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Critical analysis of competitive balance in Formula 1 motor racing. Does budget concentration affect teams' performance?

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Abstract

In this master's thesis an analysis of the competitive balance in Formula 1 between 2010 and 2021 is attempted. Although F1 represents one of the biggest sports industries in business terms, it is analysed only by little empirical research. Competitive balance directly influences the uncertainty of outcome and therefore, represents one of the main factors for sport attractiveness. The aim of this study is double: firstly, it contributes to the sports economics literature with an analysis of trends and variations in competitive balance (and its dimensions) for both the World Driver Championship and the World Constructor Championship; secondly, it empirically investigates the relationship between teams' budget and teams' performance. Results show that within-race competitive balance is reducing, meaning that F1 races are more and more predictable, and thus less interesting. Even though a slight improvement in within and inter-season competitive balance has been measured (using the Gini coefficient for points distribution), the competition remains very unbalanced. Eventually, the positive correlation between budget concentration and points concentration suggests that the more unbalanced the budget distribution, the more unbalanced the competition. Thus, this study provides scientific evidence that wealth distribution among F1 teams has indubitably an impact on the competitive balance of the league.

Keywords: sports economics, competitive balance, sports attractiveness, Formula 1, motorsport, budget concentration.

List of abbreviations

F1	Formula One
FIA	Fédération Internationale de l'Automobile
FISA	Federation Internationale du Sport Automobile
FOCA	Formula One Constructors Association
FOM	Formula One Management
GP	Grand Prix
HHI	Herfindahl-Hirschman Index
MLB	Major League Baseball
MLS	Major League Soccer
NASCAR	National Association for Stock Car Auto Racing
NBA	National Basketball Association
NFL	National Football League
NHL	National Hockey League
RRA	Resource Restriction Agreement
WCC	World Constructor Championship
WDC	World Driver Championship

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1. Introduction

Since its inception in 1950, the FIA Formula One World Championship has evolved into a global sports brand and represents nowadays one of the greatest sports events in the world, attracting millions of fans globally each Grand Prix. At present, Formula 1 is indeed a multi-billion-dollar industry in business terms, reporting annual revenues of $2.14 billion for 2021 (Collantine, 2022; Sportspromedia, 2022). F1, which takes its name from the set of regulations annually published by the FIA, is the highest single-seater category of motor racing, reason why it is considered the pinnacle of motorsport.

Formula 1 is a peculiar form of sports competition because of its hybrid form combining both individual and team sports aspects (Krauskopf, 2010; Judde et al., 2013). F1 racing can be full-fledged considered a closed league indeed, including the F1 World Driver Championship (WDC) and the F1 World Constructor Championship (WCC). Participating teams in F1 are called constructors and are composed of two main drivers. What is also unique about F1 is its nature characterised by the human sporting endeavour, team spirit, and technological excellence. However, despite its importance, only little literature in the academic community examines this sport.

One of the most relevant contributions to sports economic literature is the uncertainty of outcome hypothesis. Proposed by Rottenberg in 1956 and present in Neale's (1964) masterwork, it postulates that sports fans are more interested in competition with an unpredictable outcome. From this theory derives the crucial concept of competitive balance, which is one of the main factors for sports attractiveness. An unbalanced contest would indeed eventually 'cause fan interest to wane and industry revenue to fall' (Kesenne, 2000, p.56). Since sports enthusiasts are favourable to uncertainty of both race and championship outcome, a major goal of well-designed leagues is to produce adequate competitive balance. Nevertheless, although achieving a measure of a level-headed playing field is a primary objective in competition design, it is necessary to be prudent with its use and to consider other possible elements.

One of the biggest issues in Formula 1 over the past decades has precisely been 'an ostensible lack of competitive balance among participating teams' (Budzinski & Feddersen, 2019, p.2). *I don't follow F1 because it is boring, Hamilton always wins.*; *This Grand Prix was annoying, just a few overtakes in the whole race; I only watch the start, the rest is boring.* How many of these statements have we heard of? Probably too many times. The last twenty years were in fact characterized by the domination

of Ferrari and Michael Schumacher first and Mercedes and Lewis Hamilton later. Mercedes won all constructors' championships between 2014 and 2021. A concrete reason for this competitive imbalance relates to the basic design of the competition. In contrast to other motorsport leagues indeed, where all cars are the same, in F1 each constructor team can develop its F1 car within FIA's rules, which promotes technological innovations, but at the same time affects the equilibrium in the competition. Moreover, over the last years, there has been a huge surge in constructors' budgets, driven by the fact that, as stated by Fort (2006, p.3, cited by Judde et al., 2013), 'teams that spend the most tend to win the most'. Consequently, several regulations have been introduced by the FIA over the last period with the pure aim to improve competitive balance and uncertainty of outcome.

The aim of this master's thesis is to analyse competitive balance in Formula 1, over 12 years from 2010 to 2021. More specifically, it has two main objectives. Firstly, it contributes to the sports economics literature with an analysis of trends and variations in competitive balance for both the WDC and the WCC over time. Secondly, it empirically investigates the influence of teams' budget on teams' performance, by correlating budget concentration with point concentration. Therefore, it examines whether an unbalanced distribution of budget produces an unbalanced competition. In this way, this study contributes to closing two gaps in the existing literature: first, by updating the analysis of competitive balance in F1 until 2021, the first year after the introduction of the budget cap, and the last year before the revolution of technical regulations scheduled in 2022; second, by analysing the budgets of F1 teams for the first time since Gutierrez and Lozano (2014) and for 12 consecutive years.

The remainder of this research is organised as follows. The next chapter discusses the context in which F1 evolves, by shortly describing the history review and by giving an understanding of its structure and organisation. Chapter 3 provides an overview of the literature about sports attractiveness in professional sporting leagues and the concept of competitive balance in sports economics. In chapter 4 the data set used for the analysis as well as the methodology adopted are explained. Chapter 5 shows empirical evidence by presenting the results of the study, while chapter 6 features the discussion and the limitations of the study. Chapter 7 concludes.

2. Context: Formula One motor racing

Formula One (F1) is the world's most prestigious motor sport competition. It is licensed and managed by the Fédération Internationale de l'Automobile (FIA), the governing body for motor racing, funded in 1904 with the aim to standardise the rules through a meaningful governance. The Formula One World Championship was inaugurated by the FIA in 1950, and since then, Formula 1 has evolved into a global sport brand and represents, in business terms, one of the biggest sports events in the world. F1 takes its name from a set of technical regulations published annually by the FIA called the 'formula', to which constructors must strictly adhere. Through those technical regulations, the governing body manages the competition and sets the rules for participating at the championship, including a whole series of specific aspects for the cars such as dimensions, new technologies and safety measures. At the beginnings of motor racing, no limitations for the cars were in place and that resulted in unequal races with very different cars. The introduction of a set of rules and limits created a more even playing field for the participants. However, although nowadays all F1 cars must fulfil the FIA regulations, they can still be freely designed within the formula, which encourages and promotes technological innovations, but at the same time can affects the competitive balance (Khanna et al., 2002; F1chronicle, 2020). The term 'One' is used to distinguish the different FIA's single seater categories for motor racing, as well as other FIA's motorsport competitions.

2.1 Historical review

This part aims to give an understanding of the history of the sport, how it is born and how it has evolved throughout the years, to develop a more deeply knowledge of Formula 1 and its administration notably.

The Federation Internationale de l'Automobile (FIA) was created in 1904 as the governing body of world motorsport, 'in the absence of uniform rules governing international racing' (Khanna et al., 2003, p.1). Two years later, the Auto Club the France hold the first motor race, named Grand Prix (GP), a term which is also used nowadays (Hughes, 2004). Nevertheless, was not as early as 1947 that the FIA devised a framework of technical regulations and formulas to which all participants must adhere, called Formula A. Subsequently renamed Formula 1, it was defined to refer to the premier single seater category of international motorsport. The first FIA's official competition was introduced in 1950 with the creation of the Formula One World Drivers Championship (Smith, 2019). The

championship's format consisted in a series of races over a season and held in different countries, where around 20 pilots competed for the victory. Points were awarded after each Grand Prix and the driver accumulating most points would have been awarded the title. The Formula One Constructors Championship was introduced by FIA in 1958, as a parallel competition, acknowledging Formula 1 to become a human and a technological sport, as well as both an individual and a team sport.

During the period after the second World War, F1 was an 'uncoordinated, almost informal sport' (Henry, 2003, p.38, cited in Judde et al., 2013). Characterised by teams racing in their national colours, F1 became independent at the time the Indianapolis 500 was removed from the schedule in 1961 (Jenkins, 2010; Judde et al., 2013). The 1976 championship, marked by an intense duel between Niki Lauda and James Hunt, captured the world's attention and changed Formula 1 forever, changing it into a global television sport. At the end of 1970s, thanks to the global proliferation of television broadcasting, an 'unprecedented wealth flooded into the sport and transformed it into a very big business indeed' (Smith, 2019, p.14). TV companies were battling to have the privilege to broadcast F1 live, and sponsors were queuing to get associated with the sport (Smith, 2019). As a result, 'these developments culminated in an arms race that saw the budget of the world champion team increase from $5 million in 1980 to $40 million in 1990, before reaching $300 million in 2000 (Judde et al., 2013).

A considerable part of this success can be attributed to the person of Bernie Ecclestone. In fact, the sport was very disorganised when Ecclestone bought the Brabham team, an F1 constructor, in 1971. He started by negotiating with circuits and television broadcasters, and in 1978 he became president of the Formula One Constructors Association (FOCA), the voice of all F1 teams. Among other things, he contributed to the team's commitment to a full season of racing and their participation in all events. Before that, each team negotiated indeed their participation's terms at a GP directly on-site just some days before the race. But above all, what Ecclestone made that was significant, was the reorganisation of the way F1 commercial rights were managed, fighting between 1970 and 1980 with the FIA's arm, Federation Internationale du Sport Automobile (FISA) for the control of F1 broadcasting rights. As a result, in 1981 the first Concorde Agreement, a confidential protocol of technical, financial, and sporting regulation for the sport, was set between FIA and FOCA. FIA was recognised as the sport rule maker and owned the TV rights of each Grand Prix but had to lease them to FOCA (Khanna et al., 2003). Throughout the years, Bernie Ecclestone was able to transform a dysfunctional sport into a multi-billion-dollar industry. 'His genius lay in bringing together publicity-seeking car

manufacturers, who developed and raced cars on circuits around the world, with broadcasters, advertisers, and sponsors seeking to reach a global fan base' (Khanna et al., 2003, p.1).

In 1988, a new Concorde Agreement was set in which F1 commercial rights were leased to the Formula One Promotions and Administration (FOPA), another company founded the same year by Ecclestone, later known as Formula One Management (FOM). Under the new contract, F1 revenues were split as follow: 49% to FOPA, 1% to participating teams, and 50% to FIA. However, FOPA was put in charge of paying prize money to the teams (En-academic, 2010). Three years later, the FIA, presided by Max Mosley, long-term ally of Bernie Ecclestone, granted F1 commercial rights to the FOM, bypassing entirely the FOCA, for a period of 14 years. Since Mr Ecclestone owned 100% of FOM administration, this step gave him for the first-time absolute control of F1's commercial rights (Stylt, 2016). Under those circumstances, McLaren, Williams, and Tyrell, three main British constructors' teams, rejected an updated version of the Concorde Agreement in 1997, accusing Ecclestone and FIA to have eliminated FOCA's control on F1 rights. Therefore, the European Union investigated into the F1 business for antitrust violation, alleging FIA to exercise a monopoly power. Eventually, in 1998, all F1 teams signed in a compromise a new Concorde Agreement (Khanna et al., 2003).

From 1999 onwards, the commercial rights as well as the ownership of F1 has been a chaos, since Eccleston started selling them off. Firstly, he transferred his ownership of F1 companies to his wife Slavica who put them in a family trust called SLEC Holdings (Stylt, 2016). In 1999, the Morgan Grendell Private Equity acquired 12.5 % of SLEC shares for $325 million, and another company called Hellman & Friedman bought another 37.5% of the firm for $725.5 million. Those two companies combined their shareholdings and founded the Speed Investment, which in turn was sold to a German company called EM.TV for around $1.5 billion (Grandprix, 2002; En-academic, 2010). In 2002, the owner of F1's commercial rights were Kirch, a large pay-TV company who acquired F1's rights from EM.TV for around $1.7 billion (Khanna et al., 2003). At this time, Ecclestone had sold 75% shares of SLEC. The failure of pay-per-view TV in F1 and the consequent drop of TV revenue caused a bankrupcy of the Kirch company and consequently the shares were acquired by three banks (Grandprix, 2002; Khanna et al., 2003). In 2006 the CVC equity firm assumed the 63.4% of F1's shares for around $2 billion (Stylt, 2016).

The latest and most important windfall happened in 2016 when US investment firm Libery Media agreed to buy 100% of Formula One Group's shares for a deal of $8 billion, considered as one of the

biggest deals in sports history (BBC, 2017). Although the transaction price represented an enterprise value of $8 billion for the Formula One Group, Liberty media paid $4.4 billion in equity and issued new shares of the group as trading stock (BBC, 2016; Formula1, 2017). Bernie Ecclestone, 86 years old at the time, has been removed as chief executive after nearly 40 years of leading the F1 world. He was appointed as chairman emeritus and Chase Carey became the new chief executive officer of the group (BBC, 2017). In order to summarize the last events and have a complete picture of the puzzle, it is interesting to mention the following quote by Christian Sylt (Stylt, 2016): 'Given that F1 was practically worthless 40 years ago but now has a valuation of between $8 billion and $9.1 billion it is no surprise that Mr Ecclestone's commercialisation of the series is seen by many in the sports industry as one of the greatest-ever creations of value and a feat which is never likely to be repeated.'

Today, the Formula One Group is listed in the stock market under the ticker FWONK (Stylt, 2017). In 2020, it was announced that former Ferrari Team principal Stefano Domenicali will become the new CEO of Formula 1 (Skysports, 2020). Liberty Media's acquisition of F1's management opened the door to a raft of changes. The company rebranded completely the sport, with a new modern minimal logo, new TV graphics, and a complete embracement to social media. In addition, in contrast with Ecclestone's strategy of television broadcasting contracts, the new ownership announced a strong willingness to connect with online fans, including the launch of an F1 TV and the production of a Netflix TV series (Wood, 2022).

2.2 Structure and organisation

2.2.1 Competition design

The F1 World Championship essentially consists in an international sports league which includes two distinct championships: the F1 Drivers World Championship (WDC) and the F1 Constructors World Championship (WCC). The competitors are called teams, which are composed by hundreds of people, including drivers, technicians, engineers, and staff. They participate in the championship by producing and owning the rights of the F1 car (F1chronicle, 2020). According to the rules for the 2022 season (FIA, 2021a), a maximum of 26 cars will be admitted to the competition, which means that 13 teams will be involved, as two cars are allowed for each team. For the 2022 Formula One season there are 10 teams enrolled, and consequently 20 principal drivers compete in the championship. F1 seems not to have a big interest in accepting new teams in the competition, but

rather prefers to protect the 10 teams from financial losses, given that they already struggle to be profitable (The-race, 2020).

