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‘What are the determinants of demand for Formula One broadcasts in the United States’

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ABSTRACT

This research explores the determinants of demand for Formula One racing in the United States of America and pays specific attention to the relationship between outcome uncertainty and broadcasting demand (viewership figures). The work is timely on two fronts. First, little attention has been paid to demand for Formula One in a growing sports economics literature which considers consumer preferences for different sports. Second, the past decade has witnessed an unprecedented concentration of wins in the hands of a limited number of drivers and teams. As such, this research is motivated by the desire to establish superior measures of race-level balance to reflect this growing dominance. By considering outcome uncertainty using implied probabilities derived from market odds, along with a running total of world drivers and constructors championship points, this work offers a new and improved approach to those currently established in the literature. As the United States is a key broadcasting market for the Formula One Group, the research has practical implications and can offer insights into the determinants of demand in the most important market for the sport. At present research has only examined broadcasting demand in the German Formula One market, (Schreyer and Torgler, 2018).

The dataset covers eighty-one Formula One Grand Prix from 2016 to 2020, broadcast across ESPN, NBC, ABC and CNBC in the United States. Using both Huber and Stepwise regression models, the research aims to discover how various factors influence viewership demand figures. In addition to quantifying outcome uncertainty using a new approach, the research considers the impact of other determinants of viewership such as season long competitive balance, broadcast accessibility, substitute sporting broadcasts, specific track characteristics and scheduling factors.

It is discovered that as the difference in betting odds between the first and fifth qualified driver increases, viewership figures increase. These findings do not support the uncertainty of outcome hypothesis (UOH) and show that consumers display a preference for less closely contested races. Furthermore, the scheduling and broadcast accessibility of live Grand Prix races are of high importance in order to maximise viewership figures.

1. INTRODUCTION

1.1 Research Question

This research explores the relationship between outcome uncertainty and broadcasting demand in the United States of America (USA) for Formula One racing. Formula One, referred to as Formula 1 or F1, is the highest standard of single-seater auto racing and is sanctioned by the Fédération Internationale de l'Automobile (FIA).

1.2 Rationale for Research

Since 2010 just three drivers have been crowned winner of the World Drivers' Championship (WDC), with just two constructors winning the Constructors' World Championship (CWC) in the same time period. In the eleven seasons prior to this (2000 to 2010) five drivers have won the World Drivers' Championship, which was shared among three different constructors. The evidence implies that outcome uncertainty, particularly in the World Drivers' Championship appears to increase as we look back in time. Most recently, in the 2020 F1 season Mercedes AMG Petronas F1 team secured their seventh consecutive Constructors World Championship win. The stark difference between the 2020 season and previous years is that they could have won the constructors title based solely on only Lewis Hamilton's points tally and ignoring the 223 points collected by their second driver Valtteri Bottas. Therefore, it can be questioned whether the apparent reduction in uncertainty of outcome in recent decades has impacted upon demand for the sport on television screens in the US. Formula One recorded a global TV audience of 1.92 billion in 2019, with the US audience growing by 7% in that year (Formula1, 2020). The publication of these statistics show that the demand for Formula One is not only strong, but also growing steadily.

1.3 Preview of Major Findings to Date

Rottenberg (1956) first identified that outcome uncertainty is an integral part in the demand for sport. The work of Neale (1964) is also of particular interest. His theory of the '*League Standing Effect'* can still be observed in Formula One today. Neale (1964) hypothesises that the closer the league standings are the higher the gate receipts from subsequent matches. Of course in modern times this can equate to broadcast demand as well as traditional gate receipts. Collectively, Rottenberg (1956) and Neale (1964) have contributed greatly to the framework that most sports economics papers now follow. An important part of this is the differing ways that competition can be quantified across all professional sporting settings. Primarily we are presented with two different methods, performance/league standings and betting odds. Key papers such as Knowles, Sherony and Haupert (1992) as well as Buraimo, Peel and Simmons (2013) have used betting odds as a robust measure of outcome uncertainty.

The work of Hunt, Bristol and Batshaw (1999) is also of importance in the wider context of this thesis. The authors present a conceptual approach to classifying sports fans. This is important as we aim to hypothesise the determinants of demand for F1. The authors explain, through the analogy of Fox Television Network showing the St Louis Cardinals and Chicago Cubs games while recognizing there was a significant increase in the number of people interested in this event, as temporary fans expected Roger Maris' single season home run record to be beaten. The same temporary fan behaviour could be observed within F1, as temporary fans tune in with the hope of seeing Lewis Hamilton or Mercedes failing to win. It is explained that these temporary fans may follow the sport for as little as several hours to a couple of years and are as a result classified differently by the author. Donahay and Rosenberger (2007) find that Formula One fans are up to three times more brand loyal than fans of other sports.

There is limited research concerning demand and Formula One. Schreyer and Torgler (2018) identified race outcome uncertainty as the dominant factor driving television demand for Formula One in Germany. Other aspects of the sport have been researched in more detail with competitive balance the pretence for the papers written by Mastromarco and Runkel (2009) as well as Judde, Booth and Brooks (2013). Krauskopf, Langen and Bünger (2010) explain the determinants of attractiveness of Formula One. Through their analysis of the determinants of the German Formula One number of TV viewers, the authors find that too high a level of competitive balance is as detrimental to the sport as too low a level of competitive balance.

A very recent paper by Garcia del Barrio and Reade, (2021) analyses if the certainty of the winner of the world championship diminishes the interest in the sport premature to the end of the season. The authors report that getting to know the eventual world championship winner has a negative effect on fans degree of interest in the Formula One World Championship.

1.4 Overview of What Follows

The remaining sections continue as follows. Section two addresses the existing literature surrounding sports demand as well as an explanation of the economics of Formula 1 and a history of F1 in the US. Section three explores an explanation of the descriptive statistics surrounding both the dependent and independent variables as well as an explanation of the econometric method. Section four relates to the method of analysis and the rationale for the use of this analysis. Section five presents the results as well as the robustness checks. Section six discusses the results in conjunction with the implication of these with respect to existing sports economics literature. Section seven concludes this thesis.

2. LITERATURE REVIEW

2.1 Introduction to Formula One

Although the sport is governed by the FIA , Formula One is wholly owned by American based *Liberty Media Company*, who bought the Formula One franchise from F1's original parent company *Delta Topco* for a fee of $4.6 billion in 2017 (Forbes, 2017). This acquisition strengthened Liberty Medias portfolio, that also consists of the *SIRIUSXM group*, a satellite radio company as well as the *Brave Group*, which is Liberty Medias wholly owned subsidiary *Braves Holdings LLC*, which indirectly owns Major League Baseball franchise *The Atlanta Braves.*

2.1.1 Formula One Today

Today Formula One is a global, multi-billion dollar industry that only ranks behind the Football World Cup and Summer Olympic Games in terms of live TV audience (Benson, 2011). Although it changes year by year, Formula One generally follows a twenty-one race calendar (twenty-three in 2021), starting in Australia or Bahrain at the end of March every year, with the finale of each season taking place in Abu Dhabi in early December. Twenty drivers make up the Formula One grid, representing ten different teams. Two types of teams are involved in Formula One, one being a 'constructor' and the other being a 'customer' team. A constructor team manufactures and runs their own engine, whereas a customer team purchases their engine from a constructor team. Currently, four constructors exist on the F1 grid; Ferrari, Mercedes, Renault and Honda. The FIA impose a regulation that if a team cannot secure an engine for the F1 season, the constructor that supplies the least amount of teams on the grid is required to supply that team, to ensure that the issue does not arise of a team having to exit the sport as a result of not being able to secure an engine.

As a result of limited engine suppliers, performance of the constructor teams engine has grave importance for a customer team. For example, Ferrari sell their engines to two other F1 teams, these being: Alfa Romeo F1 Team and Haas F1 Team. As a result of this, Alfa Romeo and Haas are limited in terms of engine performance in the sense that they rely on Ferrari to upgrade the engine throughout the year. The 2020 season saw Ferrari struggle to develop their engine resulting in the team being uncompetitive. This underperformance was passed onto Alfa Romeo and Haas as customer teams using the Ferrari engine. This highlights a limitation of F1 in achieving season long competitive balance because early on in the season it became apparent three teams were uncompetitive. However, it can of course work positively for customer teams, during the 2017 season Ferrari enjoyed a valiant title charge against Mercedes, at the same time Haas and Alfa Romeo enjoyed their best performances of the last five years.

As the sport has two different types of teams, it also presents two distinct types of drivers. The majority of F1 drivers reach F1 as a result of winning a junior category of the sport. Contrary to this, many drivers throughout the years have gained entry into the sport as a result of very significant financial backing, and are known as 'pay drivers'. It should be noted that pay drivers are not rookie race drivers by any stretch, it is mostly the case that they have competed in the junior categories to F1 but have not managed to win them outright. What pay drivers initially lack compared to their peers in driving ability they make up in the financial support they offer to the team. Generally pay drivers enter the sport with back-marking teams which are currently represented by teams such as Williams and Haas. Although many fans are against the idea of pay drivers occupying race seats that could be occupied by drivers who arguably deserve to be there by merit. Some of the sports most decorated drivers have started out in this fashion, most notably Niki Lauda and Michael Schumacher.

The main stakeholders of any F1 team can be summarised as; the driver, the team (e.g. mechanics, race engineers), team owners, as well as team sponsors. F1 team sponsors are an integral part of the day to day running of the team, providing much needed cash injections to allow the team to continue to develop the car throughout the season. Although most sponsors exist exclusively for the sole purpose of brand exposure (e.g. Coca Cola and McLaren), some supply vital resources to the team. *Shell*, Ferrari's fuel supplier, represents one of the longest running sports sponsorship in the world, an endorsement that dates back to 1950 (Forbes, 2016). Malaysia's largest oil corporation, *Petronas*, occupy the position of title sponsor with Mercedes, meaning the *Petronas* name is included in the full team name of 'Mercedes AMG Petronas F1 Team'. Lee and Ross (2012) state that sport sponsorship can help overcome the challenges associated with the cultural and linguistic obstacles in a global society as compared to conventional advertising. Berrett and Slack (1999) found through their research that sponsorship activities of rival companies were influential in a company's sponsorship choices. Since 2016, *Heineken* have been one of F1's main race and trackside sponsors, a deal that is worth in the region of $200 million making it one of the biggest single sponsors in motorsport history (Smith, 2018). In the case of the English Premier League, top teams who attract big sponsorship deals are very unlikely to lose their dominance, greater off-field income allows the purchase of top level players which allows teams to charge higher ticket prices (Financial Times, 2014). Mourão (2017) highlights that roughly three quarters of an F1 teams revenues come from sponsorship.

Of the top three Formula One teams (Mercedes, Red Bull, Ferrari), a host of US based companies are present and are primary stakeholders in these teams as of the 2020 season. Mercedes boast nine US based companies as listed sponsors, Red Bull also have nine and Ferrari have seven. Wilber (1988) explains that corporations focus on sponsorships that

correlate with the target markets of their products and services. Groothuis, Groothuis and Rotthoff (2011) describe that sponsors of NASCAR drivers have nonlinear pay-outs, as winning or front running drivers are shown more on television and therefore earn more from their endorsements when compared with drivers at the back of the field. The authors note in that this nonlinear pay-out system makes it difficult to quantify earnings of drivers. Apart from the obvious monetary attractions for teams to partake in Formula One, in particular it presents an opportunity to remind consumers of their available road cars. Alfa Romeo F1 Team driver Kimi Räikkönen occupied the first and last slot of every advertisement break during the 2020 Formula One season on *Sky Sports F1* in Ireland and the UK, extensively advertising their newest road car. In the 2021 season, Sebastian Vettel and Aston Martin occupied the same advertisement slot, with Aston Martin also opting to advertise their newest car available to the public.

Although exact figures aren't released, Formula One has a relatively transparent pay-out system for the teams involved. 50% of revenue earned by the Formula One Group is directly allocated to a prize money fund, with the other 50% going to the Formula One group to be distributed to various shareholders (Sportingfree, 2021). Of the 50% that is allocated to the prize money fund 23.75% is distributed evenly among all ten teams. Another 23.75% is given to the teams in differing amounts depending on how they finish in the CWC, with the winning team getting the largest amount. The remaining 2.5% is always given to Ferrari as a result of a special contractual agreement they have with the Formula One Group (Sportingfree, 2021). The twenty Formula One drivers are paid by their respective teams, the amounts of which are kept private. Like all sports, each driver has differing bonus incentives, with some expected to be race wins and others expected to achieve points finishes (up to 10^{th} place or top half finish). Both Mourão (2017) and Allen (2010) note that drivers salaries differ from regular salaries

where it is a fixed cost and is entirely independent of output. They explain that in general F1 drivers salaries are 70% retainer and 30% bonus, where bonus includes podiums, points and championship standings. Mourão (2017) furthers this discussion by adding that it is highly unlikely a driver earning less than $10 million per year would be seen on the podium. He finds a positive relationship between points scored and driver salary, explaining that the worst paid drivers consistently score the least world championship points. However, it should be added that drivers who are paid less are predominantly new to F1 and are part of smaller teams who lack the driver budget other teams do. Petróczy and Castro (2019) propose an amended model to allocate Formula One World Championship prize money among constructors. The authors highlight that Liberty Media have made commitments from 2021 onwards in order to amend the pay-out system, to help smaller teams and increase the competitive balance of the sport. This amendment could see Formula 1 move from a linear pay-out system from first to last and move towards a US draft style system where smaller teams benefit more in an effort to level the playing field and improve the competitive balance of the sport.

The 2020 season saw Liberty Media report a record loss for the Formula One Group. The season which was shortened as well as being predominantly completed in Europe due to the COVID-19 pandemic resulted in F1's revenue falling by 44% for a total loss of $386 million compared to 2019 figures. A large part of F1's revenue fall is of course the lack of ticket revenue for races behind closed doors but another factor was hugely influential on the decreased figures. Cities that would usually pay premium prices to host F1 races found themselves in the privileged position of being able to negotiate smaller fees, or in some instances avoiding paying any fee at all to host a round of the World Championship. Understandably for the Formula One Group, broadcast revenues accounted for a much larger portion of the revenue, up from 38% to 55%. The final year reports suggest that like the host

cities, broadcasters were able to negotiate cheaper agreements as a result of the unpredictable race calendar (CNBC, 2021). Demand in the US for the 2021 season has seen a strong start. Round one and two in Bahrain and Imola saw greater TV demand than any of the 2020 seasons races. A return to a normal calendar unaffected by the pandemic seems to work well for the Formula One Group. In terms of year on year growth for fan engagement across social platforms Facebook, Twitter, Instagram and YouTube, Formula One saw 99% growth in 2020, a vast difference from other Major US sports such as UFC (+48%), NBA (+4%), MLS (+3%), NFL (-10%), NHL (-26%) and MLB (-32%) (Formula1, 2021).

