooks is Associate Dean (Undergraduate) in the Faculty of Business and Economics and Professor in the Department of Econometrics and Business Statistics, Monash University. His main research interest is in applied econometric modelling of a broad range of financial and economic data, including data of relevance to sports economics. Previous research includes an analysis of test cricket strategy and performance published in *Applied Economics*, and an analysis of stock market reaction to the Sydney Olympic Games announcement published in *Applied Economics Letters*.