A F1 season is composed of several Grand Prix across the world, conducted throughout the year between March and December. Both the number and the locations can vary between seasons. The 2020 season, characterised by the Covid-19 pandemic, saw a cancellation of a conspicuous number of races especially in the first part of the year. For the 2022 calendar, FIA has approved a record-breaking 23 Grand Prix, including a debut race in Miami (Formula1, 2021). At each Grand Prix, points are awarded based on race results. According to FIA's sporting regulations (FIA, 2021c), nowadays' points table system attributes the points as follow: 25 points for the 1st, 18 for the 2nd and 15 for the 3rd placed, then 12-10-8-6-4-2-1 down to the 10th place. This scale was frequently modified over time and the current system is in place since 2010. This is a major reason why this study will focus on the period from 2010 to the present days. In addition to the current points scale, since 2019 one point is also awarded to the driver who achieves the fastest lap time of the event ranking in the top 10, with the aim to "…make the final part of the race even more interesting" (Ross Brawn, Managing Director of Motorsports at F1; cited in Formula1, 2021). Finally, as a novelty for 2021, a sprint race is introduced where points are awarded to the first 3 positions. At the end of the season, both the WDC and the WCC are awarded to the winners. The divers' world champion title is conferred to the driver who scored the most points in a season, and the constructors world champion title is allocated to the team with the highest cumulative number of points by both its drivers.

When it comes to understand the layout of competition design in F1, the anatomy of the Grand Prix itself must be clear. The so-called GP weekend is held over three days, from Friday to Sunday, but already commences a week before the race with important logistic works. The action normally starts on Friday with the free practice. It is composed by a pair of 90 minutes sessions with the objective for teams and drivers to familiarise themselves with the track (F1chronicle, 2020). Practice sessions usually last till Saturday mornings and constitute an important moment where constructors and drivers attempt to adjust the car for the specific track and conditions (Smith, 2019). Given that it is almost impossible to start simultaneously on the same line in motorsport, or at least it would require a track 100 meters wide, the starting grid concept was developed. For that reason, the qualifying on Saturday afternoon represent one major part of the GP, and probably one of the most exciting moments of the racing weekend. The aim is to establish a credible starting order based on qualifying performances, by placing the fastest driver in the front of the grid, known as the 'pole position' and the slowest at the end (Smith, 2019). Formula 1 has developed an entertaining qualifying's procedure, divided into three phases, Q1, Q2 and Q3 with a knockout mechanism. The qualifying event is held on Saturday

over a one-hour period. In the first round, all the cars take part, and the five slowest cars are eliminated. These will take the positions from 16 to 20 on the grid. The remaining 15 cars participate in the second session, and once again the last five are eliminated. The 10 fastest drivers will then participate in the Q3 fighting for pole position, a performance pursuit to the last breath (F1chronicle, 2020). On Sunday takes place the real race. The drivers will start on the grid based on qualifying results and after a warmup lap behind the safety car, they place themselves on the grid and wait for the starting procedure. One red light, two, three, four, five, and when they turn off together it all starts. The start and the first corner are moments of an incredible adrenaline. Afterwards, the drivers race for a defined number of laps, but generally for a total of about 300 kilometres, until the chequered flag (Smith, 2019).

2.2.2 Circuits

The F1 events, called Grand Prix, must be officially approved by the FIA and are reserved for F1 racing. A circuit usually starts with a straight and it is composed by several corners and chicane, whose objective is to decrease the speed and enhance the safety of the drivers. The 2022 F1 calendar comprises a maximum of 23 and a minimum of 8 races. Given that circuits have different distances, in each GP the number of laps can vary in order to reach at least 305 km and a total duration of almost two hours (Formula1, 2022). F1 tracks can also differ in terms of a normal race circuit or a street circuit, such as Monaco and Baku, and in terms of directions, mostly clockwise but with some exceptions. In 2008, the first Singapore GP introduced a new phenomenon to F1, night racing. Since then, this successful innovation was adopted in other circuits, such as Abu Dhabi and Bahrain.

From the beginning of F1 racing, 31 different countries and 71 separate circuits have hosted a F1 GP (Smith, 2019). Four F1's iconic circuits worth a special mention, since they were on the calendar for the first world championship in 1950 and are still part of the 2022 season: Silverstone (Great Britain), Monza (Italy), Monaco and Spa-Francorchamps (Belgium). The purpose of figure 1 is to show the complete list of the 2022 season with each circuit, its lengths, and laps, in order to give a broader view of the global dimension that F1 has taken. On the contrary of what it has been said previously, the total number of races will be 22, following the cancellation of the Russian GP.

Table 1: F1 2022 season's Grand Prix and circuits.

Round	Circuit	Grand Prix	Location	Length (km)	Laps
1	Bahrain International Circuit	Bahrain Grand Prix	Sakhir, Bahrain	5.412	57
2	Jeddah Corniche Circuit	Saudi Arabia Grand Prix	Jeddah, Saudi Arabia	6.174	50
3	Melbourne GP Circuit	Australian Grand Prix	Melbourne, Australia	5.303	58
4	Autodromo Enzo e Dino Ferrari	Emilia Romagna Grand Prix	Imola, Italy	4.909	63
5	Miami International Autodrome	Miami Grand Prix	Miami, United States	5.410	57
6	Circuit de Barcelona-Catalunya	Spanish Grand Prix	Barcelona, Spain	4.675	66
7	Circuit de Monaco	Monaco Grand Prix	Monte Carlo, Monaco	3.337	78
8	Baku City Circuit	Azerbaijan Grand Prix	Baku, Azerbaijan	6.003	51
9	Circuit Gilles-Villeneuve	Canadian Grand Prix	Montreal, Canada	4.361	70
10	Silverstone Circuit	British Grand Prix	Silverstone, Great Britain	5.891	52
11	Red Bull Ring	Austrian Grand Prix	Spielberg, Austria	4.318	71
12	Circuit Pail Ricard	French Grand Prix	Le Castellet, France	5.842	53
13	Hungaroring	Hungarian Grand Prix	Budapest, Hungary	4.381	70
14	Circuit de Spa-Francorchamps	Belgian Grand Prix	Spa-Francorchamps, Belgium	7.004	44
15	Circuit Zandvoort	Dutch Grand Prix	Zandvoort, Netherlands	4.259	72
16	Autodromo Nazionale Monza	Italian Grand Prix	Monza, Italy	5.793	53
17	Marina Bay Street Circuit	Singapore Grand Prix	Marina Bay, Singapore	5.063	61
18	Suzuka International Racing Course	Japanese Grand Prix	Suzuka, Japan	5.807	53
19	Circuit of the Americas	United States Grand Prix	Austin, United States	5.513	56
20	Autodromo Hermanos Rodriguez	Mexico City Grand Prix	Mexico City, Mexico	4.304	71
21	Autodromo Jose Carlos Pace	Sao Paulo Grand Prix	Sao Paulo, Brazil	4.309	71
22	Yas Marina Circuit	Abu Dhabi Grand Prix	Abu Dhabi, UAE	5.281	58

Source: Formula1. (2022)

2.2.3 Cars

F1 is a mixed sport where the performance comes from the combination of the incredible skills of the drivers, and the technical quality of the cars. A huge amount of effort goes indeed into their development and production. In fact, a F1 car must be constructed in adherence to detailed technical

regulations published annually by FIA. Nevertheless, there is still a margin for technical and design innovations, which brings teams to a 'relentless pursuit (…) to push both the rules and their research and development capabilities to the limit in order to find every little incremental advantage' (Wood, 2021). According to FIA's official 2022 technical regulations, a Formula One car is defined as follows:

'An automobile designed solely for speed races on circuits or closed courses that is propelled by its own means, moving by constantly taking real support on the ground, of which the propulsion and steering are under direct control of a driver aboard the vehicle. It runs on four non-aligned complete wheels, with wheels centres that are arranged symmetrically about the var centre plane, when in the straight-ahead position, to form the front and rear axles.'
(FIA, 2021a, p.9)

Other defining basic characteristics of those cars are the following: open wheel, single seaters, open cockpit, front wheels for steering and rears wheels for propulsion. Although these elements have not changed down to the present day, the F1 cars have evolved drastically over the curse of the years. Their design provides at the same time the least resistance and a huge down force (up to 5G) to maintain the car down upon the track during sharp corners (F1chronicle, 2021). For what concerns the overall car dimensions, the width must be of at maximum 1000mm except for tyres, the wheelbase must not exceed 3600mm (FIA, 2021a). Furthermore, 'the mass of the car, without fuel, must not be less than 775kg at all times during the competition' (FIA, 2021a, p.41).
F1 cars' engine is called power unit, which consists in 'the internal combustion engine and turbocharger, complete with its ancillaries, any energy recovery system and all actuation systems and PU-Control electronics necessary to make them function at all times' (FIA, 2021a, p.42). More specifically, the engine cubic capacity must be 1600cc and the fuel mass flow must not exceed 100kg/h (FIA, 2021a). In 2014, the hybrid power units, based on 1.6 litre V6 turbocharged engines, are introduced, defining a new era of F1 cars. The combustion engine is linked to a turbocharger and two electric units, capable of recovering kinetic and heat energy of the car (Tippet, 2021).

In 2022, another revolution touched the Formula 1 world, representing probably what should be one of the biggest overhauls in technical rules ever. The 2022 regulations, originally intended for 2021 but delayed by the Covid-19 pandemic, are supposed to transform F1 into a more competitive championship. The stated objective of this new rules package is to promote better racing, by allowing closer racing and creating more overtaking, which should translate in enhanced excitement (Stuart,

2021; The-race, 2022). To accomplish that, the aerodynamic of the new cars will be modified, with a focus on reducing the loss of downforce of a car behind another one. By doing so, every car should become more raceable and easier to follow, thanks to the reduction of the ground effect's downforce loss from 47% to 18% at 10 meters distance. Moreover, the cars will feature simplified front and rear wings, and for the first-time over-wheel winglets in the front wheels, everything to make sure that they will produce less dirty air (Stuart, 2021). The goal to promote a balanced competition is set, but eventually only the track will give precise answers.

Being F1 the pinnacle of motorsport, it worth mentioning the large number of innovations that this sport brought to the automotive industry, whether for the hybrid technology or for a modern aerodynamic feature. However, because of the global warming and CO2 emissions, the days of piston-engine power units are numbered, which push F1 to find innovative sustainable solutions. To conclude, it is important to remember that the freedom given to F1 teams to develop their cars contributes on one hand to find technological innovations to perform better but on the other hand has a negative impact in terms of competitive balance of the competition.

2.2.4 Teams and drivers

As mentioned previously, Formula 1's participants are teams, which develop and own their F1 car. Official sporting regulations for 2022 will allow a maximum of 26 cars to compete, meaning that a maximum of 13 teams will be accepted, since they race with two cars (FIA, 2021c). In 2022, there are ten teams that will compete in the F1 world constructors' championship, and consequently, 20 drivers who will fight for the F1 world drivers' championship (Formula1, 2022). F1 teams can be owned by car companies, famous brands, or privates' equities, and they could adopt different names whether form the constructor, the engine supplier, or the main sponsor.

Since the introduction of the first F1 world championship, more than 100 teams have come and gone, but only a small fraction has been able to win races and championships, emphasizing the difficulty to find success in the sport. Amongst the most successful ones in the history of F1, those who deserve a mention are Ferrari (from 1950), Mercedes (from 1954), Lotus (from 1958), McLaren (from 1966), Renault (from 1977), Williams (from 1987) and Red Bull (from 2005) (Smith, 2019). Table 2 shows the most successful F1 teams by the number of world constructors' championships.

Table 2: Most successful F1 teams by world constructors' championships (1958-2021).

Position	Team	WCC titles	Total race wins
1	Ferrari	16	238
2	Williams	9	114
3	McLaren	8	183
4	Mercedes	8	124
5	Lotus	7	79
6	Red Bull	4	75
7	Brabham	2	35
8	Renault	2	35
9	Cooper	2	16
10	Vanwall, BRM, Matra, Tyrell, Benetton, Brawn	1	various

Source: FIA. (2022)

Formula 1 drivers play a vital role in the sports since they are the real protagonists of GP races. A driver's duty is much wider than just drive a F1 car and for this reason he can be defined as 'the lone human interface between the multi-million-pound car his team have constructed for him to drive, and the 500 to 1'000 individuals whose hard work and enterprise put him there' (Smith, 2019, p.31). Each team relies indeed on their drivers for the crucial feedbacks that will allow them to develop a competitive car. Because driving a GP race is very demanding both mentally and physically, F1 drivers need to be excellent sportsmen. They can experience gravitational forces up to 6G when driving on sharp corners at high speed. Consequently, all drivers focus on improving their necks' muscles' strength in order to support such forces. Moreover, during a two-hours race, a driver can lose weight up to 4kg in sweat (F1chronicle, 2020; Tippet, 2021).

Considering that there are only 20 places available, it is extremely difficult to become a F1 driver. First, every driver who wants to race in the circuit needs to have a specific super license for Formula One, gained through sufficient experience in minors motorsport competitions. Secondly, from some years to this part, a driver must also be at least 18 years old and have a valid roar driver's license (Tippet, 2021). That being sad, it is quite obvious that with only 20 seats available, there is an extreme competition to get into it, and most of the time, the driver who can bring more money to the team will have a biggest chance even against a better driver.

Concerning the equality level in the sport, it worth mentioning that F1 is a discriminating sport both from a gender point of view (only two women ever participated in a GP) and from a nationality perspective, since Lewis Hamilton is still the only black driver in the history of the sport.

According to Smith (2019), since the beginning of Formula 1, more than 1000 GP have been held and more than 800 drivers have competed in the championship. However, the number of winning drivers is much lower, a signal confirming on one side, the difficulty of being successful in this sport and on the other side, the level of competitive imbalance in the competition. To determine the extent of a driver's performances, the most frequent indicators are the number of WDC titles, the total number of races, and the strike rate. The latter, allows an objective comparison between drivers of different eras and put into perspective winning records, by relating the number of wins with the number of starts, in the form of a percentage ratio. Table 3 shows a list of the top 20 most successful F1 drivers for race victories (Smith, 2019; BBC, 2022; FIA, 2022). Nevertheless, is worth mentioning that despite those indicators, considering such differences in the cars over time, there is no infallible measure of success.

Table 3: Top 20 most successful F1 drivers by race wins (1950-2021).