2.1.2 A Formula one Race Weekend

The sport consists of twenty cars competing over three days (Friday-Sunday) on designated tracks across the world. While the earlier days are dedicated to practice and qualifying, Sunday is race day, the only day points can be scored. The winner of the Grand Prix is the driver that can compete the requisite laps in the shortest possible time. The number of laps varies depending on the length of the track but always equals the race quota of 306 kilometres (only the Monaco Grand Prix is exempt from the 306km race quota).

A Grand Prix weekend consists of five sessions. On Friday the teams have two practice sessions - Free Practice one and two - in which the teams usually gather tyre and fuel consumption data, as well as the drivers getting used to the track. On Saturday morning Free Practice three takes place. Teams generally send the cars out on low fuel runs in order to get a good idea of the pace they will have for qualifying. On Saturday afternoon qualifying takes place, across three sessions. Q1 sees the slowest five drivers ordered from 20th to 15th on Sundays grid, in Q2 drivers are ordered from 10th to 15th. Finally in Q3 the top 10 drivers attempts to secure the all-important “pole position”. WDC and CWC points are distributed between 1st and 10th place in each race, as can be seen in Table 2.1.3, with the Grand Prix winner securing twenty five points

in the WDC as do the winning team in the CWC. An extra point is available to whichever one of the top ten drivers posts the fastest lap during the race. The current points system was last amended at the end of the 2010 F1 season.

Table 2.1.3: Formula One World Championship Points System

1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
25pts	18pts	15pts	12pts	10pts	8pts	6pts	4pts	2pts	1pt

Although the points system has been altered throughout the history of the sport, the system was changed in 2002 after Michael Schumacher famously won the WDC after just eleven rounds of the seventeen round championship. Although ten points were still awarded to the race winner in the revised 2003 points system, more points were awarded to drivers in second to eight place, with the hope of prolonging the WDC and CWC and therefore increasing competition. Perhaps the most drastic ever points system change that the Formula One group ever tried to introduce was that of 2014, when double points were used, meaning fifty points were awarded to the race winner. The system was abandoned after just one year before it was reverted to what it is today.

2.1.4 A Brief History of Formula One and Broadcast Demand

Formula One has its origins in the 1920s and 1930s but following the outbreak of World War II in 1939 all racing activity at the time stopped. The first 'Formula A', which very soon became known as a Formula 1 race was held in 1946 in Turin, Italy and was known as the Turin Grand Prix. Four years later in 1950 Silverstone in the United Kingdom was the venue for the first World Championship race. It wasn't until 1953, when the series branched out to a race in Argentina that the series wasn't entirely completed in western Europe. To further its reach as

a global sport it was decided to include the Indianapolis 500 as a qualifying round, a decision that lasted for eleven years, before it was admitted that the 500 mile race on a banked oval track had no connection to Formula One. The early years of the WDC saw a unique points system used, which remained for some time. Points were distributed on a 8-6-4-3-2 basis to the first five finishers at each of the six Grand Prix. However, only a drivers best four races counted towards the championship, meaning failure to finish a race wasn't detrimental to a drivers championships hopes. In its early years the Silverstone track was relatively underdeveloped, this resulted in Mirabel Topham (owner of Aintree Horse Racing Course) investing £100'000 to build a track on the grounds of Aintree in May 1954. Aintree's National Hunt course had been struggling financially as a result of a limited number of races each year. The cost of the Grand Prix track construction was passed on to spectators with grandstand tickets costing two pounds and five shillings (now £2.25) which was 15 shillings (75p) more expensive than Silverstone. In its early years, like they are now, venue changes as well as points system alterations were purposely made in order to grow and accommodate new growth in popularity of the sport.

Endorsements associated with F1 began to grow in 1971 which saw the first sponsored Grand Prix being the 1971 'Woolmark British Grand Prix'. A more drastic change was seen with regard to the cars in the following 1972 season. Not only did tobacco company *John Player* purchase the title sponsorship of the British Grand Prix, they also agreed a deal with the Lotus F1 Team to name their 1972 car 'The John Player Special', although it was not well received at the time. It marked the start of teams engaging in an array of endorsements as a source of additional income. The costs associated with F1 were only to increase. In 2000 it was reported that it would cost Irish owned F1 team 'Jordan' £100 million to design, build and race their two cars for the 17 round race season. Title sponsor *Benson and Hedges* would supply £40

million of this investment, with secondary sponsor *Deutsche Post* contributing £20 million, and several smaller sponsors contributing £5-£10 million each. It was later revealed that it costed Jordan in the region of $2400 for each lap each car completed, which equalled $400 per kilometre (Hamilton and Brawn, 2020).

2.1.5 The F1 Driver Market

The Grand Prix Drivers Association (GDPA) collectively represents all F1 drivers. Founded in 1961 by Stirling Moss and chaired by several famous drivers such as David Coulthard, Michael Schumacher and most recently, George Russell. The primary function of the GDPA is to ensure driver safety standards are upheld by the FIA. Currently, in order to be allowed compete in Formula One, each driver must be over the age of eighteen on the day of the race as well as being a holder of an FIA issued 'Super Licence'. A Super Licence is given to drivers who are qualified to race in the Formula One World Championship. In 2016 the FIA introduced a points based qualification system for the Formula One Super Licence, sparked by Red Bull Racings sister team Toro Rosso's introduction of their sixteen year old driver Max Verstappen, who couldn't legally drive a road car. Drivers need to accumulate forty super licence points in the three years prior applying for a super licence. Although there are various different disciplines that super licence points can be awarded, there are primarily two that are most common. The full forty requisite points are awarded to the top three Formula 2[1] classified drivers as well as the IndyCar Series champion. It is of course in the interest of Formula One stakeholders to have the best drivers in the world as ambassadors for the sport as better drivers generate increased demand.

[1] Formula 2 or F2 is the junior category to Formula 1 that follows a similar race calendar.

The F1 driver market isn't too distant from the system used in football. Drivers are usually scouted and signed at a young age by driver academies. These academies provide the best chance for these drivers to break into F1, particularly if they lack the financial support needed to reach the pinnacle category of motorsport. Celik (2020) analyses the labour market of F1, highlighting several important factors in deciding how long a driver spends in F1. He finds that each time a driver exits the sport, the length of each successive spell decreases, exemplified by the case of Michael Schumacher. Schumacher retired at the end of the 2006 season and completed a comeback in 2010 where he drove for the new Mercedes F1 team which we know to be so dominant today with Lewis Hamilton. However, for Schumacher the 2010 to 2012 seasons were spent closer to the back of the grid where he helped the team get started in F1, but failed to register a race win and only one podium. In addition Celik (2020) reports that the percentage of points the driver earns of the teams total points each season is another defining factor. He explains that the human capital accumulated is very important in Formula One, and that like other sports where players can prolong their playing career by switching teams, so can drivers in Formula One.

Mourão (2017) analyses the betting opportunities associated with modern day Formula One. As 94% of Formula One drivers fail to win a race in their career the author notes that a different method must be employed to attempt to predict the future performance of drivers. He hypothesises that drivers with the highest start to podium percentage represents the best opportunity for return, interestingly it is noted that as a driver ages their performances are expected to deteriorate, which supports the findings of Celik (2020) as explained above.

2.2 Overview of the Literature and Theory

Several papers such as Noll (1974) and Horowitz (1978) consider under what conditions fans consume sport. These works were then furthered by Borland and McDonald (2003). Although the authors deal with sport in a general sense, the theories identified are applicable to the sport of Formula One. Borland and McDonald (2003) highlight that Sutton and Parrett (1992) describe the product of sport to be the contest between two teams (ten in the case of F1). As well as that the sum of these individual contests give rise to what the authors refer to as the 'league product' which is of greater importance than just the sum of the individual sporting contests (e.g. a Formula One season). Other microeconomic factors suggested by the authors include consumer preferences (e.g. tastes for different tracks) and the relative quality of individual contests (e.g. outcome uncertainty).

However, the authors note that rivalling athletes that compete the least often generate the most interest, e.g. boxing, swimming and football. Considering F1 drivers compete against one another roughly twenty one times a season, the effect of a rivalry may be limited. Reams and Eddy (2017) highlight that the UFC don't sell season tickets or have a home arena where attendance can be reasonably predicted. The same can be said for F1 with tracks having fluctuating capacity. Formula One also presents an additional difficulty in the sense that tickets are sold individually across the three day weekend along with a three day pass, meaning double counting attendees becomes increasingly likely. Fans who attend Formula One practice and qualifying sessions should in theory not be included in attendance data, in terms of the UFC, weigh in attendees could be regarded as a similar example. With each F1 track being responsible with releasing the number of weekend attendees as opposed to the Formula One Group being the sole reporter of attendance data makes it near impossible to compile accurate consumer attendance data. This problem was brought to the fore when the organisers of the

2017 Canadian Grand Prix were forced to withdraw their original claim of an attendance of 360’000 people, which was proved to be over-estimated by at least 180’467 (Forbes, 2017).

In terms of pricing however, the UFC and F1 operate under very distinct models. The UFC operates on a Pay Per View (PPV) and subscription based service. Contrary to this, F1 broadcasts are predominantly subscription based services but are offered as free to air broadcasts in select countries (e.g. subscription – USA/ESPN, Ireland/Sky Sports, Germany/Sky Sports). Significantly, over time there has been a shift in how the demand for sport is quantified, with television demand outweighing in-person attendance (Allan and Roy, 2008). Across several North American professional leagues it has been noted by Noll (2007) and Watanbe (2015) that broadcast revenues now surpass gate receipts, supporting the theories put forward by (Buraimo, 2008) and (Forest, Simmons, and Buraimo, 2005).

In recent times Butler, Butler and Maxcy (2020) use Nielsen ratings and pay-per-view buys to analyse the determinants of demand for professional boxing. The authors discover that boxing fans display a preference for relatively unbalanced fights. Interestingly, they also found that main events taking place in Europe attract less viewers. With nine of the twenty one races of the Formula One race calendar taking place in Europe it is possible we will see similar results in this research. Both Caruso, Addesa and Di Domizio (2017) and Schreyer, Torgler and Schmidt, (2018) proxy the determinants of television demand for football, using Italian Serie A data and German Bundesliga matches respectively. In the case of the Italian Serie A, the authors found that consumers are indifferent to the quality of the match. Artero et al. (2019) look at demand for Spanish international football games. They discover that a TV audience increase of 4-5 million viewers can be observed in the final stages of competitions when

compared with friendly games. An additional 1.6 million viewers are expected if the continuity of the national team at the competition is at stake.

Inspired by Van Reeth (2013), Gutiérrez and Blanco, (2016) look at continuous demand for professional cycling, analysing television viewership data for the Vuelta a España. Interestingly the authors report viewership drops during advertisement breaks, a variable Formula One broadcasts are exempt from given the races are a continuous stream. Dang, Booth, Brooks and Schnytzer (2015) find that uncertainty of outcome is directly correlated with greater television audience figures in their exploration of evidence from the Australian Football League (AFL). The authors discover that greater anticipated outcome uncertainty is positively correlated with a higher television rating. They also report a strong timing effect, stating Thursday, Friday and Monday night games attract higher television viewership numbers than matches broadcasted during the day on a Sunday. Paul and Weinbach (2007), Sung et al (2017) and Tainsky and McEvoy (2012) all model broadcasting trends for the National Football League (NFL), with a common theme of outcome uncertainty across all three papers. Particularly Paul and Weinbach (2007) find that fans prefer close games between high quality teams, as well as preferring high scoring to low scoring contests.

2.2.1 Formula One and the United States

In terms of sport in the United States, it must be noted that a large majority of the sport is shown on cable TV. This is a relatively cheap service in which broadcasters recoup the money spent on broadcasting rights from intense advertising. The average global audience for a Formula One Grand Prix in 2020 was 87.4 million people, a slight reduction from 2019 as a result of the shortened calendar due to the COVID-19 pandemic, with the Hungarian Grand Prix recording the highest global TV audience of 103.7 million. It is noted that this average TV

audience is less than was anticipated for a regular season as several key markets including the US did not have the opportunity to host their own Grand Prix, as well as European and Gulf races being broadcasted at unsociable hours in the US. In addition to this, the US Grand Prix, which usually records high US TV audience engagement as it is shown free to air on ABC as opposed through ESPN behind the paywall (Formula1, 2021).

Although across the eighty one Grand Prix Championship races a total of six different broadcast channels have been used, in reality all six channels are owned by just two parent companies; NBC and Disney. NBC are owners of the NBC, NBCSN and CNBC channels. Alternatively, The Walt Disney Company are sole owners of ESPN, ESPN2 and ABC. Both parent companies have similar strategies when it comes to choosing which channels to broadcast certain races on. Less significant races at spurious hours are shown among CNBC and ESPN2. Important races shown at various times across the season are shown on NBCSN and ESPN. Finally, the most important races for US fans in terms of circuit and start time are shown on the main channels of NBC and ABC.

On June 10th 1962, the Monaco Grand Prix was broadcasted in black and white and on a delayed basis on ABC as part of their 'World Wide of Sports' campaign, a campaign to show the US people sports from around the world. The race had taken place the week prior on June 3rd and this broadcast marked the first time a full Grand Prix race was shown in the US. By the mid 1970s the standard of ABC's coverage had increased tenfold, with live full race coverage as well as pre-race analysis included in the broadcast, with more and more Grand Prix being broadcasted over time. ESPN took over from ABC as Formula One broadcaster in 1986, which is said to be when the golden age of F1 coverage in the US began. With a much larger budget than ABC, ESPN were able to send commentators and pundits to races around

the world, enhancing the quality of the broadcast to the US. However, this travel expenditure coupled with other factors became the downfall of the service as in 1995 ESPN sold the rights to the Speed Channel after running into financial difficulty. Speed Channel went on to broadcast F1 races for 17 years along with Fox sports until in October 2012, when NBC Sports reached a deal to exclusively broadcast Formula One races in the US. The majority of races were shown behind the relatively low paywall when compared with European prices on NBCSN with four races per season shown on the free to air channel NBC (pitpass, 2017).

It is widely accepted that F1's yearly viewership peaked in 2008 when the sport amassed 600 million viewers across the season. However, since then a gradual shift away from free to air TV to Pay TV has had a significant impact on yearly viewership figures, with 490 million in 2018, 471 million in 2019 and 433 million in 2020 (Motorsport, 2021). Although given the purpose of this research it should be added that the US market has outperformed most other markets in this time with record figures for 2020 and an overall growth of 1%. F1's Director of media rights has explained that a less known factor in these decisions is what the rights owners offer back to the sport in terms of exposure and additional content for fans supplementary to race broadcasts is something which Pay TV rights holders are much better at than their free to air counterparts (Motorsport, 2021).

Since 2017, ESPN have regained exclusive Formula One broadcasting rights in the US, possibly sparked by renewed US interest in the sport after American based Haas Formula One Team (sister team of Haas NASCAR team) had just completed their first season in 2016. ESPN broadcast the vast majority of races on their second channel ESPN2 with more prolific races such as the British Grand Prix and other races being shown on the main ESPN channel. The

US Grand Prix along with the Canadian Grand Prix is shown free to air on ABC. ESPN utilise the race feed provided by European partner BSkyB, now Sky UK Ltd.

The Indy 500 track was included in the first eleven years of the Formula One World Championship as a qualifying round. US fans first opportunity to attend a round of the World Championship on home soil was in 1961 when Watkins Glen, the Grand Prix circuit outside New York was added to the World Championship season. Watkins Glen would go onto occupy the slot of US Grand Prix from 1961-1980. Long Beach California, Las Vegas, Detroit and Arizona all held US Grand Prix races from 1980-1990. A ten year absence from the F1 calendar then followed as a result of poorly attended races, when in 2000 the race returned to Indianapolis to a modified NASCAR track which would continue to hold the race until 2007.

The Indianapolis track brought with it a large amount of controversy, none more than the 2005 US Grand Prix, as explained by (Valentine, 2021). At the time, two tyre suppliers were present among the ten teams, with Ferrari, Minardi and Jordan using Bridgestone with the remaining seven teams opting to be supplied by Michelin. Ultimately the track was poorly designed for the purpose of Formula One Racing, and as a result the tyres were unable to cope with the vertical load required of them around the track, resulting in several tyre blowouts across the practice sessions. Renault Team Principal, Flavio Briatore released a statement the day prior to the 2005 US Grand Prix stating his cars would not partake in the race. On race day, fourteen drivers pulled into the pits on safety grounds and did not take part, heavily influenced by the tyre manufacturers who believed full speed racing could result in a serious accident. Regardless of who the blame was to lie with, it heavily damaged F1's US reputation. Coverage of the race shows fans throwing bottles and debris onto the track at the beginning of the race, with most fans leaving not long after it was clear the race was not to be run as planned. After another

absence from the F1 calendar, this time of five years, from 2007-2012 the US Grand Prix returned in a brand new specially built Formula One circuit, the Circuit of The Americas in Austin Texas. To this day the US Grand Prix is still held here with MotoGP and FIA World Endurance Championship Races also utilising the circuit throughout the year. The 2022 season will see a return of two annual US Grand Prix's, as the Miami Grand Prix was announced in April 2021. The purpose built street circuit is set to circumnavigate the Hard Rock Stadium, home of the Miami Dolphins. A return to more than one US Grand Prix a season highlights the Formula One Groups' commitment to the US as an emerging market.

Currently, US consumers can avail of ESPN's sports package through the ESPN+ service for €5.22/$5.99 a month (ESPN,2021). In comparison, European consumers best offer currently comes from NOW TV, a sports subscription service provided by BSkyB. Consumers can access all Formula One races as well as other sports for €34/$41per month (NOWTV, 2021). As outlined by Dietl and Hasan (2007), US consumers benefit when compared to their European counterparts who pay higher subscription services to view the same sports. Syzmanski (2010) notes that most major sports in the United States are viewed free to air or at a relatively cheap subscription price, and are financed through intensive advertising or as part of a basic cable package. The authors also noted that at the time of writing, Formula One was one of the few sports that opted to not yet move to a pay TV model and instead remained as a free-to-air broadcast, however as the authors say it merely illustrates the point that owners of sports rights in Europe can obtain more money from pay TV broadcasts. As explained by Meier, Koner and Stroth (2018) consumers of free TV primarily face opportunity cost since they can revise their entertainment easily with no great financial loss, as opposed to those who pay for PPV events or expensive subscription services. The authors find in their analysis of

boxing, that when faced with a trade-off between quality and outcome uncertainty, consumers prefer quality.

It should be added that since May of 2018 Formula One have attempted to profit from the growing demand for live F1 broadcasts and have introduced '*F1 TV'* a subscription service that allows consumers to purchase race coverage directly from Formula One. The *'F1 TV Pro'* option gives consumers additional perks that Sky or ESPN customers don't get, including on-board cameras of every car, a pit lane channel where they can hear correspondence from every driver and team, as well as pre and post-race analysis shows. The launch of F1 TV move coincided with BSkyB taking all rights of UK broadcasts, in previous years Channel 4 had purchased the rights to show ten races per season from the BBC (Motorsport, 2016). In order to watch races live, consumers must opt into the '*F1 TV Pro'* option which costs $10 per month/$80 per year. '*F1 TV Pro'* is not available in Ireland, Germany and the United Kingdom, all countries where BSkyB hold all Formula One rights. In times where more and more countries move to pay TV services for the broadcasting of Formula One, Chinese free to air broadcaster *CCTV* has begun showing live F1 races and has reported increased demand of 69% (Formula1, 2020). However, F1 under Liberty Media has been questioned regarding the methods employed to calculate viewership figures. Before Liberty Media took ownership of the Formula One Group consumers had to watch 15 consecutive minutes of an F1 broadcast to be counted in viewership figures. Liberty Media altered this method to be reduced to three consecutive minutes which vastly boosts viewership figures (Forbes, 2021). Formula One is not estranged from viewership figure controversy, in 1999 F1 claimed to have 57.8 billion viewers which was ten times more than the world's population.

According to Sylt (2015), Formula One's parent company at the time received roughly $500 million per year for TV broadcasting rights. Mourão (2017) explains that in a sense F1 can control this revenue, as individual Grand Prix tracks and their organisers keep all gate revenue it could be argued that it is in the interest of the Formula One group to not encourage Grand Prix organisers to expand the capacity of Grand Prix tracks as more consumers will then pay to watch broadcasts of the race.

2.2.2 Major Sport Broadcasts

Horky (2021) explains the affect the COVID-19 pandemic has had on professional sports and more importantly the positive affect it has had for broadcast revenues. The author explains that the German Bundesliga benefitted from being the first major sport to return to play. He notes that higher than normal media attention, growing consumer capital and more lucrative broadcasting contracts were all products of the pandemic.

Baseball, like all sports has seen a shift from using attendance data to television viewership data (Chung, Lee and Kang, 2016). The authors approach their research in a unique way, explaining that sporting event attendance is determined by ex-ante expectations, on the other hand, for those who are watching on TV, changing channels costs consumers nothing. Ex-ante game quality proved to be the second most significant factor among the other examined effects on TV ratings. This, along with other findings, suggests that the upkeep of competitive balance has a possibility of becoming a critical element of professional sports leagues. The conclusions of this paper support that of Paul and Weinbach (2007), where it was found that half time score differential was statistically significant in terms of within game uncertainty in the case of Monday night football.

With collegiate sports being so prominent in the US, it is not uncommon to analyse television viewership data of college games. (Kang et al. 2018) find in their research of National Collegiate Athletic Association (NCAA) basketball games that a diversified national TV audience prefer to watch games with a definitive favourite. It is highlighted that this points to the assumption that viewers tune in hoping to see the favourite beaten by the underdog. Tainsky (2009) looks at US television broadcast demand for National League contests, using television viewership data. He finds that there is a premium for games that are held in primetime, in conjunction with this he discovered that team quality has a positive rating on broadcast ratings. Formula One has been criticised in the past for including tracks in the race calendar that are widely seen as producing unexciting racing, particularly Abu Dhabi and Circuit Paul Ricard in France. Track characteristics make it difficult for cars to overtake and in turn the race order rarely changes drastically from the qualifying order.

Like Formula One, National Association for Stock Car Auto Racing (NASCAR) has limited research papers under the topic of demand, but it too is growing in recent years. Schwartz, Isaacs and Carilli (2007), Berkowitz, Depken and Wilson (2011) as well as Humphreys and Frick (2019). Schwartz, Isaacs and Carilli (2007) test the hypothesis proposed by Von Allmen (2001) regarding the inefficiency of the NASCAR reward system. They report that drivers who display skill in early races are less likely to get involved in racing incidents. In conjunction with that, they found unskilled drivers to be more aggressive early on in the season, in anticipation of their end of season points tally.

Berkowitz, Depken and Wilson (2011) find similar results as other sports in their research into outcome uncertainty in NASCAR. In order to quantify race outcome uncertainty the authors

use the ‘adjusted churn’ method developed by Mizak, Neral and Stair (2007). Adjusted churn quantifies the change in starting and finishing position of each driver in the race. They conclude that the greater the outcome uncertainty in individual races the greater is fan interest. Interestingly they note that attendance is not affected by contemporaneous competitive balance measures. F1 has been criticised for including ‘boring’ race tracks in the seasons schedule. Under the adjusted churn method of measurement these tracks would have very low expected outcome uncertainty as the result tends not to differ much from the qualifying order. However, a key drawback of the adjusted churn method is that it is not known prior to the race start, whereas the difference in qualifying time is. In the context of this research its effect on TV viewership would be limited.

Depken, Hood and King (2015) highlight that television audience for NASCAR broadcasts comes only second to those of the NFL. In addition to that, the season runs from February to November, meaning the events compete with every other major North American sport. The authors explain that consumers view other sporting events as substitutes for NASCAR. It’s noted by Von Allmen (2001) that NASCAR’s prize money structure is relatively flat when compared to golf and other similar events. In addition to that Depken and Wilson (2004) hypothesise that drivers avoid risky moves within a race to an extent for the simple reason that season long rewards are much stronger than race specific incentives, which has implications for the quality of racing observed by fans. Momentum and consistency is the pretence of Depken, Hood and King (2015). With Lewis Hamilton winning the last four consecutive WDC titles and Mercedes winning seven CWC titles in a row, one would think momentum and consistency play a large part in their success. The authors draw on the works of Arkes (2010) who found that in NBA matches free throw shooting players have a 2-3% increased likelihood of scoring a free throw, if they scored their most recent attempt.

The emergence of the eSports market has added another dimension to the avenues in which fans consume live sport. According to eSports data provider Newzoo, 443 million people tuned in to watch live e-Sports events in 2019, with the vast majority of viewers under the age of thirty five (Financial Times, 2020). In 2019 F1 introduced their 'Virtual Grand Prix' series to fill the void of F1 action as a result of the COVID-19 pandemic. The entire series was shown live on Sky Sports as well as YouTube, featuring current and former Formula One drivers as well as celebrities and professional eSports drivers. Formula One's professional eSports series saw 11.4 million views in 2020, a 99% increase from the 2019 series, with the grand final of the series reaching 1.7 million social media engagements, an all-time high for an F1 eSports event (Formula1, 2020). Lombardo and Broughton (2017) explain that sport consumption among the younger generations is declining, reflected in diminishing live sport attendance and an ageing TV viewer demographic. Brown et al. (2018) find that esports fans seek to consume esports content in a manner that complements traditional sport fandom. The authors believe that eSports fans ought to be regarded as major players within the sporting world.

2.3 The Economics of Formula One

As mentioned in the introduction, Formula One has received relatively little attention in the sports economics literature when compared to other popular sports such as baseball, basketball and football. There are a number of key contributors to the literature including Kipker (2003), Mastromarco and Runkel (2009), Krauskopf, Langen and Bünger (2010), Anderson (2012), Judde Booth and Brooks (2013), Mourão (2017) and Schreyer and Torgler (2018) and Budzinski and Feddersen (2020).

Kipker (2003) quantifies outcome uncertainty by the points difference between the first and last placed driver in the WDC table. In a similar sense, Krauskopf, Langen and Bünger (2010) proxies outcome uncertainty in a race setting through a concentration index based on championship points. Schreyer and Torgler (2018) explain that although these methods are both effective and viable, the approaches give too much weight to the possible effect of minor teams, who have little effect on both the WDC and CWC. In the case of race outcome uncertainty, the authors have similar criticism of the work of Budzinski and Feddersen (2020).They explain that like championship outcome uncertainty, race outcome uncertainty is seldomly affected by teams at the back of the grid.

Mastromarco and Runkel (2009) find in their exploration of the effect of rule changes on competitive balance that a rule change at the start of an F1 season should be expected if uncertainty of outcome in the previous season was low. The authors also note that even rule changes that have a primary intention of increasing the safety standard of the sport can exert a significant positive impact on competitive balance of a season. In addition to improving competitive balance, rule changes are introduced if the revenue gained by introducing new rules exceeds the current revenue position. Given the outcome uncertainty in the 2020 season was so low, it is not at all surprising that the FIA introduced new rule changes prior to the start of the 2021 season. The FIA banned the use of 'party modes' for qualifying, with the intent of reducing the gap between the top and midfield teams, with world champions Mercedes standing to lose the most with the new ruleset. This of course did not come without backlash from the Mercedes team, with Lewis Hamilton stating "they're (the FIA) always trying to slow us down" (PlanetF1, 2020).