Position	Driver	WDC titles	Total race wins	Strike rate
1	Lewis Hamilton	7	103	36%
2	Michael Schumacher	7	91	29%
3	Sebastian Vettel	4	53	19%
4	Alain Prost	4	51	26%
5	Ayrton Senna	3	41	25 %
6	Fernando Alonso	2	32	-
7	Nigel Mansell	1	31	-
8	Jackie Steward	3	27	27%
9	Jim Clark	2	25	35%
9	Niki Lauda	3	25	-
11	Juan Manuel Fangio	5	24	47%
12	Nelson Piquet	3	23	-
12	Nico Rosberg	1	23	-
14	Damon Hill	2	22	19%
15	Kimi Raikkonen	1	21	-
16	Mikka Häkkinen	2	20	-
16	Max Verstappen	1	20	-
18	Stirling Moss	0	16	24%
19	Jenson Button	1	15	-
20	Graham Hill	2	14	-
20	Jack Brabham	3	14	-
20	Emerson Fittipaldi	2	14	-

Source: FIA. (2022)

Amongst the most decorated drivers of all time, it is yet necessary to mention a few of them that, over the course of the years, have made the history of this sport. Juan Manuel Fangio (Argentinian), competed in F1 between 1950 and 1958, winning 24 races and four championships, with an incredible strike rate of 47%, for which is still considered by many the greatest of all time. Jim Clark (British) was active from 1960 to 1968, a period in which he was able to win 25 races and two championships, and a strike ratio of 35%. Niki Lauda (Austrian), was active in F1 racing between 1971 and 1979 and later between 1982 and 1985, winning 25 races and 3 championships. However, he is famous as a survivor of a brutal incident which saw his car burst into flames, but also for his rivalry with James Hunt, subject of the film Rush. Alain Prost (French), competed in Formula 1 from 1980 to 1993, managing to set a record of 51 race victories, four championships, and a strike rate of 26%. Ayrton Senna (Brazilian) was another legendary F1 driver, whose career was characterized by the intense rivalry with Prost. He won 41 races and three championships, with a strike rate of 25%, but his tragic death during the San Marino Grand Prix ended prematurely his life. Michael Schumacher (German), considered the greatest F1 driver of the history, won 91 races and seven championships, with a strike ratio of 29%, during his long career from 1991 to 2006 and later from 2010 to 2012. With Ferrari, he won the championship for five years consequently. In 2013, one year after he left one of the world's most dangerous sport, suffered of a skiing accident who left him comatose. Sebastian Vettel is another great German F1 driver, who tried to carry the legacy by winning 52 races and especially four consecutive drivers' titles with Red Bull between 2010 and 2013. Finally, one of the true legends of Formula 1, from 2007 and still active, is Lewis Hamilton. The British is the first ever black driver in the sport, and up to end 2021, he secured a record of 103 race victories. For the moment he also holds together with Schumacher the record of 7 world championship titles.

2.3 Teams' budget

In order to analyse F1's competitive level, it is necessary to better understand the economics behind the scenes of a F1 team. Unlike other more specific and regulated motor sport competitions such as NASCAR, F1 is much more customized, as each team can develop their own car within the regulations set by the FIA. That freedom has evidently an influence on competition's performances, because it results in big disparities between teams, as it is demonstrated that 'teams that spend the most tend to win the most' (Fort, 2006, p.3, cited by Judde et al., 2013). This part will indeed examine the business of F1 teams, split into two parts: revenue in a first moment and costs in a second one.

2.3.1 Teams' revenue

Revenue generated by F1 teams could be divided into two main sources: Formula One Group (FOM) payments and private sponsorships.

In the first place, a special attention will be devoted to the way the FOM redistribute its revenues to the participating teams. In 2019, Formula 1 reported an overall revenue of $2.02 billion, but in 2020, it dropped to $1.145 billion due to the Covid-19 pandemic (Saward, 2021). According to Judde et al. (2013) and Khanna et al. (2002), F1's revenues that are shared between teams represent the 47% of the previous year's TV broadcasting revenues.

To understand the way teams' payments are organised, it is necessary to resort the different Concorde Agreements, a series of secret documents signed by the teams that prefix their conditions in participating in the Formula 1 World Championship. The document, which was never officially published, is a deal between the FIA, the participating teams and the FOM, the F1 commercial rights holder. The 7th and second last Concorde Agreement signed in 2013 and valid until 2020, 'provides the FIA with significantly improved financial means to pursue its regulatory missions and to reflect the enhanced role undertaken by the FIA in the motor sport' (FIA, 2013). However, this document, stipulated when Bernie Eccleston was still the CEO of the FOM, have indirectly created big financial disparities between F1 teams and consequently, the dominance of richer teams. Before describing hereafter more in detail the different FOM payments, it is important to mention that, although those figures are trustworthy, they are estimated data, since every Concorde Agreement is kept confidential.

According to the 2013 Concorde agreement, in 2019, each team was attributed with an equal 'participation payment' of $ 35 million (Thef1clan, 2020; Rencken & Collantine, 2019). The also known Column 1 payment, consists in a fixed amount for each team that has finished in the top ten of the championship for two of the last three years. The second payment that teams receive concerns the prize money distribution based on the previous season's results. The so-called Column 2 payment, in 2019 varied from $66 million for Mercedes finishing 1st, to $15 million for Williams in the last place. Comparing it to other competitions' revenue distribution, in this case the sliding scale is very unbalanced, since the first ranked team receive more than the quadruple of the last ranked. In comparison, in the Premier League for the 2019/20 season, the highest earning club received 1.8 times the amount received by the lowest earning club (PremierLeague, 2016).

Until that point, the FOM revenue distribution system could be understood. Unfortunately, there are other forms of payments that complicate the situation. The Constructor's Championship Bonus is a payment reserved for only four teams: Ferrari, Mercedes, McLaren, and Red Bull. It concerns a deal

between Bernie Ecclestone and big F1 teams with the purpose to keep them in a strong position for a medium-long term. For those bonuses there is no fixed amount and can varies with top performing teams receiving a little bit more than the others (Thef1clan, 2020; Siddharth, 2021). Furthermore, there are four other payments distributed to three teams and negotiated individually. The Heritage payment of $10 million is accorded to Williams, on behalf of their long history in the competition. The second payment is accorded to Mercedes if the team succeeds to win back-to-back the world championship before 2020. The third one concern Red Bull, receiving a bonus for have been the first team to sign the Concorde Agreement. Finally, there is another controversial payment named the Long-Standing Team payment, accorded to Ferrari for a sum of $73 million per year on the basis to be the only team to have participated in all F1 season since 1950 (TheF1clan, 2020, Siddharth, 2021; Rencken & Collantine, 2019). Table 4 summarizes the situation of FOM payments to F1 teams before the start of the 2019 season.

Table 4: Estimated payments to F1 teams in 2019 season.

Team	Column 1 ($ million)	Column 2 ($ million)	CCB ($ million)	Other ($ million)	2018 WCC ranking	Total ($ million)
Ferrari	35	56	41	73	2	205
Mercedes	35	66	41	35	1	177
Red Bull	35	46	36	35	3	152
McLaren	35	32	33		6	100
Renault	35	38			4	73
Haas	35	35			5	70
Williams	35	15		10	10	60
Racing Point	35	24			7	59
Sauber	35	21			8	56
Toro Rosso	35	17			9	52

Source: TheF1clan. (2020)

The revenue's distribution is thereby glaringly unequal and questionable, and clearly affects the balance of the competition, by favouring the older teams. Moreover, this scheme is economically unsustainable, with teams facing more and more financial problems. Nevertheless, a new Concorde agreement has been signed in 2020 and will last until 2025. According to a statement from Formula 1 (Formula1, 2020), 'the agreement will secure the long-term sustainable future for F1 and combined with the new regulations, announced in October 2019 that come into force in 2022, will reduce the financial and on track disparities between the teams, helping to level the playing field, creating closer racing on the track that our fans want to see more of'. In addition, the new regulations will also

introduce a budget cap for the teams, or more precisely a cost cap, but more on that will be discussed later in the next chapter. To summarize, there is clearly a willingness of F1 rights holder Liberty Media, in collaboration with FIA, to take an important step into the direction of a more balanced competition. This vision is reflected into the FIA financial regulations, published in 2022, where it is affirmed that new rules are designed to: 'promote the competitive balance of the Championship; promote the sporting fairness of the Championship; and to ensure the long-term financial stability and sustainability of the F1 teams; while preserving the unique and engineering challenge of Formula 1' (FIA, 2021b, p.2).

After witnessing the revenue distribution system for the teams, it is important to be aware that it does however not represent their primary revenue stream, which is sponsorship. A F1 car is indeed a moving billboard blathered with famous brands' advertisements. A lot of companies seek to associate themselves with a Formula 1 team to reach a very large audience. The total amount of teams' sponsorship was nearly $1.5 billion in 2015 (Reid, 2015, cited in Budzinski & Feddersen, 2019), but reached $1.9 billion in 2020 (Limacher, 2020). Nevertheless, since all F1 teams 'compete on the same track at the same time, it is inevitable that sponsorship revenues flow more easily toward successful teams' (Judde et al., 2013, p.413). For this simple reason, it is easy to understand why winning teams can rely on high paying sponsorship deals, while weaker teams attract fewer sponsors. An example above all is the recent huge five-years deal between Red Bull Racing and Oracle, worth approximately $100 million per season, set to become the biggest in F1 history, even more than the iconic 1997 title sponsor of Marlboro (Philipp Morris) with the Scuderia Ferrari (Racingnews356, 2022). Before the official global ban in 2006 indeed, the tobacco industry has massively funded Formula 1.

Also in this case, unfortunately official data are not shared in the public domain, and thus only estimations are available, some more reliable than others. One of them is present in the Business Book GP 2020 (Limacher, 2020), where the 73 most important sponsorship deals of 2020 F1 season are listed. In this case the largest sponsors are often represented by the manufacturer themselves, such as Mercedes-Benz, Ferrari, Renault, and Alfa Romeo, with amount exceeding one million dollars. Other huge sponsors are some of the world's leader's petrol and oil companies, like Petronas for Mercedes, Shell for Ferrari, Castrol for Renault, and Esso for Red Bull. Other forms of sponsorship in F1 could be an official suppliers or technical partner; in this case global apparel brands could sponsor more than one team, as the example of Puma. Table 5 shows more in detail the top 20 of the largest sponsorship deals for 2020 season (Limacher, 2020).

Table 5: Top 20 F1 sponsorship deals in 2020 season.

Rang	Sponsor	Team	Amount
1	Red Bull	Red Bull / Alpha Tauri	$283m
2	Mercedes-Benz	Mercedes / Williams	$237m
3	Philipp Morris	Ferrari	$178m
4	Renault	Renault	$130m
5	Alfa Romeo	Alfa Romeo / Ferrari	$113m
6	Haas Automotive	Haas	$90m
7	BAT	McLaren	$68m
8	Petronas	Mercedes	$65m
9	Honda	Red Bull / Alpha Tauri	$56m
10	Canada Life	Racing Point	$47m
11	BTW	Racing Point	$45m
12	DP World	Renault	$40m
13	Shell	Ferrari	$34m
14	Aston Martin	Red Bull	$34m
15	Ineos	Mercedes	$34m
16	Castrol/BP	Renault	$34m
17	Rokit	Williams	$34m
18	Pirelli	All teams	$28m
19	UPS	Ferrari	$27m
20	Kaspensky	Ferrari	$27m

Source: Limacher, M. (2020)

2.3.2 Teams' expenses

The expense to run a Formula 1 team is significant and not always justifiable. In this sense, an interesting element to measure the efficiency of a team can be the cost per point, by dividing the budget of a team in a precise season with its budget. Results show that top winning teams, despite having a large budget, score an important number of points, which translates in a cost of less than $1 million per point. On the contrary, last ranked teams have a cost per point higher than $5 million or more (Rencken, 2020).

Digging more into detail of F1 teams' finances, this part will analyse the principal costs that they have to face to compete in the sport. The costs incurred by the teams could be split into four main categories: research & development, production and manufacturing, operations expenses, and staff

salaries. The first one, includes the whole work behind the scenes whom objective is to deliver a new competitive F1 car each season. This occurs by a lot of hours of testing on and off the track.
The second category comprises the effective production of the car, including the engine. It worth to note that in 2021, the teams were equipped by only four engines (all of them 1.6 V6 turbo engine): the Mercedes engine, used by Mercedes, McLaren, Aston Martin and Williams, the Ferrari engine, which powers Ferrari, Alfa Romeo and Haas, the Honda engine used by Red Bull and Alpha Tauri and finally the Renault engine utilised by Renault only (Siddharth, 2021).
The third big category of costs is characterized by the logistic expenses, touching more than $50 million per year in most of the cases. According to Forbes (Stylt, 2020), Toro Rosso F1 team reported an expense of $45.6 million in 2018 for the travel, maintenance and energy and telecoms. Eventually, one of the biggest costs for a F1 team are staff and drivers' salaries. In this case, all salaries from engineers, factory executives, team principals, mechanics and drivers are included, reason why F1 is considered an important employment generator. F1 drivers are among the most famous athletes in the world and as a result, some of them are paid as superstars. An article from Forbes (Knight, 2021b), reported that Lewis Hamilton, the highest paid driver of 2021, received a base salary of $55 million with a $7 million bonuses, while is estimated that Verstappen had a base salary of $19 million but combined with the championship bonus, he took home around $42 million at the end of the season.

Based on reliable sources combined, although those are again only estimations because the official data are not published, table 6 exhibit the 2021 estimated season drivers' salaries (Lange, 2021; Knight, 2021b; Hall, 2021; Limacher, 2021). A trend that can be observed is that experienced drivers are paid more than rookies or young drivers, and evidently race or championship winners like Alonso or Vettel are also paid a lot more than their respectively teammates, despite not being in a top performing team. In addition, is interesting to note the huge gap between the top paid and the less paid drivers, with amounts ranging from around half a million $ to $62 million.

Table 6: Estimated F1 drivers' salaries in 2021 season.

Position	Driver	Team	Salary
1	Lewis Hamilton	Mercedes	$62 million
2	Max Verstappen	Red Bull	$42 million
3	Fernando Alonso	Alpine	$25 million
4	Daniel Ricciardo	McLaren	$17 million
5	Sebastian Vettel	Aston Martin	$15 million
6	Charles Leclerc	Ferrari	$12 million
7	Valtteri Bottas	Mercedes	$10 million
8	Sergio Perez	Red Bull	$8 million
9	Carlos Sainz	Ferrari	$8 million
10	Kimi Raikkonen	Alfa Romeo	$8 million
11	Esteban Ocon	Alpine	$5 million
12	Lando Norris	McLaren	$4 million
13	Lance Stroll	Aston Martin	$2 million
14	Pierre Gasly	Alpha Tauri	$2 million
15	George Russel	Williams	$1 million
16	Nicholas Latifi	Williams	$1 million
17	Antonio Giovinazzi	Alfa Romeo	$700'000
18	Yuki Tsunoda	Alpha Tauri	$500'000
19	Michael Schumacher	Haas	$500'000
20	Nikita Mazepin	Haas	$500'000

Source: Limacher, M. (2020).

2.3.3 F1 budget cap

Difficult financial situations for F1 teams are not an exception in the history of the sport. To limit the expenses of participating teams and ensure the survival of the F1 world championship, the FIA took some crucial decisions over the past few years. In 2010, for the very first time, a budget cap of $70 million was proposed by FIA, but it was soon rejected by some teams. However, another deal was implemented, the Resource Restriction Agreement, with the aim to reduce teams' budget by 50% of the 2008 season (Judde et al., 2013).