Krauskopf, Langen and Bünger (2010) assume in their hypotheses that Formula One is not attractive if all drivers have an equal chance of winning. In recent times it has been suggested that to make Formula One more exciting that the competition design of Formula 2 could be adopted. All F2 cars are designed by Italian race car manufacturer Dallara and are mechanically identical to one another. This competition design is centred around the idea of the driver being the key element of the team, in an effort to identify the best drivers of a generation. The authors refute this competition design as although it provides a closer race spectacle, there is no surprise when an outsider wins a race. They also explain that the sports competitive balance is harmed when a driver dominates the entire competition and can lead to a season being decided prior to the last race. As a result losing the incentive for consumers to tune in, causing demand to decrease as the season continues. For the past four consecutive seasons (2017-2020) both the WDC and CWC have been already won prior to the last race of the season. In a similar sense to this F1 season predictability, as reported by the Financial Times (2014) in the case of English Premier League football it was found that 47% of the final league table can be predicted by the teams league positions after six games. After thirteen games a team is expected to move at most 3.4 places up or down the table, which gives teams an idea whether they will be in the top or bottom half of the table.

Anderson (2012) is critical of the Formula One points system in his paper *'Maximum likelihood ranking in racing sports'*. He states that although it is not stated explicitly by Formula One, presumably the points accumulated over the course of the season is to determine the best driver of the season. One of his issues with the points system employed in Formula One is that drivers who finish outside the top ten do not score any points, which is the same as what a driver who fails to complete the race receives. If finishing outside the top ten requires more skill than failing to finish the race then the points system used by F1 is flawed. Although, he references

that if a driver is to retire as a result of a mechanical issue then they would be unfairly penalised by a revised points system.

Judde, Booth and Brooks (2013) analyse the varying effects that Formula One and FIA rule changes have on the competitive balance of the sport. The authors find that F1 teams act as point maximisers while the FIA act as profit maximisers. They also discover that rule changes aimed at improving competitive balance result in the World Drivers Championship being decided 6.9% further into the season. In addition to this they find that regulation change contributes to the increased outcome uncertainty of a championship, findings that support the work of Mastromarco and Runkel (2009). The authors explain the differing levels of TV exposure teams and their sponsors enjoy, they hypothesise that it is directly related to championship standing. According to the authors the 2006 season saw Renault become World Constructor Champions, amassing 29.8% of total TV race exposure, followed by Ferrari at 22.5% and McLaren at 13.1%. As a result of top teams and their sponsors continually getting the highest TV exposure, a downward spiral can be created for smaller F1 teams, who cannot attract sponsors as a result of consistently running at the back of the field.

In his book '*The Economics of Motorsports'* Mourão (2017) dedicates a chapter to competitive balance and outcome uncertainty in Formula One. Similar, but differently to Schreyer and Torgler (2018) the authors classifies an outsider as a driver outside the top three of the WDC at the end of the season, despite having secured a podium at one point that year, treating those who partake in the season but don't score a podium as insignificant. 2020 saw an unusually high amount of podium finishers, thirteen to be specific, which could point to the fact that other teams are getting increasingly competitive (Formula1, 2021). In contrast, across the five seasons 2015-2019 collectively only fifteen different drivers secured a podium finish.

Removing Lewis Hamilton, Valterri Bottas and Max Verstappen from this list of thirteen drivers as they were 1st, 2nd and 3rd in the WDC, means ten 'outsiders' for the 2020 season made the podium. The author notes that the 1982 F1 season had a 64.5% chance of outsiders making a podium, meaning two outsiders were expected on every podium that year. The statistic observed from the 1982 season (the highest observed) indicated a very competitive F1 season. Mourão (2017) also notes the necessity to utilise several indicators when analysing competitive balance and employs the Hirschman-Herfindahl Index (HHI) in his research. A HHI score of one indicates a single driver obtains all available points, and so impossible in Formula One, alternatively a low HHI informs us of a competitive championship. For the 2014 season, a HHI of 0.109 can be observed in the WDC and 0.211 in the CWC. The author notes that as we look back in time outcome uncertainty appears to increase, although different points systems have been used across different F1 era's, making HHI's use limited.

Schreyer and Torgler (2018) study 400 Grand Prix broadcasts between 1993-2014 with the aim of explaining the role outcome uncertainty plays in demand for F1 broadcasts in Germany. It should be noted that at the time Formula One broadcasts were available free to air in Germany through the country's largest free-to-air broadcaster, Radio Television Luxembourg (RTL). This ended in 2020 and Sky UK Ltd now hold the rights of F1 broadcasts in Germany. The authors employ a revised version of the model used by Budzinski and Feddersen (2011). The model the authors use works on the presumption that race outcome uncertainty can be quantified by summing the differences in qualifying times set by the fastest three drivers, as opposed to the fastest five used by Budzinski and Feddersen (2020). The model used by the authors hypothesises that the smaller the difference between the top three qualifiers the higher the estimated outcome uncertainty is for the subsequent race. Some of the control measures used by the authors include dummy variables indicating whether the Grand Prix clashed with

Bundesliga matches, European Football Championship games, FIFA World Cup games and the Olympics. As well as that, the model published includes the total number of German drivers starting the race, the best grid position of those starting drivers, and a dummy variable indicating whether a German driver would start the race from pole position. Interestingly, to account for the possibility of the 'super star effect' as seen in the work of Gooding and Stephenson (2017), a dummy variable is included to show whether or not Michael Schumacher was racing. Gooding and Stephenson (2017) report a 50% rise in television viewership in PGA golf broadcasts during high profile tournaments featuring Tiger Woods, alluding to the 'star effect'[2]. This paper reports some mixed findings, the authors explain that German F1 fans prefer races wherein ex ante competition exists between a group of three to four drivers which in return results in an uncertain race outcome. However, they also report findings that are in line with the classic outcome uncertainty hypothesis.

Budzinski and Feddersen (2020) close the gap in the existing literature in terms of the sport economic analysis of the F1 business as well as adding to the literature on competitive balance in sports. The authors explain that there are three dimensions of competitive balance as first explained by Berkowitz, Depken and Wilson (2011), these being; within-race competitive balance, within season competitive balance and inter-season competitive balance. Within race competitive balance deals with outcome uncertainty in a singular race, within-season regards the uncertainty of the evolution of the points standings and inter-season competitive balance deals with the uncertainty of the series of champions over the course of time. The authors go on to explain that the 'adjusted churn' method can be used to quantify within-race competitive balance, whereas the Hirschman-Herfindahl Index is useful to quantify the competitive balance

[2] The 'star effect' hypothesises that more fans tune in to see a superstar play, to see skill that other players do not possess.

of a full season and from year to year. However, it must be noted that in the context of this research 'adjusted churn' is not applicable as it is not known until after the race has been completed and therefore has no effect on betting odds. The authors highlight that outcome uncertainty and competitive balance work in tandem, and that when a great disparity exists between two teams or drivers the greatly superior team/driver will dominate the individual races as well as the league product and so make contest results ex ante expectable.

Table 2.3.1 gives a brief overview of the key related papers of interest. Other important papers in the context of this thesis that deal with the peculiarities of F1 are; Bekker and Lotz (2009) simulate race strategies for three 2005 F1 races in their operations-research paper. Solitander and Solitander (2010) explore theft of intellectual property that is so prevalent in the sport. Potter (2011) and his analysis of drivers reactions to new safety measures introduction to the sport, Stadelmann and Eichenberger (2008), Phillipps (2014) and Bell et al. (2016) all aim to identify the best driver in Formula One history by isolating factors such as car performance as well as other key factors. Budzinski and Müller-Kock (2018) look at the antitrust allegations surrounding the financial system and revenue distribution model employed by the Formula One group. Finally, Depken et al. (2018) analyse the importance of family connections as a factor of driver success in Formula One.

2.3.1 Literature Review Table

AUTHOR	TITLE	METHOD	FINDINGS	CONCLUSIONS
Budzinski and Feddersen (2020) **N = 61 Seasons**	Measuring competitive balance in Formula One Racing	Qualifying Times (1st-5th)	FIA are profit maximisers, F1 teams are win and profit maximisers	Points system, laps/distance lead, lead changes, qualifying differences.
Schreyer and Torgler (2018) **N = 400 Grand Prix**	On the role of outcome uncertainty in the TV demand for Formula One Grands Prix	Qualifying Times (1st-3rd)	German audiences prefer outcome uncertainty	Championship uncertainty, track conditions, unemployment. patriotism, superstars, weather.
Mourão (2017) **N = 12 Seasons**	The economics of motorsports: The case of Formula One	Hirschman-Herfindahl-Index	Outcome uncertainty increases as we look back in time	No control
Judde, Booth and Brooks (2013) **N = 60 Seasons**	Second place is the first of the losers: An analysis of competitive balance in Formula One	Hirschman-Herfindahl-Index	WDC and WCC decided on average 6.9% later in the season after rule changes	No control, adjusted churn, lead changes.
Krauskopf, Langen and Bünger (2010) **N = 17 Seasons**	The search for optimal competitive balance in Formula One	Gini- Coefficient 1st-2nd	High competitive balance as undesired as low competitive balance	No controls, time zones, cumulative points, points difference between 1st and 2nd drivers.

3. DATA

3.1 Introduction to sources of data

The dataset includes eighty one Formula One Grand Prix from round eleven of the 2016 season to the final round of the 2020 season, broadcast in the US across ESPN, NBC, CNBC and ABC. In this time period ninety Grand Prix took place, nine F1 Grand Prix are absent from the dataset as a result of them not being broadcasted on TV in the US and/or viewership data being unavailable. In that time period thirty seven races were broadcast on ESPN2, twelve on ESPN, sixteen on NBCSN, seven on ABC, and three on CNBC. Across the eighty one Grand Prix, seventy one took place on a race circuit, with the remaining ten taking place on street circuits. Similarly, sixty seven Grand Prix took place during the day in local time, with fourteen night races taking place at night across the sample four and a half seasons.

3.1.1 Dependent Variable

The dependent variable, viewership figures were obtained from *skedball.com* where all US broadcasts viewership figures are recorded and uploaded on a weekly basis. All TV viewership data relates to cable and satellite TV. No Formula One race is/was sold on a Pay-Per-View basis in the United States. The viewership data available on *skedball.com* is quantified by two groups, Persons2+ and Adults18-49. Persons2+ accounts for all viewers over the age of two year's old whereas Adults18-49 accounts for the number of people between the ages of 18 and 49 who tuned into the broadcast. Persons2+ is chosen as it represents far more viewers than the alternative of Adults18-49, an overall annual average viewership figure of 624’234 Persons2+ is reported. The Formula One Group note in their 2020 end of year report that the US market saw a downturn in viewership during the 2020 season. However, it is explained that this is

presumed to be in response to the 2020 season being predominantly completed in Europe, resulting in unsociable broadcast hours in the United States.

3.1.2 Outcome Uncertainty

Outcome Uncertainty (UO) is measured by market odds, obtained for the 2020 season (*paddypower.com*) and from varying sources for the 2019 to 2016 seasons (2019 – *sportsbettingdime.com*, 2018 – *dailymail.co.uk,* 2017 – *metro.co.uk*, 2016 – *bleacherreport.com*). Market odds obtained are for the first qualified driver through to the fifth qualified driver, concurrent with Schreyer and Torgler (2018) as well as Budzinski and Feddersen (2020) in terms of position selection drivers beyond this rarely have an effect on race proceedings. Since its inception, the Formula One World Championship has seen the pole sitting driver secure the race win 437 times (41.94%), with second place securing the race win 251 times (24.09%) and third place securing the race win 127 times (12.19%) (StatsF1, 2021).

Market odds are also manipulated using *bitodds.com* to convert them from fractional form to US form to decimal form. Outcome uncertainty can be measured using the difference in betting odds. This represents the disparity in market odds in decimal form between the lead qualifying driver and the driver qualified in fifth position. Exploiting the use of betting odds in sports economics demand literature is of use as, in the case of F1 market odds capture information such as effectiveness of car upgrades, as well as information on recent driver performance that are otherwise difficult to measure. A positive effect on demand is expected from a lower difference in betting odds. From Figure 3.1.5 it is observed that the average DIBO is found to be 0.40, with a range from 0.14 (Mexican Grand Prix, 2019) to 0.69 (Bahrain Grand Prix, 2020). Difference in Betting Odds is used in this thesis as it not only captures outcome uncertainty but has also never been used prior in F1 sports economics literature.

A good anecdotal example of the strength of using betting odds can be explained by the latter end of Sebastian Vettel's 2020 season with Ferrari. As Vettel is a four time world champion (2010-2013), he was consistently priced very similar to his then teammate Charles Leclerc. However, when it became clear towards the end of the season that Ferrari were leaning in the direction of terminating Vettel's contract, he began to be disadvantaged by the team during the race in order to benefit his teammate, which is common practice in the sport. The benefit of using betting odds is that this activity is represented by Vettel being priced slightly higher than his teammate Leclerc with the bookies pre-empting that this could happen. This example also highlights the potential shortcoming of using the difference in qualifying time measures, as seen in the existing literature. While Vettel could qualify ahead or just behind of his teammate Leclerc, the qualifying time difference wouldn't be a sufficient measure to account for the team orders that would occur during the race.

In F1 P1 to P20 is used to describe first to twentieth place on the starting grid. Mean P1 betting odds follow similar patterns as the above Hirschman-Herfindahl-Index calculations. In US format, average P1 betting odds for 2020 were found to be 1.58, with 2019 at 2.30, 2018 at 2.26, 2017 at 2.26 and 2016 at 1.96. Lower average P1 betting odds suggest less competitive world championships for both drivers and constructors, and so is congruent with the HHI findings which also suggests that 2020 was the least competitive of the sample. Evident from Figure 3.1.5, the Monaco Grand Prix's and Canadian Grand Prix's are outliers in terms of viewership figures, amassing over 5.3 Million US TV viewers across the four most popular races. The Monaco Grand Prix 2018 was broadcast free to air on ABC, as was the Canadian Grand Prix 2019. In 2017 both races were broadcast on NBC. The Monaco Grand Prix takes place in the US on the morning of the US's biggest domestic race of the year, the Indy 500.

This coupled with a US national holiday on the following Monday are expected to be important factors in the high demand for the Monaco Grand Prix. Although not part of the dataset, the 2021 Portuguese Grand Prix posted US viewership figures of 907,000 which was met with huge surprise among those involved with motorsport broadcasting not only because it was almost double the viewership recorded for the IndyCar Salt Lake City race broadcast on the same day but also because the near one million viewers is close to the highest observed in recent years for a Formula One broadcast (Skedball.com, 2021).

Drawing on the work from Schreyer and Torgler (2018) (DQT3) and (DQT5) are utilised as outcome uncertainty measures as opposed to the difference in betting odds and driver and constructor elite points measures. As explained by the authors, DQT3 is the difference in seconds between the first and third qualified driver. Similarly, DQT5 is the difference in time between the first and fifth qualified driver. The authors explain that the prior idea of these measures is that the closer in time difference the top three and top five qualifiers are, the closer they would expect the resulting Grand Prix to be. As a result the measure introduced by Schreyer and Torgler (2018) is very similar to the DIBO and Points Difference measures hypothesised here. If the OU theory is to be followed, the smaller the DIBO and smaller the points difference, the greater the demand for the Grand Prix, as is the case with DQT3 and DQT5. The authors explain that use of DQT3 and DQT5 stems from qualifying for the 1997 European Grand Prix saw Jacques Villeneuve, Michael Schumacher and Heinz Harold-Frentzen all cross the line with the exact same qualifying time, with the race going on to record an extreme audience at the time of 15.41 Million viewers

3.1.3 Race Specific Factors

Several race specific factors are taken into account in models prior to the stepwise regression, including; the number of drivers within three seconds of the lead qualifying time (ND3SEC). On average across the four and a half F1 seasons 15 drivers are within this parameter, with a range of one to twenty one, where one would indicate the greatest disparity possible in qualifying performance and twenty one would indicate all drivers are within three seconds of the lead qualifying time. It is worth noting that only on a singular occasion across the four and a half seasons in the dataset was only one driver within three seasons of the lead qualifying time, which was Ferrari's Sebastian Vettel just behind Lewis Hamilton's lead qualifying time at the 2018 Belgian Grand Prix.

As well as that, the number of F1 Grand Prix that have been held at a track (HERITAGE), circuit length (CIRCUITLENGTH), number of turns (TURNS), the number of race laps (RACELAPS), race distance (RACEDISTANCE), drag-reduction-system zones (DRSZONES), the highest recorded speed in Kph (MAXKPH) as well as the grid to turn one distance (GRID). The grid to turn one distance variable can be hypothesised two ways. A longer run into turn one can mean that drivers have a greater opportunity to overtake at the very beginning of the race. Alternatively, a shorter run into turn one can mean that the drivers then have to work more with their team to attempt to win the Grand Prix on good strategy. All race specific factors were obtained from formula1.com. Including track characteristics is a common theme among sports economics papers aiming to capture determinants of demand for motorsport, as is evident in the work of Schreyer and Torgler (2018). A weather variable accounting for the local weather in order to account for an opportunity cost of watching F1 is omitted from the eventual regression model as the US has such an array of weather across the country.

3.1.4 Qualitative factors

Qualitative variables that affect viewership are also considered. Included are TV rating of the broadcast which is directly correlated to viewership figures. Also included is a control for broadcasts near a public holiday (+/- one day), with the prior expectation being that viewership increases if a Grand Prix is broadcasted the day before or after a US public holiday. Prior to running econometric tests one would think that having a US holiday either the day before or after a Grand Prix would positively influence the demand for that Grand Prix, with the idea being that fans having an extra day off at the weekend makes them more likely to tune into an F1 race. The sample consists of races spanning across Europe, Asia, Oceania as well as North and South America. A strong emphasis and importance is placed on the outcome uncertainty measure as existing F1 sports economics literature, as well as other sport economics literature highlight that a high level of competitive balance is presumed to positively affect TV viewership. An assumption exists for most sports that fans desire to watch a contest that is not just dominated by a few players, in this case drivers. With a more balanced sport greater tension exists and so more fans are expected to tune in.

Table 3.1.5 Descriptive Statistics

VARIABLE	MEAN	SD	MIN	MAX
Viewership (Persons2+)	624,234	224,710	231,000	1,617,000
Viewership (Adults18-49)	209,814	72,364	97,000	450,000
Pacific Standard Time	9.22	2.73	1.05	15.4
TV Rating	0.4	0.15	0.15	1.04
Points Difference 1st - 20th in WDC	222	105	25	413
Points difference 1st - 10th in WDC	190	91	24	361
Points Difference 1st - 10th in CWC	389	191	37	764
Points Difference 1st - 3rd in CWC	194	96	18	371
Difference in betting odds 1st - 5^{th}	0.4	0.12	0.14	0.69
No. of Grand Prix held at a track	36	23	1	70
Circuit Length (Km)	5.15	0.85	3.34	7
Race Laps	61	9.3	44	87
Highest recorded Kph	326	13	290	350
Race Distance (Km)	306	9	260	310
Best grid position of Haas F1 team	12	4	5	18
Former WDC champions racing	4	0.5	3	4

Table 3.1.6 Independent Variable and Definitions

Variables	Explanation	Source
DIBO	Difference in betting odds 1-5	Skedball.com
Channel	Broadcast Channel (Dummy)	Skedball.com
PST	Pacific Standard Time of Broadcast	Skedball.com
Holiday	US National Holiday (=/- one day) (Dummy)	redcort.com
DOMGP	US Grand Prix (Dummy)	Formula1.com
DSLGP	Days since last Grand Prix	Formula1.com
Round	Round of World Championship	Formula1.com
eSports	eSports (Dummy)	Formula1.com
Driverptsdiff/Constructorptsdiff	First to last points difference	Statsf1.com
Driverptsdiffelite/Constructorptsdiffelite	First to tenth driver difference/ First to third constructor difference	Statsf1.com
Seasonal	Dummy if drivers' championship is won	Statsf1.com
Seasonalcons	Dummy if constructors championship is won	Statsf1.com
Motorsportdirect	Motorsport broadcast at same time as F1 (Dummy)	Skedball.com
Motorsportdaily	Motorsport on the same day as F1 (Dummy)	Skedball.com
PL	Premier League (Dummy)	Skedball.com
TDF	Tour de France (Dummy)	Skedball.com
Circuit Length	Circuit Length in Kilometres	Formula1.com
Racelaps	Number of race laps	Formula1.com
Race Distance	Race distance completed	Formula1.com
Grid	Distance from pole position to turn one	Formula1.com
Heritage	Number of Grand Prix held at a track	Statsf1.com
Start Tyre Strategy	Dummy to denote if tyre strategies are at play among top three teams at race start	Youtube.com
Domestic Team Qualifying	Best grid position of Haas F1 team	Formula1.com

Table 3.1.5 provides descriptive statistics for the independent variables in question. The highest Grand Prix viewership figures are reported for the 2018 Monaco Grand Prix with a figure of 1,617,000. The 2016 Malaysian Grand Prix represents the least viewed Grand Prix of the sample with 213,000 viewers. Understandably, both races also represent the highest and lowest TV ratings of 1.04 and 0.15 respectively, with an average of 0.40 across all grand prix. With several tracks holding back to back races in 2020 as a result of the condensed race calendar due to the Covid-19 pandemic, we are presented with the unique opportunity to model race specific events as several key independent variables remain constant from one week to the next, presenting the chance to observe race specific variables effect on TV viewership. As denoted by the minimum and maximum of the heritage variable, F1 raced in Portimaõ, Portugal for the first time in 2020, with the seventieth anniversary Grand Prix taking place in Silverstone in 2020 also. On average a Grand Prix circuit that is included in the seasons calendar has held thirty six previous Grand Prix represented above by the mean heritage figure.

A minimum value for circuit length is 3.4 kilometres at the Monaco Grand Prix Circuit in Monte Carlo. Inversely, the maximum value recorded for circuit length is found to be seven kilometres which represents the lap distance for Spa Francorchamps in Belgium. On average a Grand prix has sixty-one laps from 2016 to 2020, with the shortest number of laps being the forty four needed to achieve the race quota in Spa Francorchamps. On the other hand, eighty seven race laps were needed to surpass the race quota at the shortened Bahrain Grand Prix in 2020. The race which was run a week after the traditional Bahrain Grand Prix during the midst of the COVID-19 pandemic when a condensed F1 calendar was necessary. The track was altered to a shorter and faster circuit in order to keep fans from having to watch the same track in use two weeks in a row, the race was dubbed the ‘Sakhir Grand Prix’.

As explained previously, the race quota for a Grand Prix is 306 kilometres. Evident from Table 3.1.5, the average race distance covered is 306 kilometres, with a minimum and maximum figure of 260 kilometres and 310 kilometres respectively. With many slow corners, the Monaco Grand Prix lap takes roughly one minute and fifteen seconds to complete. This, combined with a sixty-four lap race means modern F1 cars cannot carry the required fuel load in order to race for 306 kilometres, as a result the Monaco Grand Prix is an exception to the race distance quota. The Russian Grand Prix accounts for the slightly higher than necessary and maximum race distance of 310 kilometres.

Table 3.1.7 outlines the frequency of the dummy variables included in the dataset. The variable itself is present in the left column, the frequency in which it is present across the eighty one observations is in the centre column and that frequency converted into a percentage by dividing it by the eighty one observations is explained by the column on the right. A frequency table is useful to employ as they can very quickly reveal outliers and trends within a dataset. In the case of this research it is useful to clearly display the number of Grand Prix broadcast across each channel, the number of Grand Prix in each calendar year as well as the number of clashes with major sport substitutes.

Table 3.1.7 Frequency and Percentage Share

VARIABLE	FREQUENCY	PERCENTAGE FREQUENCY
2016	10	12.35%
2017	16	19.75%
2018	18	22.22%
2019	20	24.69%
2020	17	20.99%
ESPN	12	14.81%
ESPN2	37	45.68%
CNBC	3	3.70%
ABC	7	8.64%
NBC	6	7.41%
NBCSN	16	19.75%
ESPORTS	26	32.10%
FAVWIN	39	48.15%
MOTORSPORTDIRECT	15	18.52%
MOTORSPORTDAILY	71	87.65%
PGA	12	14.81%
NFL	10	12.35%
MLB	3	3.70%
PL	27	33.33%
TDF	10	12.35%
OTHER	22	27.16%
STARTTYRESTRATEGY	19	23.46%
WEATHER	10	12.35%
NIGHT/DAY	14	17.28%
CIRCUIT/STREET	71	87.65%

Of the eighty one races covered in this dataset, ten are from the latter part of the 2016 season, sixteen are from the 2017 season, eighteen races from the 2018 season are present, twenty from the 2019 season are accounted for and all seventeen races from the 2020 season are present in this dataset.

As seen in Table 3.1.7, more than half of the eighty one Grand Prix are broadcast on either the main ESPN channel or its overflow ESPN2 channel. A dummy variable is included to quantify the possible effect eSports has on F1 broadcast demand. The variable is coded 1 if a Formula One eSports event is held in the same month as a Grand Prix. An eSports event takes place in the same month as a Grand Prix 32% of the time, although it is worth noting that the F1 eSports series runs on a condensed calendar allowing them to complete several E-Grand Prix in one day.

F1 races in this sample are broadcast at the same time as another motorsport broadcast 18.52% of the time. Also of importance is the frequency in which motorsport is broadcast on the same day as a F1 race, this is found to occur 87.65% of the time. This is primarily due to NASCAR races being broadcasted on Sunday afternoons in the US. In terms of clashes with other major sports, US F1 race broadcasts clash with English Premier League Football matches 33% of the time since the summer of 2016, it should be added that this is primarily the 2pm kick off on Sundays, concurrent with most European F1 races. Both are broadcast at roughly 9am in the US, depending on the location of the European race. F1 races are broadcast at the same time as NFL matches 12.35% of the time, across the eighty one races only three clash with an MLB game. Although it only runs for twenty three days a year, the Tour de France (TDF) represents a significant percentage of major sport clashes. A TDF stage coincides with a F1 race ten times across the eighty one races.

Interestingly, the win rate of the post qualifying race favourite was discovered to be 0.48. In short, the pole sitting driver wins the Grand Prix 48% of the time from this sample. Explained previously, two distinct types of circuits are used in Formula One, these being; race circuits and street circuits. Across the eighty one Grand Prix in this dataset, seventy one or 87.65% of races are held at race circuits around the world. The remaining 10 races or alternatively 12.35% of races are held at purpose built street circuits. Similarly, 82.72% of races are held during daytime hours locally, with the remaining 17.28% of races taking place at night.

3.2 Description of Independent Variables

Start time of the Formula One broadcast is denoted by the variable (PST) with the variable standing for Programme Start Time and is used in the same way as it is in the work of Butler, Butler and Maxcy (2018). A similar timing effect is expected here particularly in the case of European and Oceanic races.

A variable covering starting tyre strategy (STARTTYRESTRATEGY) is also included in models prior to the final model. Bekker and Lotz (2009) explain in their operational-research paper that simulates race strategy for three 2005 grand prix that when imitating Formula One race car behaviour, many characteristics including tyre compounds should be considered. Milliken and Milliken (1995) provide an in-depth analysis of these factors, noting that environmental factors have the most significant role in the choice of tyre compounds for an F1 grand prix. To explain this it must be noted that there are primarily three different tyre options available to Formula One teams for a Grand Prix weekend if the track is dry (Intermediate and Wet tyres are also available should the track see rainfall). The three dry tyres are; ‘Soft Tyres’, ‘Medium Tyres’ and ‘Hard Tyres’. Soft tyres are the quickest, with medium tyres roughly 0.6

seconds slower per lap and hard tyres slower again at roughly 1.2 seconds extra per lap, although this varies from track to track.

In recent years frontrunning teams have often taken risks in qualifying by setting their fastest lap on medium tyres, while all other drivers are forced to use soft tyres as they run the risk of being eliminated in the second qualifying session should they not be fast enough on medium tyres. If the gamble pays off, front running teams are at a huge strategic advantage for Sundays' race where they can run longer before the first round of pitstops as medium tyres last longer than softs, with the idea being that the longer they can prolong the first stint the higher the chance a safety car will be deployed and as a result they will lose less race time by pitting for new tyres.

This strategy can go one of two ways. Non frontrunning teams should be quicker early on in the race but experience tyre drop off much quicker. If non frontrunning teams do not manage to overtake the frontrunning teams early on, some past races have gone on to be a procession until the chequered flag. In short, the expectation is that TV viewership is negatively affected if there are tyre strategies employed at the race start, as already quick teams having increased strategic advantage negatively affects race excitement. As can be seen in Table 3.3, tyre strategies are employed in 23.46% of races across the four and a half seasons of this dataset. This variable was obtained through watching race highlights available via Youtube.