In 2021, alongside with the introduction of the first-ever FIA financial regulations, another form of budget cap for teams was presented. The aim of the so-called cost cap is 'to deliver a more competitive championship, promote a level playing field and ensure the long-term financial stability and sustainability of Formula 1's 10 teams' (Barretto, 2020a). The cost cap is a limitation of teams'

expenditure on car development for a calendar year. Since the total spend differs widely between the participating teams, the introduction of this element should limit the gap between the richer and the poorer teams, as well as reducing the overall cost of F1. The cap introduced in 2021 was set at $ 145 million, but it will be reduced at $ 140 million in 2022 and $ 135 million from 2023 (Barretto, 2020a). With top performing teams such as Mercedes, Red Bull and Ferrari having a budget of more than £ 400 million, this implies a huge cut in spending. It is important to note that the budget cap only includes expenses related to race car performance, excluding all other expenditures such as marketing costs and driver salaries. Although the introduction of the cost cap is a first step towards a more balanced competition, it still represents an important sum of money that some teams do not even spend that amount for all activities combined. In conclusion, the new budget cap, combined with the new package of technical regulations for 2022, will give smaller teams a reason to stay in the sport and work for better performances. In this regard, Guenther Steiner, Haas F1 team principal, for an interview with Forbes stated: 'if you have no chance, why would you do it? Knowing going into the competition, knowing that you will be last doesn't make sense. It would be madness' (Knight, 2021a).

3. Theoretical background

3.1 The economics of professional sporting leagues

The economic analysis of professional team sports differs from that in standard industries. One main theme in this sense concerns the adequate conception of professional sporting leagues around the world, which is peculiar and need to be clearly understood in order to analyse the design of those competitions. Neale's (1964) analysis of 'The peculiar economics of sport's' was one of the first attempts to define sporting leagues within an economic dimension of professional team sports. More specifically, the author mentioned that 'the first peculiarity of the economics of professional sports is that receipts depend upon competition among the sporters or the teams, not upon business competition among the firms running the contenders, for the greater the economic collusion and the more the sporting competition the greater the profits.' (Neale, 1964, p.2). In addition, in contrast with a common firm, in the sport industry monopoly is not the ideal market position for a sport team, indeed it is a disaster. In the same circumstances, Neale (1964, p.4) continues, 'a business firm (…) cannot produce any of these utilities alone. It must have the co-operation of a second business firm even to produce a game (…)'. In other words, in the professional team sports ecosystem, every performance requires the existence of an opponent. Since competitors in sporting leagues cannot produce a marketable good alone, they therefore depend on each other to produce the output.

3.1.1 Sports attractiveness and competitive balance

Another main theme related to the economic dimension of professional sports leagues, known as one of the most relevant contributions to sport economics literature is the uncertainty of outcome hypothesis, from which derives the concept of competitive balance. Proposed in the first place by Rottenberg (1956) in the Journal of Political Economy and present in Neale's (1964) exposition of 'The peculiar economics of sports', it postulates that sports fans are more interested in watching competitions with an unpredictable outcome. In this sense, Quirk & Fort (1992, p. 243) suggested that 'one of the key ingredients of fans demand for team sports is the excitement generated because of the uncertainty of outcome of leagues games.' And since outcome uncertainty is determined by the level of competitive balance, they defined competitive balance as a key determinant to financial stability of a sport league. In fact, a strong outcome uncertainty is correlated to an increased demand

for watching sports (Budzinski & Feddersen, 2019). Equally, Judde et al. (2013), agreed that the financial health of a sporting league is a reason for the competition to be balanced, because a diminishing fan interest can be translated into a reduction of revenues. Spectators prefer indeed close rather than unbalanced competitions. Therefore, while the main objective of teams is to outperform its competitors, the leagues must ensure a balanced competition to be profitable. If in other industries firms prefer weak competitors, in the professional sport teams' industry a balanced competition maximizes profits. A single dominant contestant is not desired because output quality increases with the quality of the competitors. Hence, aside from other criteria like athletic quality and presence of superstars' players, competitive balance is one main factor for attractiveness of sports leagues. However, its necessary to be prudent because it is common that TV audience's preferences diverge with from the preferences of stadium supporters and die-hard fans, who just want to see their team win.

3.1.2 Definition of the concept of competitive balance

Defining the term of competitive balance is an arduous task because there is no common unique definition in the literature. As suggested by Zimbalist (2003a, p.161), 'competitive balance is a complex phenomenon, that has many dimensions.' Consequently, to better explain this concept, an understanding of its dimensions is necessary. According to Budzinski & Feddersen (2019, p.6), competitive balance 'relates to the relative strengths of the teams and individuals competing in a sporting contest.' In other words, it can be said that the more a competitor is superior compared to its opponents, the lower is the competitive balance in the competition. Quirk & Fort (1992, p.243) defined the phenomenon of competitive balance as 'the equality of talent distribution among teams so that uncertainty of outcome is preserved', evidencing the talent distribution aspect between teams in a championship. In general, the literature describes the concept of competitive balance considering the relative quality of the competition. For this work, competitive balance is intended at the same time as the distribution of sporting quality within the competition, but also indicates a parameter to evaluate the equilibrium between participants of the event as well. As mentioned previously, it is important to be aware of the different dimensions of this concept. The most recurrent dimensions in the literature relate to the distribution of talents between teams, the likelihood of teams to win the tournament (*ex-ante*), as well as the distribution of performance, the winning percentages, and the distribution of league championships (*ex-post*) (Rottenberg, 1956, Szymansky, 2003, Quirk & Fort, 1992). A more detailed explanation of the measure of competitive balance will be defined later.

‘Competitive balance is like wealth. Everyone agrees it is a good thing to have, but no one knows how much one needs.’ (Zimbalist, 2002, p.111). This quote illustrates the dimension and the complexity of the concept. The right level of competitive balance may vary depending on the competition. It is indeed much more significant in a closed league than in an opened league. In a situation with an open sporting league such as in the case of the European model of football, where a promotion and relegation system are present, competitive balance is not crucial. In fact, within an opened championship, other multiple sub-competitions are formed, like the fight for the title as well as the one to avoid the relegation. This allows to maintain a high level of attractiveness and does not require an extraordinary amount of balance. However, if there is not a strong overall intra-season competitive balance, the matchday outcome uncertainty becomes crucial. For instance, in European football leagues, where there is uncertainty of outcome at all levels as there are more competition into one, long term competitive balance is not needed but the unpredictability of matches (Hamil, 2021). According to Szymanski (2003), leagues have always been unbalanced and big cities have always dominated, but this did not prevent European football to become that popular.
In contrast, within a closed competition, competitive balance plays a fundamental role. In this situation, an important level of balance is required to enhance the attractiveness of the competition. All the major North American professional sports leagues adopted a closed competition system, in order to avoid, from an economical point of view, the danger of the promotion and relegation system. Since the vision of sport is to maximize profits, a closed competition was designed to protect the participating clubs. Hence, competitive balance is a critical objective in competition design.

In conclusion, is crucial to have an understanding that one major goal of well-designed leagues is to produce adequate competitive balance. As stated by Zimbalist (2003b, p.503), ‘the success of a league is, to some extent, affected by the degree of uncertainty of outcome of its contests and its seasonal competitions, or stated differently, by the degree of balance among its teams.’ However, is equally necessary to acknowledge the fact that this concept alone is not enough, and a series of other elements, such as the overall players quality and the presence of superstars, contribute to enhance the attractiveness of a competition. Ultimately, even if it is hard to define an optimal level of competitive balance, it is widely recognised as one of the main factors for attractiveness in professional sporting competitions. Although achieving a measure of a level-headed playing field is a primary objective in competition’s design, it is necessary to be prudent with its use and above all, to consider other possible key drivers.

3.2 Competitive balance regulations in sports leagues

Throughout the history, a conspicuous number of regulatory interventions have been designated to promote competitive balance in professional sports leagues with the objective to enhance the attractiveness of the competition and the uncertainty of outcome. This part will analyse in a more detailed way those regulations, with the aim to develop some knowledge in competition design and have an understanding of what are the possibilities that could be applied in motor racing to create a balanced competition. As mentioned previously, the professional sporting leagues in the United States have employed a wide variety of those regulations since their foundation (Dietl et al., 2012). Above all, three main groups could be distinguished: the salary cap, the draft system, and the revenue sharing system (Szymanski, 2003; Zimbalist, 2002). Since the draft system does not have any sense to be implemented in F1, the salary cap and the revenue sharing will be discussed more specifically hereafter.

3.2.1 The salary cap

Cost control regulations are a key element in sports competitions around the world. Salary cap is a limit on the amount of money that teams can spend on player salaries per year. Fort & Quirk (1995), claim that under a situation of profit maximisation, a salary cap is the only system being able to accomplish both a better competitive balance and a financial stability of the competition. According to Diet et al. (2012, p.307), 'all four North American major team sports leagues have introduced some variant of salary cap mechanism' (…), which is now 'an integral part of the system of labour relations in the league'. Team owners and players' unions negotiate the amount of league revenue accorded to players payroll by a Collective Bargaining Agreements (Dietl et al., 2012). Salary caps differ between the major sports leagues in the United States. For instance, in 2019, NFL had a salary cap of $ 188.2 million, NBA of $ 109.1 million and NHL of $ 81.5 million (Baker, 2019). According to Cripps (2016), 'the NFL salary cap is primarily designated to enable the league to control team on players' salaries in order to limit financial risks and underpin the financial integrity of the league'. Roster limits are indeed a way to make sure that most clubs can be profitable, but at the same time constitute a core element to promote a parity of competition within the league. Salary controls are no longer just a North American phenomenon, because of their introduction into European sports (Hamil, 2021). However, the differences between the North American and the European model of sport have significant consequences in the application of salary cap rules (Dietl et al., 2012). Furthermore, is

necessary to be aware of the possibility of occurrence of some problems which could negatively impact the efficacy of that regulations, such as the use of long-term contracts, the case of the designated player rule in the MLS, or the possibility to accord bonuses to players. In addition, although it is proven that payroll caps are effective to limit players mobility, some researchers have been questioning the real effect on competitive balance (Vrooman, 2000).

An alternative to salary cap is represented by luxury taxes, consisting in a tax on salary expenditure over a set threshold (Hamil, 2021). Clubs among the league are free to spend what they want to pay players' salaries, but the amount who exceed this limit is taxed and redistributed among other teams in the league (Lang, 2020). To give a concrete example, MLB's luxury tax threshold was $ 210 million in 2021 (MLB, 2022). It is also interesting to note that MLB's luxury tax is commonly named the competitive balance tax, referring to the main idea of developing a balanced competition.

Touching the field of Formula One racing, another form of salary cap is considered. In the specific case of F1, a first form of expenditures limitation was firstly introduced in 2010, known as the Resource Restriction Agreement. Judde et al. (2008, p.429) determined that the introduction of such element 'has the potential to promote a more balanced contest between F1's independent and manufacturer teams.' As mentioned previously in the context, in 2021 another form of budget cap was introduced in the F1 world. Similarly, the main goal of this element is to limit excessive expenditures of the teams to create a more equal playing field as well reduce the overall cost of F1 (Barretto, 2019).

3.2.2 Revenue sharing

Revenue sharing is one of the most successful regulations of competitions design in the North American model, reason why it has been implemented in the European ecosystem as well. Revenue sharing devices include the distribution of gate receipts, broadcast revenues, sponsoring, licensing and merchandising income (Lang, 2020). Once again, the core idea is solidarity to help achieving a measure of competitive balance. Indeed, Sanderson & Sigfried (2003, p.268), quoted that 'revenue sharing reduces the financial incentive of each franchise to acquire more talent, because the playoff to winning is constrained by the share paid to other franchises.' The NFL, considered as the most socialistic league in the United States, provides the equal distribution of league's national television revenue and merchandise sales among participating teams, which enables an intense competitiveness (Bloom, 2014). In Europe, revenue sharing has been implemented in all major football championships but according to different criteria. The most common are the sporting performance, the TV market,

the number of supporters or the number of times the club is televised live (Hamil, 2021). One of the reasons of the success of the English Premier League is the competitive balance created by its TV revenue distribution system, considered one of the most equals on the planet. 'The league's revenue distribution mechanism – the most equal of the 'big five' European leagues – enables strength in depth and intense competitiveness as exemplified by the shock of Leicester City's Premier League title in 2015/16' (Deloitte, 2017). Without the introduction of that regulation, the league would probably have become less balanced and less attractive to broadcasters. Nevertheless, it is necessary to be prudent also in this case, since in the literature two different opinions can be found. Fort & Quirk (1995), conclude that 'increased revenue sharing will not improve competitive balance (Zimbalist, 2002, p.111). On the contrary, 'Vrooman (1995), Marburger (1997) and Kesenne (2000) each vary the assumption in the Fort & Quirk model and conclude that increased revenue sharing may indeed improve competitive balance' (Zimbalist, 2002, p.112).

In conclusion, despite it is commonly believed that the sharing of revenues among all participating teams will improve league's competitive balance, its effective influence is more convoluted. Indeed, according to Kesenne (2019, p.58), 'the complications are caused by the fact that there are not only different sharing arrangements (…). The impact also depends on the objectives of the teams, which can be profit or win maximization, as well as on the type of model that is used to analyse the impact'. More in general, in a win maximisation context, revenue sharing will improve the level of balance if it reduces large teams' revenue and increase the one of small teams. In a profit maximisation context, the absolute quality in the league must affect teams' revenue to improve league's competitive balance (Kesenne, 2019).

3.3 Competitive balance in Formula 1 motor racing

3.3.1 Literature review

The search for a competitive balance has been a longstanding subject for FIA managers. However, as mentioned by Budzinski & Feddersen (2019, p.2) 'during the past two decades, an ostensible lack of competitive balance among participating teams has continuously been one of the biggest issues for the governance of F1'. For instance, Lewis Hamilton has won six of the last seven world driver championships, and his team Mercedes won all constructor's championships between 2014 and 2020 (Formula1, 2021). F1 is a peculiar form of competition because it consists in a hybrid form combining both individual and team sports' aspects with two championships in one (Krauskopf et al., 2010;

Judde et al., 2013). Formula One motor racing can indeed be full-fledged considered a closed league competition, including the F1 WDC and the F1 WCC. A fundamental difference between F1 and other motorsport competitions relates to the fact that participating teams are responsible to design their own F1 cars within the FIA regulations. Consequently, with differently developed cars, the contest assumes a very unbalanced meaning.

Despite this situation, only a few scholarly articles analyse the field of competitive balance in F1 motor racing. Considering the impact of competitive balance on fan demand, an econometric study from Krauskopf et al. (2010) analyses television audience with the purpose to determine an optimal level of competitive balance, using the Gini coefficient. 'A high Gini coefficient implies a high disparity which in turn represents a small competitive balance' (Krauskopf et al., 2010, p.6). Moreover, the authors utilise a second index to measure the attractiveness of the competition, which is the relative distance between the first and the second driver in overall rankings. They conclude that a too high level of competitive balance is as undesirable as too low level. In addition, they also suggest that the attractiveness of F1 is maximised with a tight duel between two superstar drivers, such on the occasion of the duel between Lewis Hamilton and Max Verstappen in 2021 season. Similarly, Schreyer and Torgler (2016), explore the impact of race outcome uncertainty on TV demand in Germany.

Two others recent articles by Mastromarco & Runkel (2009) and Judde et al. (2013) analyse the impact of rule changes on competitive balance in F1. Formula One's governing body FIA publishes every year, prior to each championship, a set of official technical regulations that teams must refer to. Those rules can be implemented for several reasons, such as the safety of the drivers and the cost reduction. However, some important changes in the last few years can be related to a general aim to improve competitive balance, in order to increase fan interest and maximise broadcasting revenues. Mastromarco & Runkel's (2009) research conclude that competitive balance regulations have resulted in a significant positive impact on uncertainty of outcome. Judde et al. (2013) econometrically investigate the impact of regulations in competitive balance performing an ordinary least squares regression. In addition, they evaluate the theoretical implications of the Resource Restriction Agreement by employing a version of the Fort & Quirk (1995) two team model. They also demonstrate that uncertainty of championship outcome has a key role to the introduction of new technical regulations.

On a more general level, Gutiérrez & Lozano (2014) investigate F1 teams' budgets adopting the data envelopment analysis method. The aim of the study is to measure each constructor's performance,

and it indicates that a budget cap or a reduction in teams budgets need to be adopted to enhance their efficiency. The latter article, is, as we know, the only one analysing budgets of F1 teams.

In their research, Budzinski & Feddersen (2019) highlight three main characteristics that differ F1 from other team sports and that have direct influence on competitive balance. Firstly, the twenty drivers from ten teams race simultaneously in each GP; secondly, points for two different championships are awarded each GP; thirdly, competitiveness and performance depend on both the ability of drivers and on technical package. Hence, regarding both championships, the study distinguishes three dimensions of competitive balance: within race competitive balance (i.e., outcome uncertainty regarding a single GP); within-season competitive balance (i.e., outcome uncertainty regarding the evolution of the points standings); and inter-season competitive balance (i.e., outcome uncertainty regarding the series of champions in the course of time) (Berkowitz et al., 2011, p.255, cited in Budzinski & Feddersen, 2019). The first one, could be measured with the margin of victory or the number of lead changes. The study reveals a subtle trend towards a more balanced competition before a serious drop after 2010. The within-season competitive balance is calculated instead with a standard measure of concentration such as the Gini coefficient, outlining a negative trend meaning an improvement of competitive balance over time. Finally, concerning the inter-season competitive balance, also calculated with the Gini coefficient, the article concludes that the WDC is more balanced that the WCC. This last, was at his lowest level of balance during the 2010-2018 period, dominated by Red Bull and Mercedes.

3.3.2 Measuring competitive balance

From previous chapters, it has been claimed that competitive balance can be defined as the equality of team's level in a league. How to measure this concept constitutes a central aspect of empirical research in the business of sport. There are many ways used in the literature to analyse competitive balance, and among the more frequent, those worth a mention: the Gini coefficient of win percentages, the Gini coefficient of the concentration of championships, the standard deviation of win percentages, or the Herfindahl Hirschman Index (HHI) (Zimbalist, 2002). In his paper, Humphreys (2019) provides an exhaustive guide to measure competitive balance summarizing the commonly measures and calculations.

Measures of competitive balance in sports leagues can be divided into two main categories: static measures and dynamic measures (Szymanski et al., 2002). The first classification reflects the dispersion of winning percentages. According to Humphreys (2019, p.78), 'the basic concept behind static measures of competitive balance is that in leagues with more competitive balance, winning

percentages will be less dispersed (…)'. More generally, most of this kind of measures utilise the standard deviation as the basic measure, such as the standard deviation of winning percentages in the season, based on the assumption that all teams have the same chance to win. In the case of a perfect parity, the standard deviation of win percentages would be:

$$\sigma = 0.5/\sqrt{N},$$

with N as the number of matches played by each team (Zimbalist, 2002).

The HHI approach is another commonly used concentration measure of competitive balance. As reported by Humphreys (2019, p.84), to calculate the HHI index, you have to 'take the share of the outcome for each team (whether share is first place finishes, championships, wins or points) over some period of time (one season or multiple seasons), square that number, and then sum the values across all teams.' The HHI index is consequently expressed as follow:

$$HHI = \sum_{i=1}^{N} s_i^2$$

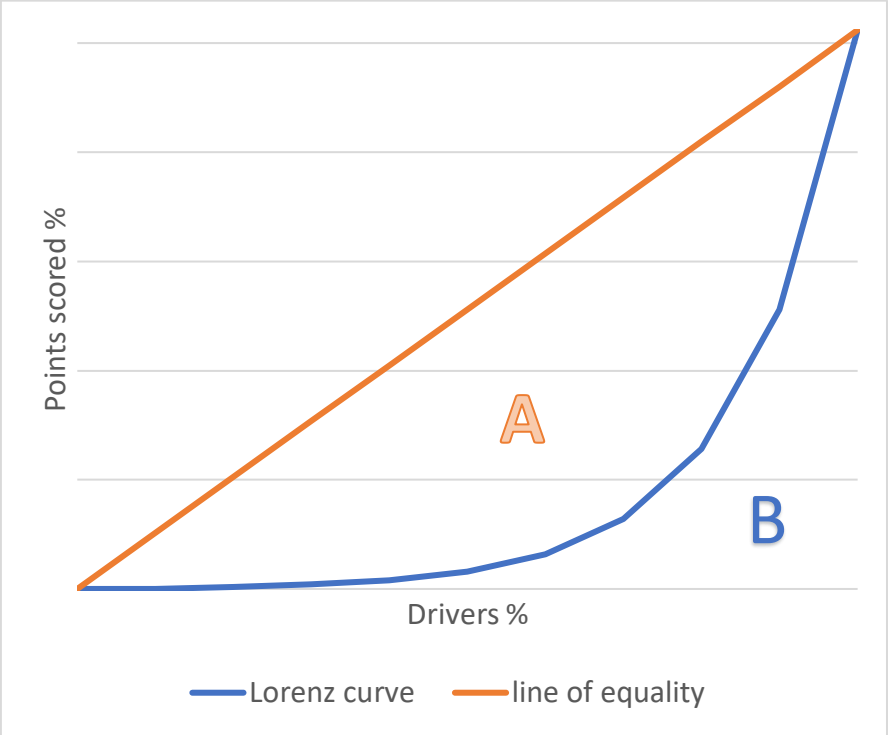
The higher the index, the higher the outcomes' concentration, the less competitive balance.

Dynamic measures of competitive balance allow to capture variations in competitive balance over time. They incorporate indeed both within-season and inter-season calculations. Humphreys (2019), proposes two specific measures: firstly, the Competitive Balance Ratio, comparing the within-team and within-league variation in winning percentages; secondly the Markov Transition Probability approach, capturing changes in teams' success over multiple years.

The Gini coefficient is another useful tool to quantify competitive balance. This concentration index is frequently used in other team sports like baseball and American football (Utt & Fort, 2002), but could be very interesting to apply it to the motor racing industry. In their study, indeed, Krauskopf et al. (2010) utilise the Gini coefficient to analyse competitive balance in Formula 1. The Gini coefficient is a statistical measure of economic inequality (CFI, 2022). From a graphical point of view, according to the website OECD (2006), 'the Gini index measures the area between the Lorenz curve and the hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line'. In other words, considering the graphical representation in figure 1, the Gini coefficient is calculated from the ratio of area A to the sum of area A and B. The index can vary from 0 to 1 (or 0% to 100%), with 0 representing the perfect equality and 1 the absolute inequality. Considering F1's perspective, the Gini coefficient could be calculated by using the x axe for the percentage of the drivers and the y axe for the percentage of points won by drivers. Therefore, the hypothetical line of equality shows the situation where all drivers gain the same points and the Lorenz Curve represents the real concentration of points gained (Krauskopf et al., 2010). The Gini coefficient quantifies the actual disparity in points scored by the drivers through the season. On one hand, a

significant Gini coefficient implies an important inequality representing a small competitive balance. On the other hand, a small Gini coefficient indicates high equality in the league and therefore a high level of competitive balance.

Figure 1: Graphical representation of the Gini coefficient.



Other interesting ways to measure and analyse competitive balance in F1 could be founded in Budzinski & Feddersen's (2019) paper, in which they distinguish three dimensions of competitive balance: within-race, within-season, and inter-season competitive balance. One of the most common measures of within-race competitive balance in the literature is the number of lead changes in F1 races (Berkowitz et al., 2011; Judde et al., 2013; Budzinski & Feddersen, 2019). This indicator makes it possible to analyse uncertainty of race outcome, while providing elements at the top of race ranking. The higher the number of lead changes, the higher the competitive balance of the race. Berkowitz et al. (2011) give another example of within-race competitive balance's measure, namely the margin of victory. However, in this case, only information about the difference between the first and the second drivers are provided. Finally, another measure which considers the rest of the field more broadly as well, is the Gini coefficient of qualification times (Budzinski & Feddersen, 2019).

To conclude, having seen the various possibilities on how to measure competitive balance in F1, this article will use two in particular: the Gini coefficient in the case of inter and within-season competitive balance, and the number of lead changes in the case of within-race competitive balance.

4. Data and methodology

4.1 Data: source and treatment

For this study, in order to analyse the evolution of competitive balance over the years and the impact of teams' budgets on race's performance, a statistical dataset of F1's indicators has been constructed over a 12-years period, from 2010 to 2021. This choice is attributable to several reasons. Firstly, because the current race point system was introduced right in 2010, which facilitates the analysis of teams' and drivers' performances. Secondly, previous studies related to the subject of competitive balance in F1, generally covered a period before 2010 (Judde et al., 2013, Krauskopf et al., 2010; Mastromarco & Runkel, 2009), reason why it is interesting to continue an analysis in this sense. That being sad, from a perspective of team's budgets, there was equally a lack of reliable data before 2010, which led to the decision to analyse a period after that year. Eventually, in 2010 a new Concorde Agreement was signed, which introduced for the very first time a budget cap in the sport, called at the time the Resource Restriction Agreement. However, that package of technical and financial regulations led to a period of lack of competitive balance, with the domination of Red Bull from 2010 to 2013 and Mercedes from 2014 to 2021. It is therefore interesting to try to understand what did work and what did not work in terms of improving competitive balance.

For this research all statistical data were obtained from secondary sources. Drivers' and teams' performances data has been gathered primarily from the official Formula 1 and FIA websites, including the number of points scored at the end of each season for both teams and drivers. Moreover, additional information for more specific indicators such as the number of GP entries, the total race wins, or the number of lead changes per race, were obtained from three specific database websites to ensure consistency: http://www.race-database.com/f1/, https://www.racing-statistics.com/en, and https://www.motorsport-total.com/formel-1.

As regards to constructors' budgets data, it is lawful to mention that official documents of F1's teams' finances are not publicly accessible, which creates more difficulty to conduct proper research in this sense. Therefore, several sources of budget estimations were used and combined with the aim to create a reliable and consistent dataset. First of all, the online versions of the Business Book GP 2020 and 2021 (Limacher, 2020, 2021) provided a pertinent source of information regarding budget statistics, covering a period between 2015 and 2021. In addition to that, numerous motorsport magazines were consulted, such as Autosport (Rencken, 2013, 2014, 2015, 2016, 2017), Racefans

(Rencken, 2018, 2019), F1metrics (2015) and Crash (Wilkins, 2015), but also news articles like Forbes (Forbes, 2012, 2014; Stylt, 2018), and motorsport forums like F1technical (2011) and F1stats (2013). All budget data has been aligned adopting the US$ as reference currency, converted with the average exchange rate of each year, which makes the analysis more sensible and the data more comparable. In addition, being F1 a sport where constructors are over the years often rebranded, budget data of teams which have changed their name were analysed as a unique team, such as Alfa Romeo (previously Sauber), AlphaTauri (previously Toro Rosso), Aston Martin (previously Racing Point and Force India) and Alpine (previously Renault and Lotus). Table 7 (Appendix A) shows the complete dataset for F1 teams' budget and points from 2010 to 2021.

4.2 Methodology

At this moment, it is worth remembering the two main objectives of this research: on one hand to analyse trends and variations in competitive balance for WDC and WCC and over time, and on the other hand to empirically investigate the influence of teams' budget on performances, and therefore to examine whether an unbalanced distribution of budget produce an unbalanced competition. The methodological approach adopted to achieve both research objectives is structured as follow. In a first instance we will analyse the evolution of competitive balance. In the within-race case the number of lead changes will be measured, while in the case of within/inter-season competitive balance the point concentration will be calculated thanks to the Gini coefficient. In a second instance, we will focus on analysing F1 teams' budget, and in this case the Gini index is utilised as the statistical measure of reference. Finally, third part will see a comparative analysis being carried out, by correlating point concentration and budget concentration of F1 teams in the WCC.

As mentioned, the Gini coefficient is thus used as the statistical measure of reference to conduct the study. More specifically, for every season, the Gini index of teams' and drivers' ranking points, as well as the Gini index of teams' budget has been calculated. Throughout this method, it has been possible to provide an accurate picture of teams' budget concentration as well as of teams' point concentration. As explained in the theoretical background section, the Gini coefficient is a statistical measure of economic inequality, which can vary from zero (absolute equality) to one (absolute inequality). However, in the case of the F1 world championship, it is impossible that only one team scores all the points available and other teams never score points. Consequently, with the actual points system, in a hypothetical situation where the first team wins all Grand Prix (its drivers make first and second), the second team arrives always second (its drivers make third and four) and so on, the

maximum value of the Gini index will be 0.70, meaning an extreme inequality. Likewise, in the case of budget concentration, since it is reasonably unthinkable for one team to have a budget of 1000 million and the others of 1 million, the estimated maximum value of the Gini index is around 0.5. Table 8, which can be found in the appendix B, summarizes our descriptive statistics of the Gini coefficient.

5. Results

The results presented in this chapter are structured in three sections. Firstly, the evolution of competitive balance in F1 is analysed, for both within-race and within-season situation, with a special focus on the evolution of point concentration for the WDC and the WCC. Secondly, this paper examines the evolution of F1 teams' budgets and budget concentration over time. In the third place, the average budget, and points by teams, as well as the relationship between budget concentration and point concentration are analysed.