This can be interpreted in two ways. If tyre strategies are not employed at the start of the race teams generally have to win the race from their competitors by making use of good race strategy. Bekker and Lotz (2009) explain that a pitstop during an F1 race comprises of the operational time it requires the team to work on the car as well as the reduced speed required

to drive in and out of the pitlane, which results in significant time loss to competitors who are not in the pits at that time. It is for this reason that it is in the interest of F1 teams to minimise the number of pitstops in a race. By starting a race on the medium compound tyres the likelihood of having to stop more than once is slightly reduced. Starting tyre strategy can also have a positive effect on race excitement. Just recently at the 2021 French Grand Prix both Max Verstappen and Lewis Hamilton started on medium tyres with most of the rest of the field starting on soft tyres. Non-frontrunning drivers had little to no effect on the race, and Verstappen went on to take the lead from Hamilton just one lap prior to the end of the race. This exemplifies the fact that if frontrunning drivers are on the same strategy, an exciting race can still occur.

Dummy variables are employed to capture the effect, if any, major sport substitutes have on viewership figures of US F1 broadcasts. Included are dummy variables for motor sport broadcasts at the same time as the F1 broadcast (MOTORSPORTDIRECT), motorsport on later or earlier in the day of the F1 broadcast (MOTORSPORTDAILY), English Premier League (PL), Tour De France (TDF), Major League Baseball (MLB), Tennis (ATP), Golf (PGA), American Football (NFL) aswell as (PGA). As seen in the frequency Table 3.1.7 the most common clash of major sports with F1 is the English Premier League, which clashes with a Grand Prix 33% of the time. It should also be added that because all Grand Prix races are held on Sundays, those that do clash with Premier League matches tend to clash with the matches of most importance. For example, BSkyB have taken to referring to Sundays Premier League matches as ‘Super Sunday’, alluding to the quality of teams playing. As mentioned above, Stroth (2018) explains that those who watch free to air sports can revise their choices very easily as they are not paying to view them. Similar behaviour can be expected of those who pay for a subscription package to watch both the Premier League and Formula One. If a

sports subscriber has access to both the F1 and PL it has no additional cost to switch over to either sport.

Season long competitive balance is also a key factor in demand for the sport. As a result a measure of season long competitive balance is accounted for through a running total of the drivers and constructors championship points system. Primarily two methods are employed, (DRIVERPTSDIFF) and (CONSTRUCTORPTSDIFF) quantify the difference in points between the first placed driver/constructor and the last placed driver/constructor. (DRIVERPTSDIFF) and (CONSTRUCTORPTSDIFF) are included in the some earlier models for one main reason, this being; to include a variable that quantifies season-long competitive balance. As explained by Sutton and Parrett (1992) the sum of individual contests, in this case F1 races give rise to a 'league product' that is of far more importance than any singular F1 race. The results from earlier models point to the fact that the league product generated by the F1 season is important to F1 fans, as viewership is negatively affected by an increasingly uncompetitive league product in terms of the WDC, with the opposite occurring for the WCC. Alternatively, a more refined variable is also included, (DRIVERPTSDIFFELITE**)** which quantifies the continuous difference between the first placed driver and the tenth placed driver in the WDC. Similarly (CONSTRUCTORPTSDIFFELITE) quantifies the difference between the first and the third placed constructor in the CWC.

Also included are (SEASONAL) and (SEASONALCONS), these dummy variables represent at what point the WDC and CWC are won. As originally hypothesised by Krauskopf, Langen and Bünger (2010) we would expect broadcast demand to fall as the difference in WDC and CWC points increase. Similarly, when the WDC and CWC were secured by Rosberg and Hamilton as well as Mercedes we would again expect TV broadcast demand to fall. However,

a general consensus among F1 fans would be that the WDC is of greater importance than the CWC and so a prior expectation of these explanatory variables would be that (SEASONAL) would have a greater coefficient than (SEASONALCONS).

As outlined previously, since 2016 an American F1 team has competed in Formula One. Sister team of Haas NASCAR team, Haas Formula One Team gives US consumers an extra incentive to tune into F1 race broadcasts. To account for this, an independent variable denoting the highest starting grid position of the two Haas cars (DOMESTICTEAM) is included in the earlier models. Prior expectation is that as Haas grid position increases so does TV viewership.

(DOMGP**)** is included in early models as one could argue that a US Grand Prix would have a positive effect on local TV viewership. However, as we saw above the US Grand Prix's reputation has been heavily damaged in the past. As a result, the alternative possibility is that a home race could negatively affect viewership as die-hard US F1 fans who would travel and watch the race in person as opposed watching the live broadcast. (DSLGP) is included in early models as the 2020 season saw a condensed season calendar. By including this variable it presents the opportunity to test the effect, if any, 'triple header' and 'double header' races have on TV viewership. Triple header and Double Header are terms to denote consecutive weeks where races are held.

3.3 Summary and Conclusion

In conclusion, the methods and data employed are similar to those used by Schreyer and Torgler (2018). However, in addition to this, more robust and several new key independent variables are included. These include betting odds as a measure of outcome uncertainty, grand prix fixed effects and several new explanatory variables. These are aimed at capturing the effect

of , eSports, race strategies, track characteristics and historical circuits have on viewership. In terms of similarities, the effect of a home team, national holidays as well as major sport substitutes are expected to all have similar results to those of Schreyer and Torgler (2018). The model of Budzinski and Feddersen (2020) are also of importance. The use of dummy variables as well as a running total of WDC and CWC points systems aims to account for the possible effect of season long competitive balance and is expected to give insight on the magnitude of effect an uncompetitive championship has on TV viewership figures.

4. METHOD

4.1 Introduction to method of analysis

A Huber (1965) is used as a result of the variation across the dependent variable -viewership figures. One of the key benefits of using a Huber regression is that it is robust to outliers, as we are dealing with viewership figures ranging from hundreds of thousands to over a million it is important we estimate a model that can handle this variation. Compared to a traditional OLS model, a Huber regression is much less sensitive to outlier or spurious data. Grand prix fixed effects are included for each model.

The regression models employed can be written as follows;

1. (Y) PERSONS2+ = ß0 + ß1*ESPN+ ß2*ESPN2 + ß3*ABC + ß4*NBCSN + ß5*CNBC + ß6*TURNS + B7*CIRCUITLENGTHKM + ß8*HERITAGE + ß9*MOTORSPORTDIRECT + ß10*MOTORSPORTDAILY + ß11*DIBO + ß12*GRID + ß13*RACEDISTANCE + ß14*WEATHER + ß15*PST + ß16*HOLIDAY + ß17*PL.
2. (Y) PERSONS2+ = ß0 + ß1*ESPN+ ß2*ESPN2 + ß3*ABC + ß4*NBCSN + ß5*CNBC + ß6*TURNS + B7*CIRCUITLENGTHKM + ß8*HERITAGE + ß9*MOTORSPORTDIRECT + ß10*MOTORSPORTDAILY + ß11*DRIVERPTSDIFFELTE + ß12*CONSTRUCTORPTSDIFFELITE + ß13*GRID + ß14*RACEDISTANCE + ß15*WEATHER + ß16*PST + ß17*HOLIDAY + ß18*PL.
3. (Y) PERSONS2+ = ß0 + ß1*ESPN+ ß2*ESPN2 + ß3*ABC + ß4*NBCSN + ß5*CNBC + ß6*TURNS + B7*CIRCUITLENGTHKM + ß8*HERITAGE + ß9*MOTORSPORTDIRECT + ß10*MOTORSPORTDAILY + ß11*DQT3 + ß12*GRID + ß13*RACEDISTANCE + ß14*WEATHER + ß15*PST + ß16*HOLIDAY + ß17*PL.

4. (Y) PERSONS2+ = ß0 + ß1*ESPN+ ß2*ESPN2 + ß3*ABC + ß4*NBCSN + ß5*CNBC + ß6*TURNS + B7*CIRCUITLENGTHKM + ß8*HERITAGE + ß9*MOTORSPORTDIRECT + ß10*MOTORSPORTDAILY + ß11*DQT5 + ß12*GRID + ß13*RACEDISTANCE + ß14*WEATHER + ß15*PST + ß16*HOLIDAY + ß17*PL.

Prior to the use of the Huber regression, in order to narrow the focus of a dataset a stepwise regression is employed in order to extract the key variables that have a role in affecting US TV viewership for Formula One broadcasts. The stepwise model stems from the combination of two other models; step-up/forward and step-down/backward. The stepwise model operates on the premise that if an independent variable is included but isn't found to be significant at a pre-selected significance level, then it is dropped completely from the model. In this instance a cut-off point of 10% significance is used. The simple idea behind the use of a stepwise regression is to build a regression to test independent variables and add or remove variables throughout the process until such time that there is no longer a justification for adding or removing any other explanatory variables. In the case of this research the stepwise model is useful as with only eighty one observations and potentially over thirty explanatory variables overfitting a statistical model becomes an issue. However, complementing the stepwise regression is the addition of several variables that make theoretical sense to include in order to ensure underfitting the model does also not occur. A well-documented criticism of stepwise regressions is that some real explanatory variables that actually have an effect on the dependent variable are incorrectly dropped if they happen to be not significant in the stepwise regression. To mitigate this effect, several regressions were run along with the stepwise regression and key theoretical variables remain in the model in order to best capture the determinants of US F1

TV demand. The stepwise regressions gives great insight into the factors that are of most importance when estimating the determinants of demand for F1 broadcasts in the US.

Models three and four test the theory put forward by Schreyer and Torgler (2018). Both DQT3 and DQT5 are found to be useful predictors of Grand Prix demand in Germany. However, in the context of this research their use is as a check against both the DIBO and points difference measures of outcome uncertainty/balance. As betting odds are widely seen as the gold standard of outcome uncertainty measures in sports economics literature DQT3 and DQT5 are included in models three and four in an effort to test their suitability in estimating Grand Prix demand.

4.2 Description of method and rationale

With so many independent variables available to explain the variation in one dependent variable it's important to run several regressions to gain insight into the variables that consistently come out as significant predictors of the dependent variable. For this reason, the econometric results presented are a product of several regressions.

In order to establish a general model, the first model explores the relationship between viewership figures (PERSONS2+) and seventeen explanatory variables. The independent variables included in the finalised model are those that are statistically significant in preliminary regression equations, are deemed to be theoretically sound, and are included in the finalised stepwise regression. As mentioned previously, suggested by Schreyer and Torgler (2018) several key factors are accounted for among the independent variables, including; outcome uncertainty (race OU and season OU), timing effects, substitute sports as well as track characteristics. While all significant and even insignificant variables are of importance, as it relates to viewership figures the coefficients of the highest magnitude are of most interest. In short, stakeholders of F1 would have greater interest in those independent variables that bring

in tens of thousands of additional viewers and have vast importance as opposed to other explanatory variables that may only influence viewership figures by a few hundred or less viewers.

The model in question is in a sense quite similar to the model originally hypothesised by Schreyer and Torgler (2018). Outcome uncertainty, clashes with other major sporting events, the issues of timing effects and track characteristics are all represented in some way in their existing paper, although related to the German market rather than the US market. However, key additional variables are present in the above model, most importantly, DIBO. DIBO is included in an attempt to quantify if diminishing viewership figures are observed as the difference in betting odds between the first and fifth qualified drivers increases. The constant term is necessary as an underlying assumption is that there will always be a basic level of viewership.

4.3 Summary and conclusion

In conclusion, a Huber (1965) model is used as it is important that the general model is as robust as possible to outliers when the dependent variable is skewed. As explained by Huber (1965) "A model is said to be robust when its performance is insensitive from small deviations of the actual situation from the idealized theoretical model". In simpler terms, the model must be insensitive to a few extreme observations. In his paper, Huber (1965) makes the important distinction that although the aim is to reduce the spurious effect that outliers can have on a model, it must be remembered that in some cases the minority of observations that are deemed outliers can be the data that are informing and driving the theoretical model. The stepwise approach is employed to avoid presenting a model that includes too many explanatory variables for the number of observations and so avoiding overfitting the model.

5. ANALYSIS

5.1 Introduction and presentation of results

As mentioned above, the regression below stems from the original model put forward by Huber (1965). Presented in Table 5.1.1 is the preliminary stepwise regression that was used in order to reduce the number of independent variables.