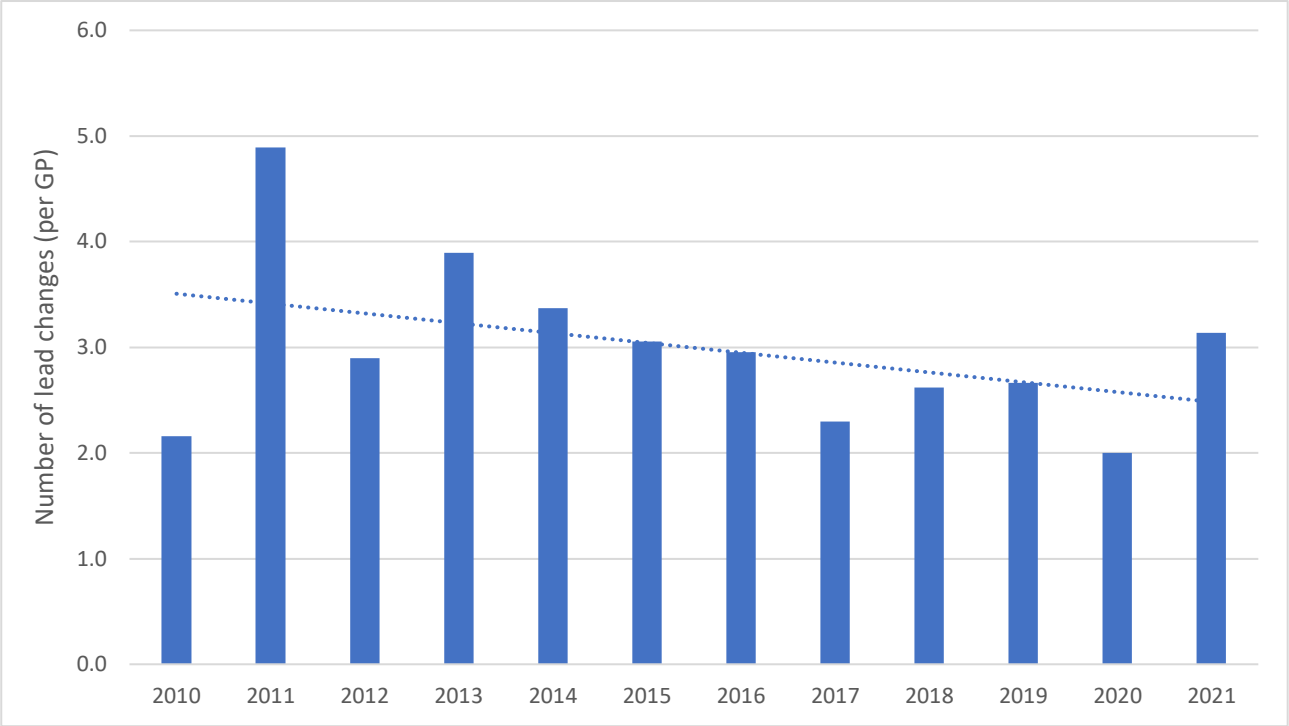
5.1 Evolution of competitive balance in F1 World Championship

The present section aims to examine the evolution of competitive balance in F1 in order to identify trends that can explain the phenomenon from 2010 and derive valuable information from it. The first part will examine within-race competitive balance, while the second one will study within and inter-season competitive balance. In this way, both uncertainty of race and season outcome will be analysed in an empirical way.

5.1.1 Within-race competitive balance

One common measure of uncertainty of race outcome utilised in the literature is the number of lead changes in F1 races (Berkowitz et al., 2011; Judde et al., 2013; Budzinski & Feddersen, 2019). Throughout this measure it is possible to analyse competitive balance of every single race in F1 World Championship. Although this measure does not provide information on the rest of the ranking, it represents an important indicator of race uncertainty, considering that a lead change in F1 it is the exception rather than the rule. It is assumed that the higher the number of lead changes, the more uncertain the race result, and therefore the higher the competitive balance of the race. Figure 2 displays the average lead changes per season from 2010 to 2021. The y-axis on the figure is showing the number of lead changes per GP, averaged for each season between 2010 and 2021.

Figure 2: Average lead changes per season in F1 races (2010-2021).



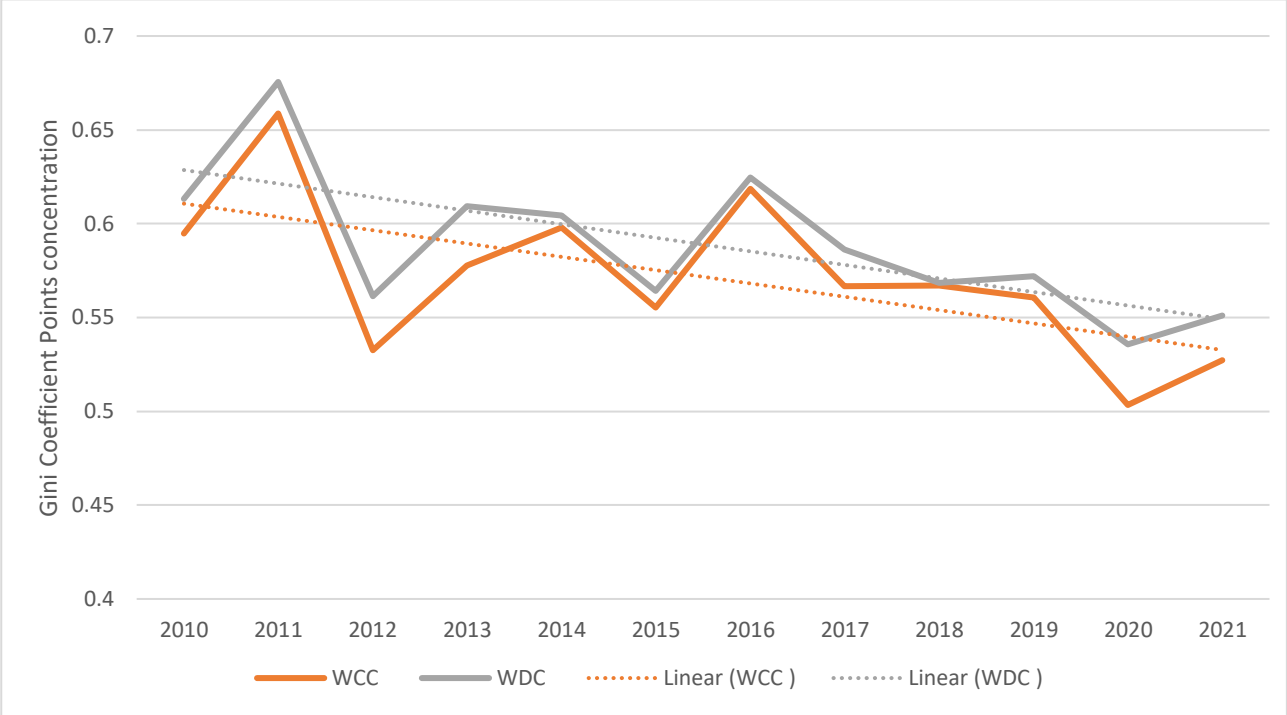
Over this period, the season with the highest number of lead changes is 2011, with a season average of approximately five changes for the lead of the race. On the contrary, the year with fewer lead changes is 2020, with just two lead changes per GP. Overall, a clear negative linear trend can be observed, implying a deterioration of within-race competitive balance over the last 12 years. Nevertheless, two years in particular are marked by an exception, 2010 and 2021. In both cases, a change in financial regulations (introduction of the RRA and the cost cap) has occurred.

5.1.2 Within/inter-season competitive balance

This part will examine the evolution of point concentration with the objective to identify potential time trends and provide a wide picture of competitive balance's level in F1. Figure 3 displays the points concentration in the two F1 World Championships, measured with the Gini coefficient, between 2010 and 2021. It is necessary to remind that a Gini index of zero indicates maximum equality between the distribution of points, while a value of one denotes maximum disparity. However, it has been mentioned that for the F1 World Championship it is impossible that only one team scores all the points available. Hence, the maximum value of the Gini coefficient calculated in

this case is 0.7. The grey line represents the trend of point concentration for the F1 WDC, and the orange line represents the WCC instead.

Figure 3: Evolution of point concentration in WCC and WDC (2010-2021).



From the figure 3 it may be noted that the value of the index is, overall, quite significant. Considering that the maximum value is 0.7, the coefficient of both championship is higher than 0.6 multiples times, highlighting a strong disparity in points distribution and therefore meaning that the competition is very unbalanced. The average value over this period is 0.57, even if there are some important fluctuations. Indeed, the most unbalanced year is 2011, with a Gini index of 0.67 for the WDC and of 0.66 for the WCC. On the contrary, 2020 is the most equilibrated year in terms of points distribution, although with a high value, with a coefficient of 0.5 for the WCC and of 0.53 for the WDC. From the figure it appears more broadly that the grey line always has a higher coefficient, which means that the WDC is more unbalanced that the WCC. Nevertheless, as it can be seen by the dotted lines, both championships undergo a similar trend linearly decreasing, which results in an improving level of competitive balance in the competition over the last 12 years. Two exceptions characterise the downward trend: from 2012 to 2016 but also after 2020, an upwards evolution can be noted.

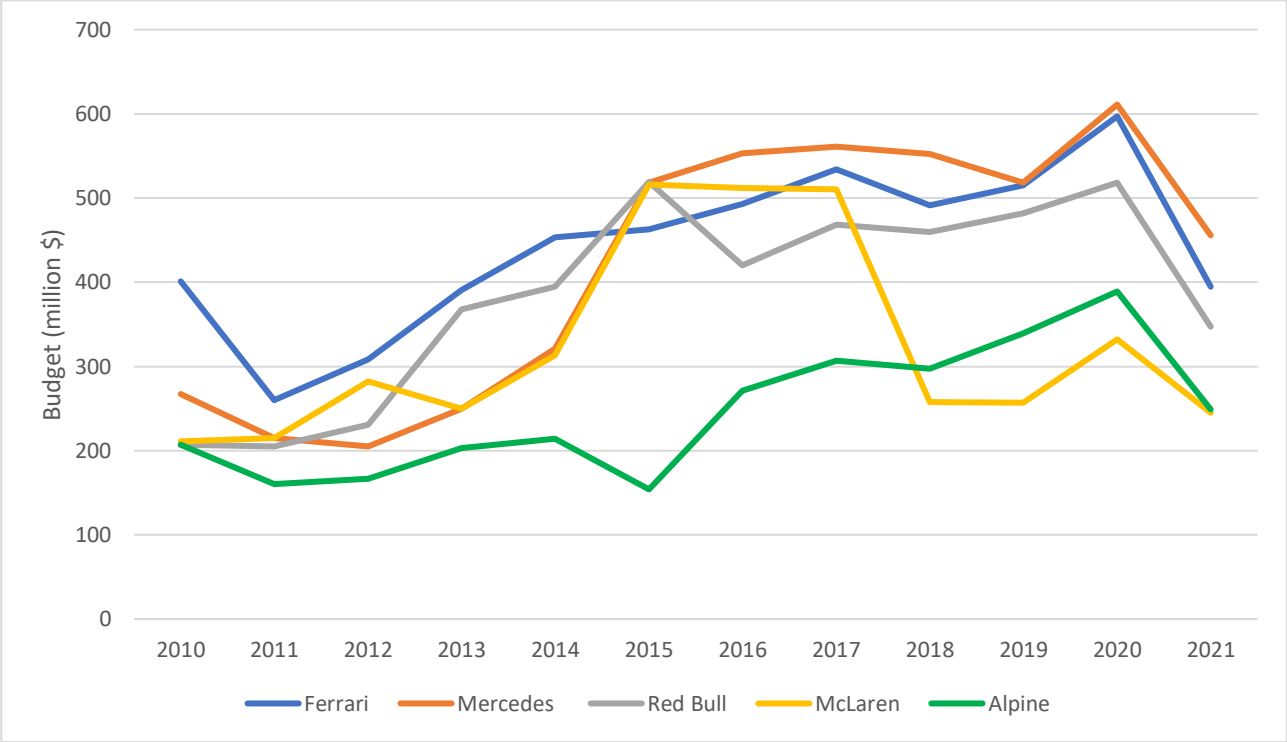
5.2 Evolution of F1 teams' budget

In this section, the evolution of F1 teams' budget is analysed. The first part will consider the evolution of budget for the top five team. In the second part, the evolution of budget concentration is examined in order to debate the level of competitive balance in respect of teams' finances.

5.2.1 Evolution of top five F1 teams' budget

Figure 4 illustrates the evolution between 2010 and 2021 of the budget of the top performer F1 teams during this timelapse: Ferrari, Mercedes, Red Bull, McLaren and Alpine. The budgets, which are measured in million $, are unofficial estimates since official data are not publicly accessible.

Figure 4: Evolution of the budget of the top five F1 teams (2010-2021).



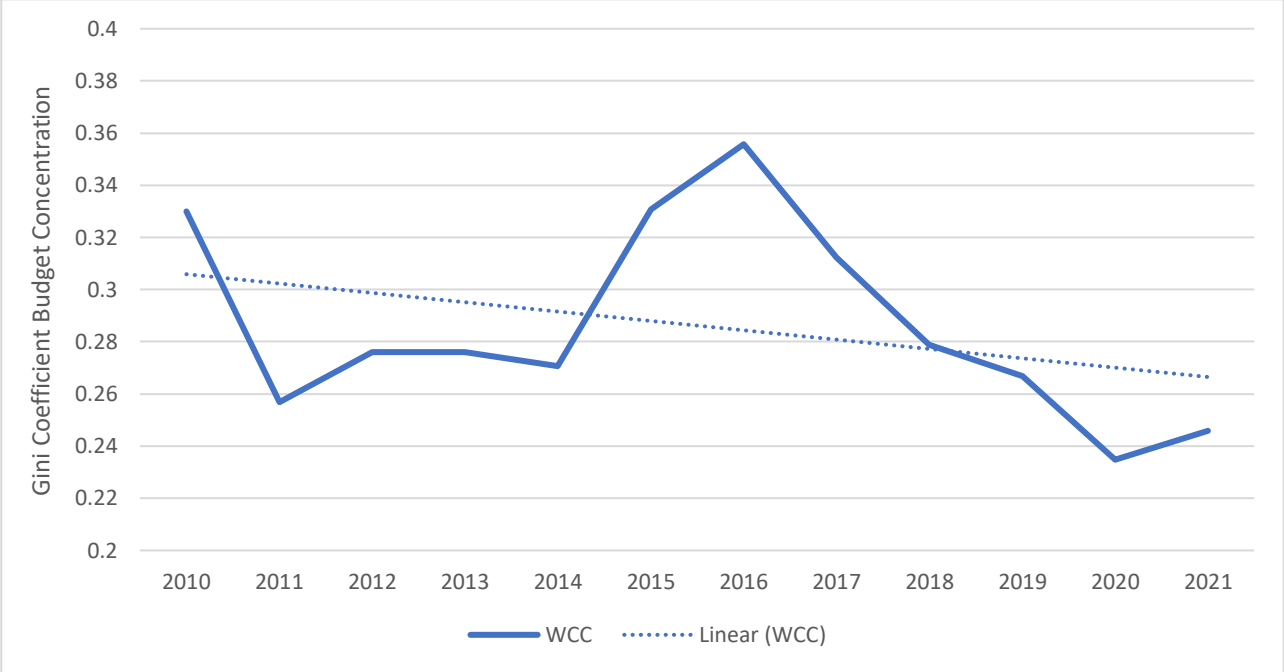
It appears that most budgets follow a similar trend: expect between 2010 and 2011, a clear upward trend can indeed be seen until 2020, after which a sharp decrease is seen. The only two times when budgets have decreased for all teams are thus in 2011 and 2021. In both moments, a new financial regulation was introduced by FIA with the aim to reduce the gap between the richer and the poorer teams, as well as to reduce the general expenditure. In 2011 the Resource Restriction Agreement came into force, while in 2021 the new budget cap was implemented. The decade between these two

occasions has seen a steady increase in budgets, peaking in 2020. During this period, Ferrari and Mercedes had the larger budget, followed by Red Bull, McLaren and Alpine. Overall, it is permissible to mention that the three richest teams have raised their budget in an impressive way, touching sum of money three or four times higher than weaker teams, going from $ 250 million to $600m in only ten years. F1 teams' budget significantly declined in 2021 with the implementation of the cost cap, which has the intention to promote a more competitive championship and ensure the financial stability of the teams.