Table 5.1.1 Stepwise Regression Results

VARIABLES	***STEPWISE***
MOTORSPORTDAILY	80,987*
	(-43,440)
RACEDISTANCE	-9,239***
	(-1,178)
HERITAGE	1,546***
	(-507)
DAYNIGHT	76,720**
	(-35,172)
ESPN	181,003***
	(-56,491)
ESPN2	190,539***
	(-52,642)
ABC	576,001***
	(-63,543)
NBC	562,301***
	(-67,783)
NBCSN	129,662**
	(-55,481)
ESPORTS	76,654**
	(-30,147)
DRIVERPTSDIFFELITE	-993***
	(-190)
SEASONALCONS	80,894**
	(-40,088)
CONSTANT	3221816***
	(-368,326)
Observations	81
R-squared	0.88

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

* Includes Country fixed effects

Table 5.1.2 Regression Results

VARIABLES	*1*	*2*	*3*	*4*
ESPN	-177,214***	-132,230**	-85,778	161,918***
	(-56,428)	(-52,458)	(53,911)	(58,971)
ESPN2	-259,861***	-198,860***	187,760***	264,251***
	(-52,480)	(-48,348)	(50,658)	(55,452)
ABC	69,897	79,604*	66,739	54,434
	(-48,284)	(-43,571)	(45,578.279)	(50,274)
NBCSN	-309,010***	-242,994***	233,478***	313,141***
	(-57,978)	(-53,306)	(55,957)	(60,937)
CNBC	-416,502***	-381,017***	344,005***	418,553***
	(-69,933)	(-65,286)	(67,532)	(73,821)
TURNS	-84	-46	-3,550	-2,393
	(-4,209)	(-4,116)	(3989)	(4,483)
CIRCUITLENGTHKM	-8,787	-4,628	5,736	-2,377
	(-18,189)	(-16,679)	(17,442)	(20,100)
HERITAGE	464	329	88	265
	(-615)	(-568)	(592)	(647)
MOTORSPORTDIRECT	-129,502***	-46,741	-54,451	117,312***
	(-38,995)	(-35,824)	(37,461)	(41,169)
MOTORSPORTDAILY	57,314*	33,357	66,849**	61,664*
	(-31,931)	(-32,956)	(30,768)	(33,607)
DIBO	180,461**			
	(-83,687)			
DRIVERPTSDIFFELITE		-662***		
		(-203)		
CONSTRUCTORPTSDIFFELITE		347*		
		(-178)		
DQT3			-3,173	
			(6,676)	
DQT5				1,396
				(9,032)
RACEDISTANCE	-11,112***	-13,070***	-14,691***	-11,590***
	(-1,907)	(-1,885)	(1,829)	(2,011)
GRID	-19	-18	-27	-18
	(-51)	(-48)	(49)	(54.)
WEATHER	-64,386**	-35,519	-47365	-66,589**
	(-30,376)	(-28,773)	(29,299)	(32,080)
PST	20,853***	20,414***	18,288***	17,534***
	(-5,897)	(-5,403)	(5650)	(6,261)
HOLIDAY	35,122	25,104	20803	32,911
	(-44,330)	(-42,438)	(42,655)	(46,883)
PL	41,631*	18,095	29,626	34,208
	(-23,265)	(-22,572)	(22,431)	(24,488)
CONSTANT	3,955,398***	4,638,699***	5,072,178***	4,214,925***
	(-569,631)	(-553,672)	(-543,705)	(596,600)
Observations	81	81	81	81
R-squared	0.926	0.908	0.895	0.866

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
* Includes Country fixed effects

5.2 Detailed analysis of results

5.2.1 DIBO Model

The model specified in Table 5.1.2 has eighty one observations. Additionally, the overall model is significant at the one percent level, with an r squared figure of 0.926 meaning that 92.6% of the variation in PERSONS2 can be explained by the seventeen explanatory variables presented. This model analyses the effect these various explanatory variables have on US TV demand for Formula One broadcasts from 2016-2020. A number of general results emerge from the preceding analysis. In line with the findings of Schreyer and Torgler (2018) some race specific elements are significant when explaining viewership figures. Albeit a small effect on viewership figures when compared with other variables, track characteristics do play an important role in shaping the demand for F1 broadcasts in the US.

Of the seventeen independent variables tested, six in the above model are not significant, these being; HOLIDAY, GRID, HERITAGE, CIRCUITLENGTHKM, TURNS and ABC. Non-significant variables in the case of this research are all variables that are not significant at the ten percent level or lower. The lack of significance of ABC is in itself significant, one would expect additional interest in the sport of F1 given it was available free to air for US consumers. Although these variables are not significant in the case of this model, it is intuitive to know that these theoretically sound variables aren't influencing TV viewership.

Unsurprisingly, it is discovered that all other channels are found to be significant. Of most importance is CNBC, which is found to be significant at the one percent level with a negative coefficient of 416,502. Also significant at the one percent level is NBCSN, with a negative coefficient of 309,010. Both ESPN and ESPN2 are significant at the one percent level with negative coefficients of 177,214 and 259,861 respectively. As a reference group for all the channel variables, NBC is used. As a result of this it can be reported that the channels above

all record lower viewership figures than NBC. As well as that, as the regression coefficients are significant, it can be assumed that the viewership figures relationship with the reference group NBC is statistically significant also.

The outcome uncertainty variable, DIBO is significant at the five percent level and has a positive coefficient. An additional 180,461 viewers can be expected for every extra unit increase in the difference in betting odds between the first and fifth qualified driver. The coefficient suggests that F1 fans are not motivated to watch when race outcome uncertainty is lower. This could be as a result of some US fans being die hard F1 followers, OU of the sport is not a concern but simply enjoying Grand Prix racing is their aim.

The coefficient observed for MOTORSPORTDIRECT, which covers any motorsport on other US channels while a F1 grand prix is being shown live is concurrent with prior expectations. Significant at the one percent level, MOTORSPORTDIRECT has a negative coefficient of 129,502, meaning less people watch live F1 broadcasts when other live motorsport is available to watch in the US. MOTORSPORTDAILY, covering motorsport that is broadcast on the same day as an F1 race, has a positive coefficient of 57,314 and is significant at the ten percent level. Therefore, it can be assumed that 57,314 additional people watch live F1 race broadcasts when other live motorsport is available earlier/later in the day of an F1 race. The MOTORSPORTDAILY coefficient figure is higher than expected. A rationale for this could be as a result of the Monaco Grand Prix and the Indy 500 being run on the same day every year in this sample. This, combined with a US public holiday the following day has a very positive impact on F1 TV viewership figures. It is understandable that less viewers tune in if there is competing motorsport broadcasts on at the same time, similarly it was also a prior expectation that more fans would tune into a Grand Prix if other motorsport is on at the same time.

RACEDISTANCE, reports a negative coefficient of 11,112. However, it should be noted that specifically RACEDISTANCE is strongly affected by the Monaco Grand Prix. The Monaco Grand Prix is the only grand prix on the calendar that does not complete the usual race quota of 306km and instead has a race distance of 260KM. This, combined with the race being consistently the most watched race of the season give rise to a negative effect by RACEDISTANCE on viewership figures.

WEATHER is a dummy variable included to account for both dry and wet races. In this regression, WEATHER is significant at the five percent level and has a negative coefficient of 64,836, signifying that fewer people watch an F1 Grand Prix when a wet race occurs. It could be argued that wet races usually shake up the traditional grid and allow smaller teams and less experienced drivers to score points and sometimes podiums. Once again, US F1 fans appear not to be concerned with competitive F1 races. However, generally, when a wet race occurs there tends to be a red flag. When a red flag is shown to drivers they must return to the pitlane and wait for the danger on track to be cleared (in the case of a wet race it can be excessive rain or a crashed car). Red flags tend to cause long delays and races can take anywhere from 15 minutes to 45 minutes to restart, which could explain the negative affect observed in this regression.

PST, is an important variable in the wider context of this regression as it encapsulates the drawback for F1 fans in the US. Programme Start Time is a variable covering the start of the F1 broadcast in hours from midnight. In this regression it is found to be significant at the one percent level and carries a coefficient of 20,853 suggesting that an extra 20,853 fans watch an F1 broadcast for every additional hour past midnight it is broadcasted at in the US. It is clear

from these results that US F1 fans have a preference for Grand Prix that start later in the day, as opposed to those broadcast at unsociable hours, this is concurrent with existing findings across many sports.

PL, which accounts for clashes with the Premier League goes against the priori of expectations. Significant at the one percent level and with a positive coefficient of 41,631 it is clear that races that clash with Premier League matches benefit from an additional 41,631 viewers. These results suggest that when fans are presented with the option of the Premier League or Formula One that more choose F1, resulting in Premier League being an opportunity cost of F1.

5.2.2 Points Difference Model

Like the above DIBO Model the Points difference model has eighty one observations and is significant at the one percent level. An r squared figure of 0.908 is observed, signifying that 90.8% of the variation in PERSONS2 can be explained by the explanatory variables listed above. This model has two extra explanatory variable with DRIVERPTSDIFF and CONSTRUCTORPTSDIFFELITE representing both the continued changes in the WDC and CWC.

Unlike the DIBO model however, nine variables of the eighteen independent variables are found to be insignificant. These include; TURNS, CIRCUITLENGTHKM, HERITAGE, MOTORSPORTDIRECT, MOTORSPORTDAILY, GRID, WEATHER, HOLIDAY and PL.

The channel variables are again as expected the most important as they present the coefficients of the greatest magnitude. CNBC, is significant at the one percent level and again has the coefficient of the highest magnitude of -381,017. NBCSN is also significant at the one percent

level and presents a negative coefficient of 242,994. Both ESPN and ESPN2 are found to have similar coefficients in -132,230 and -198,860 with ESPN significant at the five percent level and ESPN2 found to be significant at the one percent level. Surprisingly, with a new measure of outcome uncertainty ABC is found to be significant at the ten percent level and presents the only positive coefficient of the channel variables with 79,604. The results here, like the results of the model above indicate that US consumers react favourably to races that are shown on free to air channels rather than subscription channels.

Significant at the one percent level DRIVERPTSDIFFELITE is found to have a negative coefficient of 662, meaning that for every additional point difference between the driver leading the WDC and the driver in tenth position 662 less people tune into an F1 broadcast. As well as this, CONSTRUCTORPTSDIFFELITE is significant at the ten percent level. Interestingly, an inverse effect is seen in terms of constructors points difference, the coefficient of 347 suggests that 347 more people watch an F1 broadcast for every extra point difference between the first placed team and the third placed team in the CWC. However, although it is significant, a coefficient of this size does not warrant a policy or rules change in order to attract more viewers. This could be closely related for the calls for the F1 group to change the points system, from these results it is suggested that US fans are not concerned with increasing points differences.

RACEDISTANCE is also found to be significant at the one percent level and carries a negative coefficient of 13,070. Like the interpretation of RACEDISTANCE in the DIBO model, this is expected to be strongly influenced by the high demand for the Monaco Grand Prix. However, with the Russian Grand Prix representing the longest race distance for a Grand Prix and it being

poorly viewed in the US, this is also expected to play a large role in the magnitude of this coefficient.

PST is discovered to be significant at the one percent level once again with a positive coefficient of 18,095. This signifies that an additional 18,095 people tune into an F1 broadcast for every hour after midnight it is broadcast in the US, once again reaffirming the idea that US fans prefer races broadcast later in the day as opposed to the early hours of Sunday morning.

5.2.3 DQT3 Model

In the DQT3 model an r squared of 0.895 is discovered across the eighty one observations. In this model eleven of the seventeen variables are found to be insignificant, including; ESPN, ABC, TURNS, CIRCUITLENGTHKM, HERITAGE, MOTORSPORTDIRECT, DQT3, GRID, WEATHER and HOLIDAY. Of most importance is the insignificance of the outcome uncertainty measure DQT3. The use of DQT3 here is as a result of its use in the work of Schreyer and Torgler (2018). However, as is outlined at the beginning of this thesis, DIBO is widely seen as the gold standard of outcome uncertainty measures in the sports economics literature. Although both measures are good estimates of outcome uncertainty, the use of DIBO is found to be a better fit for this viewership data as is evident in its significance in model one.

As is to be expected, the channel variables once again account for several of the significant variables. ESPN2 is significant at the one percent level and carries a negative coefficient of 187,760.131. NBCSN is also significant at the one percent level with a negative coefficient of 233,478.082, as is CNBC with a negative coefficient of 344,005.678. Under the DQT3 model MOTORSPORTDAILY is found to be significant at the five percent level and it maintains the expected positive coefficient, this time at 66,849, once again indicating that if a motorsport

broadcast is shown on the same day as a grand prix then 66,849 less people are expected to tune into the Grand Prix.

RACEDISTANCE, like the channel variables is also significant at the one percent level with a negative coefficient of 14,691.345. As is outlined with both the difference in betting odds and points difference models, this is heavily influenced by both the Monaco and Russian Grand Prix's. In this model 14,691 less viewers are expected for every additional kilometre raced. PST, is again significant at the one percent level with a positive coefficient of 18,288 reinforcing the prior expectations that for every hour after midnight that a race is broadcast in the US an additional 18,288 viewers can be anticipated.

5.2.4 DQT5 Model

Under the DQT5 model the independent variables explain 86.6% of the variation in the dependent variable of PERSONS2. In this model nine variables are found to be significant with eight not significant in predicting PERSONS2, with these being; ABC, TURNS, CIRCUITLENGTHKM, HERITAGE, DQT5, GRID, HOLIDAY and PL.

Once again like the three prior models, most of the channel variables are among the significant variables. Excluding the insignificant ABC, all four other channel variables are significant at the one percent level in the DQT5 model. ESPN, ESPN2, NBCSN and CNBC all carry negative coefficients of 161,918, 264,251, 313,141 and 418,553 respectively. Collectively, these coefficients allude to the fact that in the US, free-to-air broadcasts attract more viewers than paid TV channels. Like the DIBO, PTSDIFF and DQT3/5 models NBC is used as the comparison group for these channel variables.

Both MOTORSPORTDIRECT and MOTORSPORTDAILY are significant in this model with MOTORSPORTDIRECT significant at the one percent level and with a negative coefficient of 117,312. On the other hand MOTORSPORTDAILY is significant at the ten percent level with a positive coefficient towards PERSONS2 of 61,664. RACEDISTANCE is once again significant at the maximum level of one percent, this time with a negative coefficient of 11,590. Ultimately these variables are significant as they go some way to predicting the TV viewership in the US, however, MOTORSPORTDIRECT is concurrent with prior expectations in the sense that F1 is not the most watched motorsport in the US. Therefore when a Grand Prix clashes with other motorsport such as NASCAR, we would expect TV viewership to decrease significantly, which it does in this case. Similarly we would expect motorsport on earlier or later in the day to positively affect viewership, which it does. If consumers have decided to spend an afternoon watching motorsport they would be inclined to also tune into a Grand Prix before or after other motorsport broadcasts.

In this model both WEATHER and PST are also significant, with the former significant at the five percent level with a negative coefficient of 66,589 and the latter once again significant at the one percent level with a positive coefficient of 17,534, once again indicating that US fans prefer later races. With PST holding its coefficient very robustly across all four models, it can be safely said that although it isn't as big of a factor as the channel variables, it can be recorded as a key factor into shaping US F1 TV demand.

5.3 Robustness checks

A robustness check is employed as it is important to see whether the core regression coefficient estimates behave once the regression specification is altered, either by adding or removing explanatory factors. The robustness check employed is to drop the three Monaco Grand Prix

from the dataset in order to observe if the significance of the coefficients remain similar. This is done as the Monaco Grand Prix consistently posts the highest rating and viewership figures within this dataset, so much so that the viewership figures seen for the three Monaco Grand Prix's could be considered outliers among this dataset. The large variation between the high figures posted by the Monaco Grand Prix's and the lesser viewed Malaysian Grand Prix's have a large part to play in the decision to use a Huber regression in the context of this research. As is outlined above, a model specification that was suitable to handle the large variation among the dependent variable was central to the choice of model specification.