5.2.2 Evolution of budget concentration

This part examines the evolution of budget concentration with the objective of providing a general overview of competitive balance's level in F1 based on the distribution of wealth. Figure 5 depicts budget concentration coefficients in the World Constructor Championship between 2010 and 2021. The minimum value of the Gini coefficient in this case is zero, whereas the maximum value in a realistic case of team's budget is around 0.5.

Figure 5: Evolution of budget concentration in WCC (2010-2021).



First, from figure 5 a quite irregular trend of the WCC coefficient can be observed. The index values vary between 0.36 and 0.22, indicating therefore a certain imbalance in teams' budgets. Interestingly, the line of the WCC shows a u-shaped development over the observation period, with lows in 2011

and 2020 and highs in 2016. Overall, as showed by the dotted line, the budget coefficient of the WCC undergo a linearly downward trend, which translates into an improvement of wealth distribution amongst F1 teams.

5.3 Relationship between teams' budget and teams' performances

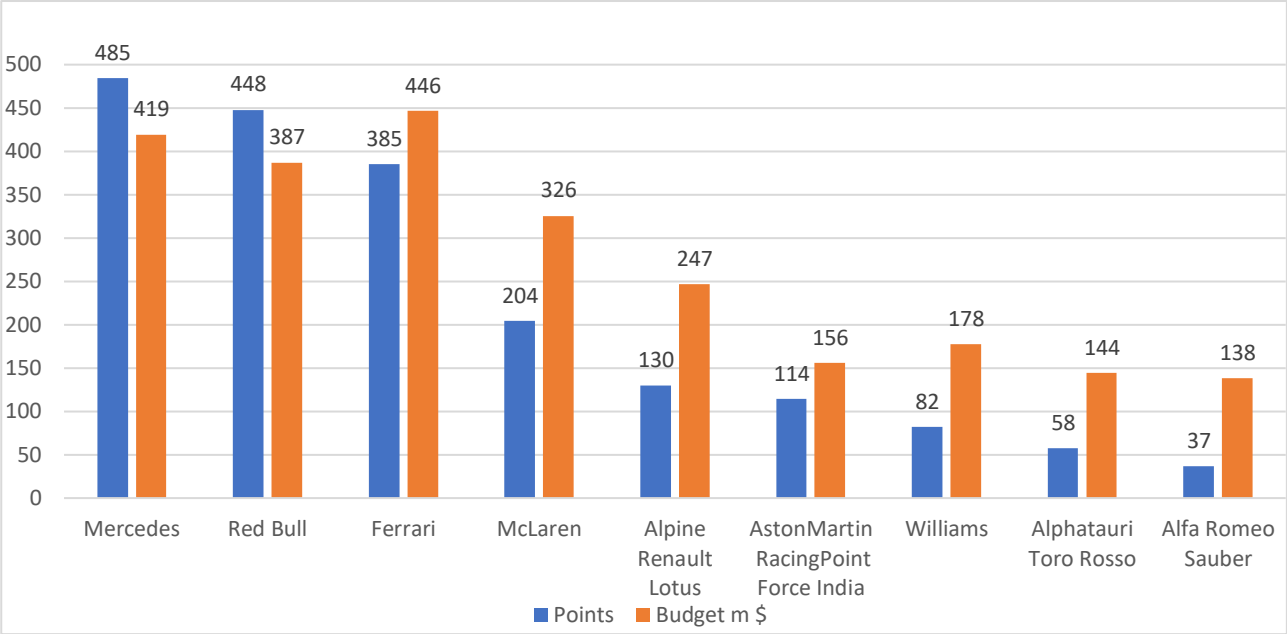
The final section presents the relationship between teams' budget and teams' performances, with the aim to evaluate how F1 teams' budget effectively influences their performances in terms of championships points. First, we examine the average budget and points by team for the last 12 years. Second, to critically assess competitive balance in F1, an analysis of the relationship between budget concentration and point concentration is undergone.

5.3.1 Average budget and points by F1 team

The aim of this part is to provide a big picture of the level of teams' budget and their performance in terms of points over the observation period. Figure 6 exhibits the average F1 teams' points as well as the average F1 teams' budget over a twelve-years period between 2010 and 2021. The x-axis on the figure is showing the various F1 teams that has competed in the F1 World Championship during the past decade. Some of them have been rebranded over the years, such as Toro Rosso who became AlphaTauri, but in this figure they have been put together to facilitate the analysis. The blue bars display the number of points each team scored averaged over the observation period, while the orange bars display the average budget of each team in million $.

Figure 6 shows that Mercedes scored the highest number of points since 2010, with an average of 485 points per season, followed by Red Bull with 448 points and Ferrari with 385 points. It is therefore not surprising to remember that Red Bull dominated the Constructors Championship with four consecutive titles from 2010 to 2013 and Mercedes won eight consecutive constructors' titles since 2014. The mid-field's teams are McLaren, Alpine and Aston Martin, with an average of 204, 130 and 114 points per season respectively. At the bottom of the ranking in terms of performances over the last 12 years, there are Williams with 82 points per season, AlphaTauri with 58 points and Alfa Romeo with merely 37 points per season. In addition, it can be noted that the differences in terms of points scored is drastic between the participating teams, indicating an unbalanced competition.

Figure 6: Average teams' points and budget between 2010 and 2021.



Afterwards, we examine the level of the budget of each constructor team since 2010. It appears from figure 6 that Ferrari has the biggest budget of the field with $446 million on average, followed by Mercedes, the only other team to boasts a budget higher than $400 million, with $419 precisely. Red Bull is close to the leaders with an average budget of $387 million, while McLaren, the fourth ranked team has a budget of $326 million, more than $100 million less than the richer team, Ferrari. In fifth position comes Alpine with $247 million, which is around $200 million less than Ferrari. Finally, the four teams at the bottom of the ranking are Williams, Aston Martin, AlphaTauri and Alfa Romeo, with a budget of $178 million, $156 million, $144 million, and $138 million respectively. Overall, the figure shows that the last team (Alfa Romeo) has three time less money than the richer team (Ferrari), highlighting an important disparity for teams in the same competition.

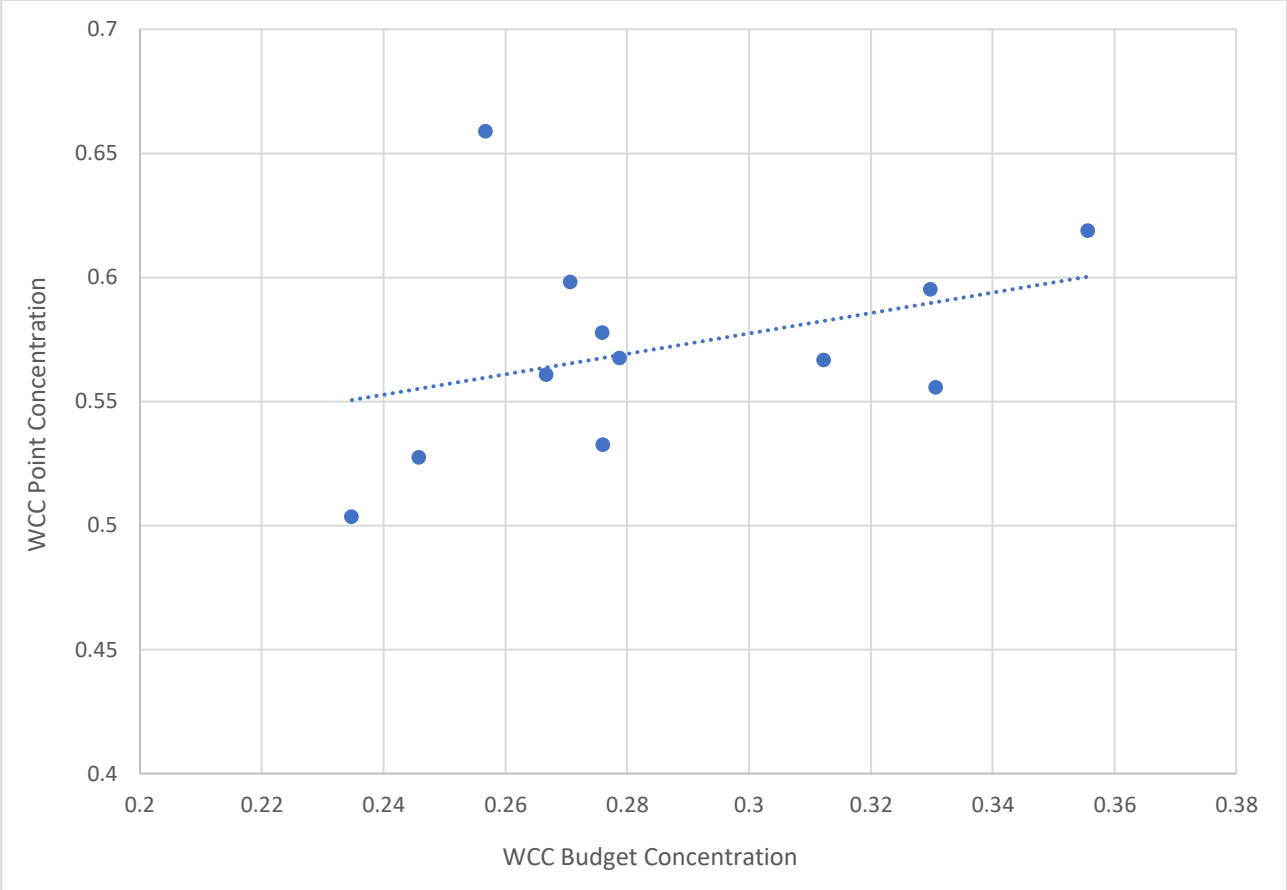
It is important to note that the average values of teams' budget and points are comparable. The higher the budget of a team, the higher the number of points scored. The smaller the budget, the fewer points the team scores. Two small exceptions aside, for Williams and Ferrari, the ranking of the average budget over 12 years is the same as the ranking of points made.

5.3.2 Correlation between budget concentration and point concentration

After initially analysing, on one hand the evolution of point concentration and, on the other hand the evolution of budget concentration, this part combines them with the aim of finding a common

relationship. This will enable us to understand how the budget imbalance influences the unbalance of points, and therefore, to analyse the competitive balance in Formula 1 world championship. Figure 7 exhibits the correlation between budget concentration and point concentration in a scatter plot expressed with the Gini coefficient.

Figure 7: Correlation between budget and point concentration (2010-2021).



The dots represent the level of budget concentration and point concentration for each year, in the world constructor championship. Since the observation period covers a timeframe of 12 years, the scatter plot is composed by 12 points. It appears that the trend line follows an upward trend, which signifies a positive correlation between budget and point concentration. The scatter plot shows therefore that the more unbalanced the budgets, the less balance there is in points distribution and thus the lower the competitive balance in the championship. Figure 7 thus provides scientific evidence of the influence of budget on team performance.

6. Discussion

6.1 Discussion of findings

F1 world championship is peculiar because it consists of a hybrid form combining both individual and team sports' aspects within two championships. F1 motor racing can indeed be full-fledged considered a closed league competition, including the WDC and the WCC. F1 is also peculiar because of its three components' nature. It is a combination of driver performance, car performance and mechanical engineering. In this context, money play an important role, even more that in any other team sport. Moreover, it is difficult to control teams' finances since some constructors' teams work in collaboration with their own automotive brand.

A set of technical, financial, and sporting regulations is set every year to manage the competition and establish the rules for the upcoming season, to which teams must refer. However, although F1 cars must fulfil the regulations, teams can still autonomously design their own cars within their budget. This last aspect affects indubitably the competitive balance of the competition and represents a major issue for the sport. According to Budzinski & Feddersen (2019, p.2) indeed, 'during the past two decades, an ostensible lack of competitive balance amongst participating teams has continuously been one of the biggest issues for the governance of F1'. Even if it boasts the highest driver's quality possible, F1 needs its competition to be more balanced in order to remain attractive. The situation that saw Lewis Hamilton win six of the last seven driver championships, and his team Mercedes all constructor's championships between 2014 and 2020, brought to a decreased fan interest in the sport. The 2021 season was an exception, because of the very close battle at the top of the ranking between Hamilton and Verstappen. As confirmed by an academic point of view by Krauskopf et al. (2010, p.4), 'a duel at the top leads to more attractiveness'.

Since the little literature relating to the topic agrees with the fact that competitive balance in F1 is too low and represents an issue for competition managers, this study aims to update the research until 2021. In addition to this, the analysis will be pushed forward by including the influence of teams' budget on performance, and thus on the equilibrium of the competition. Throughout the construction of a reliable dataset, we have been able to analyse competitive balance in F1 between 2010 and 2021. Our results are structured in three sections: the first one focuses on the analysis of within-race and within/inter-season competitive balance, the second one analyses the budget of F1 teams, and the third and final one correlates point and budget concentration.

The first section of our results analyses both within-race and within/inter-season competitive balance, to identify the evolution of the latter. In the first case, a clear negative linear trend has been observed, which results in a decreased uncertainty of race outcome over the observation period. The reduction of the number of lead changes implies that F1 races are more predictable. This is a problem that could cause a fall in fan interest and in sport's attractiveness as well. Since fans are indeed more engaged when the outcome is unpredictable, F1 must address this issue in order to avoid a decrease in revenue (broadcasting revenue especially). In the case of within/inter-season competitive balance, the point concentration is measured with the Gini coefficient for both the WDC and the WCC. Results show that the driver championship is a little more unbalanced than the constructor championship, but both undergo a similar trend linearly diminishing. This can be translated into an improvement of competitive balance's level from 2010 to 2021. The longstanding willingness of F1 managers toward a more balanced competition seems to be starting to show some results. However, it must be noted that the value of the Gini index is overall quite important, which still highlights a strong disparity in point concentration. Thus, the competition remains very unbalanced, and the uncertainty of championship outcome is weak. To summarize, the direction is the right one: the inter-season competitive balance in F1 world championship is improving. Nevertheless, it remains some work to do before having a balanced competition, because the within-race competitive balance is reducing. In this sense there is a lot of hope in the new set of technical regulations for 2022.

The results' chapter examines, in the second section, the evolution of teams' budget on one hand and the evolution of budget concentration on the other hand. Regarding the evolution of the level of teams' budget, to facilitate the analysis, only the top five teams has been considered. Here, a similar upward trend has been observed from 2011 until 2020, which means that teams' budgets are steadily increasing over the last 12 years. Interestingly, in two occasions (2011 and 2021), there has been a considerable drop of teams' budget. It is no coincidence that it occurred following the introduction of new financial regulations. In 2011, the FIA introduced the Resource Restriction Agreement indeed, an initial form of budget cap, while in 2021, the new cost cap was implemented. However, it is important to mention that the significant drop in teams finances this year is also a consequence of the Covid19 pandemic in 2020, that strongly impacted revenues of the entire sport. The $145 million cost cap introduced in 2021 had the objective to reduce operating costs, by limiting the amount of money that teams can spend in a calendar year (Barretto, 2020b). It can be easily deduced the desire of F1 owners to improve the competitive balance of the league, to make the sport even more attractive. The influence of Liberty Media, as an American company, can be seen in this situation. Indeed, in 2022

another set of rules came into force; in this case for the new technical regulations that will allow F1 cars to overtake more easily.

With regards to budget concentration, our results highlight an irregular trend of the Gini coefficient for the WCC. The index's value shows lows in 2011 and 2020 and a peak in 2016, where it measures 0.36. This represents a very high level of competitive imbalance regarding money distribution. In other words, there are big disparities between the budgets of the teams. Basically, there are wealthy ones and other with budgets four time smaller. Nevertheless, the linear trend line is downward, indicating an improvement of budget concentration among F1 teams. This could be a consequence of several factors, but the Covid19 pandemic in 2020 as well as the 2021 cost cap played an important role for sure. F1 teams' expenditures need to be better controlled and especially reduced in order to ensure the long-term financial stability of the league, but also to promote a more level playing field.

The third section our results examines the relationship between budgets and performance. First, the average values of teams' budget and teams' points over a twelve-years period has been analysed. Results show that the values are comparable: the more money a team has, the more points it scores. Overall, the ranking of average budgets is very similar to the ranking of average points. Consequently, this indicates once again that the competition is predictable, and thus, less attractive.

With the purpose to provide a more scientific analysis, the final section our results combine the evolution of point concentration with the evolution of budget concentration, through a scatter plot. This allows to understand the influence that budget imbalance plays to points unbalance. The relationship between these two statistical measures highlights a positive correlation, meaning that the more unbalanced the budgets, the more unbalanced the league. Thus, our results provide scientific evidence that money distribution among F1 teams clearly affects the competitive balance in the league. In other words, this study suggests that the more inequality in wealth distribution between F1 teams, the less competitive balance in the F1 world championship. We therefore align with what is quoted in the literature, "teams that spend the most tend to win the most' (Fort, 2006, p.3, cited by Judde et al., 2013). Hence, in F1, money clearly do affect performance, more than in any other sport, which reduce the competitive balance of the league.

6.2 The future of Formula 1

As mentioned previously, in 2022 a new set of technical regulations was introduced by the FIA. Furthermore, it must be remembered that the budget cap at $145m was implemented the previous year, and that it will drop at $140m in 2022. This new set of technical rules has been presented as a

revolution, featuring a game changing design for F1 cars, specifically designed to promote better racing (Stuart, 2021). The principle is simple: F1's competition designers want a more balanced competition, and cars allowing closer racing and more overtakes. The desire to enhance both within-race and within-season competitive balance has never been this high. The American ownership of F1 is trying to improve as much as possible the attractiveness of the sport, and thus boring races are not desired. The 2022 regulations highlight indeed the willingness to enhance race and championship unpredictability.

Those changes mean a new generation of F1 cars. The first key change relates to the ground-effect floor, a concept popular in the 1970s. The goal of this feature is to create a bigger and better-preserved downforce, which enables closely following of cars and thus, enhances the likelihood of overtaking. The second major change relates to the simplified front wing and a new rolled rear wing, both designed to send airflow outwards and create less dirty air. The third fundamental rule transformation is that cars will feature, for the first time, 18-inch low profile tyres but also over wheel winglets. The lower profile tyres will reduce its overheating and thus helping closer racing, while the winglets will help direct air away from rear wing (Stuart, 2021). Overall, it can be simply noted that all those new features have the objective of creating better and closer racing, that aims to enhance the show of the competition. There is much hope for those rules since the last few years were characterised by too much competitive imbalance.

Apart from these regulations, some other actions could be taken for the purpose of enhancing the attractiveness of the competition by ameliorating the competitive balance. This part aims to resume some of the causes of competitive imbalance in F1 over the last years, and to suggest some recommendations for competition designers that could improve the situation of this sport's future.

First, one of the main aspects affecting competitive balance in F1, relates to the basic design of the competition. As opposed to other motorsport competitions, where every car is the same, in F1 each constructor team can develop its own F1 car within FIA's rules. However, this directly influences the equilibrium of the competition. It has always been the case and represents one of the core values of F1, where a big goal is technological innovation. It is not only a contest between drivers and teams, but also from a mechanical point of view. Here the question arises: do F1 still need this mechanical aspect, or should it focus on the purely sporting dimension? It probably does, since the engineering part plays a crucial role for a huge proportion of motorsport enthusiasts. But it will worth a thought.

Secondly, another cause of competitive imbalance in the sport is about big differences in teams' budgets. Such a situation can be related to the prize money distribution's system. Indeed, the way the

revenue sharing is distributed among participating teams by F1 owner is odd and unbalanced. The first step to be taken should be to immediately stop odd individual payments to Ferrari, Red Bull, Mercedes, McLaren, and Williams. The second one is to adopt a more equal sliding scale for the revenue prices based on the championship ranking. As mentioned previously in the subchapter 2.3.2, in F1 the first ranked team earns four time more than the last ranked, while in the Premier League for instance, the difference between the first and the last is only 1.8 times (Premierleague, 2016). Our suggestion is to reduce as much as possible such disparities in teams' payments, by adopting a more equal sliding scale in revenue sharing between the first and the last ranked team at the end of the season. This solution will benefit both the financial stability of teams and the competitive balance in the championship.

A third aspect which affects competitive balance in this sport can be related to regulation changes. Over the last years indeed, some rule changes have been introduced with the only aim to improve competitive balance and increase fan interest. Mastromarco & Runkel's (2011) research conclude that competitive balance's regulations have resulted in a significant positive impact on uncertainty of outcome. Also, Judde et al. (2013) demonstrate that uncertainty of championship outcome has a key role to the introduction of new technical regulations. Consequently, some revolutionary regulations could be considered. For instance, the actual point system could be questioned. Nowadays, the winner scores 25 points while the second only 18, with a difference of even seven points (more than the seventh placed). Since its introduction in 2010, F1 has in fact experienced a decade of extreme competitive imbalance. But in the past, the point system was more equal; for example, from 2003 to 2009 it foresaw ten points for the first, eight for the second and six for the third. Thus, a return to the origin may be considered. Another revolutionary sporting regulation change that should be carefully thought about concerns the introduction of a drivers' salary cap. It has never been the case in F1 before, but with the introduction of a budget cap for teams, the equivalent for drivers becomes thinkable. Today top teams can afford two superstar drivers, while low profile teams have to be contended with two rookies. An initial salary cap of $30 million, for instance, could force teams to pair a superstar with a rookie driver or with two medium drivers. Probably, this is going to create a large debate in F1 world in the near future.

Overall, it can be said that there still are some ideas that could eventually become effective regulations having the pure objective to enhance the competitive balance in F1, but they will require a constant evaluation of the situation before entering into force.

6.3 Limitations of the study

To conclude, attention should also be drawn to mention some limitations of this study. Firstly, the major issue concerns the fact that all budget data are estimations and not official figures, since the latter are, justifiably, not publicly accessible yet. Because of the introduction of new financial regulations, as well as of the budget cap, teams will have to provide accounting evidence of their expenditures and therefore it will be possible to have more reliable financial data later.
Another limitation of this research is that there are different ways to measure competitive balance in motorsport. On one hand, considering within-race competitive balance, the relative distance between the first and the second driver (margin of victory), or the distribution of qualification times could be used. On the other hand, regarding within-season competitive balance, the HHI ratio, the Spearman's rank correlation coefficient, or the number of different race winners are other possible indicators that could provide more accurate results in additional analyses. Moreover, further research could use a linear regression model to analyse more deeply the relationship between points concentration and budget concentration.
An additional limit of the study is the timeframe of the analysis, being only a twelve-years period, from 2010 to 2021. Although the reasons of this choice have been explained previously, a deeper analysis should consider a longer timeframe. For instance, both Judde et al. (2013) and Budzinski & Feddersen (2019), examine competitive balance in F1 from 1950.

In conclusion, an interesting topic for further research could be to investigate the effects of competitive balance on fan demand. In this case, in the literature only Krauskopf et al.'s (2010) paper analyses the determinants of attractiveness of F1 indeed. It would be very useful for competition designers to better understand how fans react to the introduction of new regulations that have the objective to enhance the attractiveness of the competition. It will therefore be possible to know how much competitive balance is required in order to create a fascinating contest that will generate more revenues. In such a case, it would be interesting to explore the possibility to conduct a qualitative analysis, interviewing both sides: fans and competition managers.

7. Conclusion

Formula 1 is an atypical form of competition that can be considered a closed league from a sports economics dimension. Professional sporting leagues are peculiar since they are subject to fan demand. An attractive sports competition requires indeed high uncertainty of outcome, which in other words, means that the final result cannot be predictable. Assuming that outcome uncertainty is determined by the level of competitive balance, this represents a key determinant of the attractiveness and the financial stability of sporting leagues. F1 is also peculiar whereas its hybrid nature, combining drivers' abilities with team (or car) performances and mechanical engineering. Furthermore, even if teams must fulfil the FIA official regulations, they can still develop their own F1 cars within their budget. Since there are significant differences in team wealth, this has indubitably an impact on the equilibrium of the competition.

This study analysed competitive balance in F1 from 2010 to 2021. After having presented what the F1 motorsport represents, its history, its structure, and its characteristics, attention was focused on the literature review related to the economics of sporting leagues, as well as to the concept of competitive balance and sport attractiveness. The research had two major aims. Firstly, it examined trends and variations of competitive balance for both the WDC and the WCC as well as over time. Secondly, it empirically investigated the influence of teams' budgets on performance, and therefore it tried to understand whether an unbalanced distribution of budgets produces an unbalanced competition. Since a lower level of competitive balance is undesirable because it reduces the outcome uncertainty of the competition (for both race and championship) and thus the attractiveness of the sport, it represents nowadays a crucial aspect for competition designers.

Regarding the evolution of competitive balance between 2010 and 2021, we found that within-race competitive balance is reducing, meaning that F1 races are more and more predictable, and thus less interesting. Instead, we observed a slight improvement in within and inter-season competitive balance, measured with the Gini coefficient for points distribution in both WDC and WCC. Even though the situation is getting better, a strong disparity in point concentration has been identified over the observation period, which means that the competition remains very unbalanced. Being the uncertainty of the championship's outcome low, the attractiveness of the sport suffers, jeopardising fan demand and overall revenues as well.

About F1 teams' budgets, the study analysed the evolution of budget figures in the first instance and the evolution of budget concentration in the second instance. Considering the budget of the top five F1 teams, a linearly increasing trend appeared, meaning that team expenses are steadily increasing since 2010. However, in two occasions (2011 and 2021), a significant drop in team budgets has been observed. In both cases, it can be explained by the introduction of a new financial regulation specifically designed to reduce team expenditures. The evolution of budget concentration in the WCC has been analysed to provide an accurate picture of the wealth distribution among teams. It appeared an irregular trend slightly decreasing, which denotes a subtle improvement of budget concentration. Nevertheless, since the Gini coefficient's values are quite high, it means that there are big disparities between teams' budgets. Hence, money distribution in F1 is unbalanced.

Eventually, this research examined the relationship between budget and performance. Throughout a scatter plot, the evolution of budget concentration has been correlated to the evolution of point concentration. This statistical measure highlighted a positive correlation which implies that the more unbalanced the budgets, the more unbalanced the competition. Thus, our study provides scientific evidence that wealth distribution among F1 teams has indubitably an impact on the competitive balance of the league. Moreover, we demonstrated that the ranking of average teams' budgets is very similar to the ranking of average teams' points over the observation period. This means that the competition is more predictable and thus less attractive. In F1, money does affect performance and reduces the competitive balance in the sport. For this reason, team expenditures need to be better controlled and reduced to ensure the long-term financial stability of the league, but also and specially to promote a more level playing field.

Besides the contribution to sports economics and the subject of competitive balance in sporting leagues, this study widens the little literature related to F1. Our research provides an empirical analysis of competitive balance and its dimensions (within-race, within-season, and inter-season) for both the WDC and the WCC and over time and offers examples of how to measure it. In addition, the analysis has been extended including teams' finances and their influence on performance. Thus, this study contributes to the existing literature by closing the gap regarding F1 teams' budget analysis. Further research in this sense could apply a linear regression model for an even better understanding of the correlation between points and budget concentration.

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Appendix A

Table 7: F1 teams points and budget data (2010-2021).

	2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021	
Team	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*	*points*	*Budget (m)*
Mercedes	214	267	165	215	142	206	360	250	701	321	703	518	765	553	668	562	655	553	739	518	573	611	613.5	457
Red Bull	498	207	650	205	460	231	596	368	405	395	187	519	468	421	368	486	419	461	417	483	319	518	585.5	347
Ferrari	396	402	375	260	400	309	354	391	216	453	428	464	398	494	522	535	571	491	504	515	131	597	323.5	396
McLaren	454	212	497	215	378	283	122	250	181	313	27	516	76	512	30	511	62	259	145	258	202	332	275	245
Alpine/ Renault	163	207	73	160	-	-	-	-	-	-	-	-	8	271	57	307	122	298	91	339	181	389	155	250
Williams	69	131	5	125	76	167	5	141	320	173	257	206	138	183	83	214	7	218	1	162	0	233	23	141
Aston Martin/ R.P./F.I.	68	120	69	120	109	116	77	156	155	165	136	143	173	145	187	164	52	139	73	168	195	230	77	201
AlphaT../ Toro Rosso	13	126	41	105	26	107	33	110	30	148	67	152	63	134	53	140	33	162	85	154	107	231	142	159
Alfa Romeo/ Sauber	44	71	44	90	126	116	57	141	0	148	36	114	2	121	5	103	48	162	57	208	8	242	13	144
Haas	-	-	-	-	-	-	-	-	-	-	-	-	29	86	47	133	93	149	28	161	3	186	0	128
Lotus	0	80	0	95	303	167	315	203	10	214	78	154	-	-	-	-	-	-	-	-	-	-	-	-
Marussia/ Manor	0	56	0	65	0	67	0	80	2	115	0	92	1	83	-	-	-	-	-	-	-	-	-	-
Caterham	-	-	-	-	1	93	0	102	0	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HRT	0	51	0	50	0	59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix B

Table 8: Descriptive statistics of the Gini coefficient.

	max	min	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
WCC gini points	0.7	0	0.59488	0.65872	0.53243	0.57757	0.59784	0.55534	0.61866	0.56653	0.56712	0.56056	0.50337	0.52723
WDC gini points	0.7	0	0.61319	0.67552	0.5614	0.60933	0.60436	0.56426	0.62466	0.58633	0.56853	0.57206	0.53568	0.551
WCC Gini budget	0.5	0	0.32987	0.25684	0.27612	0.27594	0.27067	0.33075	0.35573	0.31233	0.27876	0.26679	0.23478	0.24581