Expectations prior to the regressions were that the US holiday the day after the Grand Prix, coupled with the Indy 500 taking place the evening of the Grand Prix were driving US TV demand. As well as that, and central to this research, the DIBO figures observed for the three Monaco Grand Prix present in the dataset are all below or equal to the average DIBO observed for all eighty one Grand Prix. DIBO's of 0.39 for 2017, 0.25 for 2018, 0.33 for 2019 point to the fact that all prior expectations would suggest that the Monaco Grand Prix's are playing a large part in driving demand figures. Although there are slight differences, both regressions are very similar, with only one variable becoming significant or insignificant when the three Monaco Grand Prix are removed. Some coefficients change slightly but not drastically.

Both the original model and robustness check model are significant at the one percent level, with the F-statistic decreasing from 46.64 in the original model to 20.01 in the robustness check. ESPN becomes insignificant after being significant at the one percent level in the original model. ABC and NBCSN move from one percent significance to ten percent and five percent respectively, CNBC is the only channel to remain at one percent significance. Collectively, TURNS, CIRCUITLENGHTKM, GRID and HERITAGE all remain

insignificant, concurrent with the original model. MOTORSPORTDIRECT and MOTORSPORTDAILY change slightly in opposite directions. MOTORSPORTDIRECT becomes significant at the one percent level as opposed to five percent significance whereas MOTORSPORTDAILY becomes significant at the ten percent level as opposed to previously being significant at the five percent level. RACEDISTANCE changes slightly from one percent to ten percent significance. DIBO, STARS and PST all remain significant at the one percent level when the 2017, 2018 and 2019 Monaco races are removed from the model. HOLIDAY remains an insignificant explanatory variable and PL changes slightly from five to ten percent significance.

In particular ESPN, ABC, RACEDISTANCE and WEATHER change significantly more than the other variables when the three Monaco Grand Prix are removed from the model. The movement in both ESPN and ABC can be attributed to the sheer difference in viewership that these channels bring in between the Monaco Grand Prix and less popular races. As is touched on previously, the Monaco Grand Prix's are the only races of the eighty one in question not to reach the race quota of 306 kilometres it is not surprising that when the three races are removed from the model that the significance of the coefficient drastically changes. In terms of the changes observed in the WEATHER variable, the Monaco Grand Prix while very prestigious is not known by fans to produce the most exciting racing. F1 fans know that qualifying for the Monaco Grand Prix is what generally decides the race winner as there is little space on track for overtakes to be made throughout the race. With this in mind, adverse weather conditions (which are also rare in Monaco as the race is completed in May each year) rarely have a significant effect on race proceedings. As a result it is not overly surprising that the coefficient undergoes significant change in the robustness check.

Table 5.3.1 Robustness Check Results

VARIABLES	*1*	*2*	*3*	*4*
ESPN	-16,523	-93,655	-10,158	-14,234
	(-63,034)	(-63,968)	(65,251)	(65,690)
ESPN2	-105,877*	-161,694***	-122,674*	-121,453*
	(-58,092)	(-59,241)	(61,486)	(62,104)
ABC	108,745**	108,246**	88,672*	82,822
	(-46,939)	(-47,891)	(49,675)	(50,322)
NBCSN	-132,978**	-200,670***	-156,313**	-155,525**
	(-63,661)	(-64,404)	(66,706)	(67,472)
CNBC	-264,966***	-345,180***	-280,620***	-280,620***
	(-71,049)	(-73,477)	(75,300)	(76,239)
TURNS	448	376	-2,338	-1,547
	(-3,784)	(-4,131)	(3,926)	(3,952)
CIRCUITLENGTHKM	2,262	-93	5915	3,185
	(-16,904)	(-17,229)	(17,514)	(17,783)
HERITAGE	207	160	25.73	6.967
	(-574)	(-590)	(611.96)	(612)
MOTORSPORTDIRECT	-88,020**	-49,403	-64,625	-61,637
	(-42,110)	(-42,512)	(44,296)	(44,754)
MOTORSPORTDAILY	50,253*	37,310	59,890*	57,308*
	(-29,552)	(-33,841)	(32,464)	(31,621)
DIBO	183,206**			
	(-77,224)			
DRIVERPTSDIFFELITE		-713***		
		(-207)		
CONSTRUCTORPTSDIFFELITE		384**		
		(-181)		
DQT3			3,432	
			(6,688)	
DQT5				-4,173
				(7,971)
RACEDISTANCE	-10,930	-17,377**	-10,383	-10,920
	(-7,228)	(-7,524)	(7,772)	(7,841)
GRID	19	-9.393	4.39	-7.692
	(-46)	(-48)	(49)	(50)
WEATHER	-41,825	-31,313	-46,911	-49,482
	(-28,837)	(-30,247)	(31,118)	(30,937)
PST	36,240***	24,616***	29,499***	29,705***
	(-5,808)	(-5,903)	(6,160)	(6,171)
HOLIDAY	17,368	26,320	21,926	38,035
	(-40,584)	(-43,461)	(43,900)	(46,170)
PL	35,209*	14,280	24,907	31,058
	(-21,027)	(-22,761)	(22,862)	(23,238)
CONSTANT	3537326	5859003**	3,550,862	3,731,410
	(-2202669)	(-2,291,449)	(2,368,145)	(2,385,556)
Observations	78	78	78	78
R-squared	0.808	0.807	0.770	0.770

Standard errors in parentheses, *** p<0.01, ** p<0.05, *p<0.1

*Includes Country fixed effects

5.3.1 DIBO Model Robustness Check

In this robustness check the number of observations is decreased from eighty one to seventy eight, as a result the r squared figure decreases from 0.926 to 0.808, meaning that in this model 80.8% of the variation in the dependent variable can be explained by the independent variables listed.

A significant decrease in all the channel variables can be observed once the three Monaco Grand Prix are dropped from the dataset. ESPN becomes insignificant, ESPN2 changes from a one percent significant level to a ten percent significant level as well as the coefficient decreasing from 259,861 to 105,877. Interestingly, ABC switches from insignificance in the original model to ten percent significance in the robustness check model. NBCSN undergoes a significance change from one to five percent as well as the coefficient increasing from -309,010 to -200,670. CNBC remains significant at the one percent level however the coefficient changes from -416,502 to -345,180. The change observed in ABC can be attributed to one of the three Monaco Grand Prix being broadcast on that channel. Collectively the coefficient changes allude to the fact that as the Monaco Grand Prix races bring in such high viewership figures, that their omission causes the coefficients to change significantly. With ESPN broadcasting the most recent Monaco Grand Prix, and its omission in the robustness check model resulting in ESPN becoming insignificant, it is suggested that US F1 fans are less likely to pay ESPN subscription prices if the broadcaster has not secured the rights to broadcast the prestigious race. Collectively, the changes observed across the channel variables point to the fact that the Monaco Grand Prix's are a driver in the magnitude of the coefficients as a result of such large viewership figures for the three races.

All five variables TURNS, CIRCUITLENGTHKM, HERITAGE, GRID and HOLIDAY all remain insignificant when the three Monaco Grand Prix are removed from the model. As mentioned previously, it is expected that the Monaco races were driving the strong negative coefficient associated with the RACEDISTANCE variable, this is confirmed with the robustness check as the RACEDISTANCE measure changes from one percent significance to insignificance in the robustness check model.

MOTORSPORTDIRECT becomes significant at the five percent level as opposed to the one percent level with the coefficient increasing from -129,502 to -88,020. MOTORSPORTDAILY remains significant at the one percent level and has a slight coefficient decrease from 57,314 to 50,253.

The outcome uncertainty measure in DIBO remains almost identical to the original model. Still significant at the five percent level, the coefficient undergoes a very slight increase from 180,461 to 183,206. The fact that there is such little change observed in the outcome uncertainty measure when the three Grand Prix's with the highest viewership figures are removed is further proof of the strength of the outcome uncertainty measure. As well as that, the robustness of the positive coefficient across both models suggests that the DIBO measure captures the die-hard US fans that are willing to tune into a race broadcast regardless of increasing difference in betting odds across the top five drivers.

WEATHER changes from being a significant variable in the original model to an insignificant coefficient in the robustness check for the DIBO model. Similar to the DIBO variable, PST remains very similar in significance and coefficient value to the original model with a

significance level of five percent and a positive coefficient of 36,240. PL remains significant at the one percent level and has a slight coefficient change from 41,631 to 35,209.

5.3.2 Points Difference Model Robustness Check

Compared to the nine insignificant variables found in the original points difference model, eleven of the explanatory variables are discovered to be insignificant when the Monaco Grand Prix's are removed from the dataset, including; ESPN, TURNS, CIRCUITLENGTHKM, HERITAGE, MOTORSPORTDIRECT, MOTORSPORTDAILY, GRID, WEATHER, HOLIDAY and PL. A decrease in the r squared figure is also observed, from 0.908 to 0.807.

In the points difference model several changes are observed among the channel variables when the three Monaco Grand Prix are dropped from the regression. ESPN becomes insignificant having been significant at the five percent level in the original model. ESPN2 remains significant at the one percent level but with a slight coefficient increase from -198,860 to -161,694. For ESPN, it highlights the importance of being the broadcaster who manages to secure the rights to broadcast the Monaco Grand Prix, as it not only brings huge demand on the day, but a positive fan experience could result in casual viewers that only tune in to watch the Monaco Grand Prix becoming regular viewers over time. Inversely, ABC increases in significance when compared with the original model, this time at five percent significance as opposed to ten percent significance, ABC also undergoes a slight coefficient increase from 79,604 to 108,246. Both NBCSN and CNBC maintain their one percent significance in the robustness check model with slight coefficient increases observed in both.

Both outcome uncertainty measures in DRIVERPTSDIFFELITE and CONSTRUCTORPTSDIFFELITE, are significant in the robustness check model. DRIVERPTSDIFFELITE maintains its one percent significance and decreases very slightly in

coefficient size. At the same time, CONSTRUCTORPTSDFIFFELITE increases in significance and coefficient value from ten percent to five percent significance and 347 to 384. Lastly, RACEDISTANCE and PST are both significant at the maximum one percent level and are affected by slightly increased coefficients, RACEDISTANCE increases from -13,070 to -17,377, whereas PST increases from 18,288 to 24,616.

5.3.3 DQT3 Model Robustness Check

Compared with the original DQT3 model the r squared of the robustness check model falls slightly from 0.895 to 0.770. Like the original DQT3 model, eleven variables are insignificant, with six variables making up the significant variables. Among the insignificant variables in this model are; ESPN, TURNS, CIRCUITLENGTHKM, HERITAGE, MOTORSPORTDIRECT, the outcome uncertainty measure itself DQT3, RACEDISTANCE, GRID, WEATHER, HOLIDAY and PL.

In the DQT3 robustness check model, ESPN2 moves from one percent to ten percent significance and a coefficient decrease from -187,760 to -122,674, which once again reiterates how important the Monaco Grand Prix is to these broadcasters, as it attracts so many viewers. ABC becomes significant when compared with the eighty one observation model, carrying a positive coefficient of 88,672. NBCSN falls slightly from one percent to five percent significance and from -233,478 to -156,313. As well as that CNBC maintains its one percent significance but also falls slightly in coefficient value from -344,005 to -280,620.

Only two variables that are not part of the channel variables are found to be significant. MOTORSPORTDAILY is significant at the minimum ten percent level in this robustness

check and with it a positive coefficient of 59,890. Also, PST is once again significant at the one percent level and with a positive coefficient of 29,499 towards PERSONS2.

5.3.4 DQT5 Model Robustness Check

The DQT5 robustness check model has an identical r squared figure when compared with the above DQT3 robustness check model. The figure of 0.77 across both models indicate that seventy seven percent of the variation in the dependent variable can be explained by the seventeen independent variables. In the DQT5 model four variables are found to be significant, these being; ESPN2, NBCSN, MOTORSPORTDAILY and PST. Explanatory variables ESPN, MOTORSPORTDIRECT, RACEDISTANCE and WEATHER all go from significant to insignificant in the robustness check model, with the remaining variables insignificant in both models.

ESPN moves from a position of one percent significance in the original model to ten percent significance in the robustness check model, as well as a large coefficient decrease from -264,251 to -121,453. NBCSN has a slight significance change from one to five percent but also has a very large coefficient change from -313,141 to -155,525. MOTORSPORTDAILY undergoes much less change in the robustness check model with it maintain ten percent significance and only changing coefficient slightly from 61’664 to 57,308. Finally, PST is unsurprisingly once again significant at the maximum one percent level, as it is across all four original and all four robustness check models. Compared with the original DQT5 model however, the coefficient increases moderately from 17,534 to 29,705.

5.4 Relationship to the literature findings

Sutton and Parrett (1992) note that fans display preferences for different tracks, it was for this reason combined with the fact that the stepwise regression suggested that they were true

explanatory variables that they were included in the model. However, given the finalised regression, the variables accounting for circuit length, the number of Grand Prix held at a track and the pole position to turn one distance are not significant explanatory variables of US viewership figures.

Butler, Butler and Maxcy (2020) report that boxing fans are relatively indifferent to balanced fights, as do Caruso, Addesa and Di Domizio (2017) in terms of football fans being unconcerned with the quality of Serie A matches. Similar results can be observed above in terms of the DIBO model, a negative coefficient would be the prior expectation, meaning that as difference in betting odds increases between the first and fifth qualified driver, viewership decreases. However, the inverse is reported meaning that F1 fans don't appear to display a preference for a more competitive race, in fact fans appear to display a strong preference for an uncompetitive race. This could be very similar to the findings of Gooding and Stephenson (2017), as explained above. The authors reported that a 50% viewership increase was observed in Professional Golf Association (PGA) events when Tiger Woods was playing. The same can be hypothesised for Lewis Hamilton. As Hamilton further strengthens his claim as the greatest F1 driver of all time, the US viewership patterns could be attributed to US fans desire to watch perhaps the best driver of all time at work.

The findings here are also opposite to the findings of Dang, Booth, Brooks and Schnytzer (2015) wherein they discover outcome uncertainty is directly correlated to greater TV audiences in the case of the AFL, and the work of Mizak, Neral and Stair (2007) where the authors report that NASCAR fans display a preference for greater outcome uncertainty. The findings regarding increased difference in betting odds resulting in increased TV demand is also related to the findings of Kang et al. (2018). The authors report that NCAA basketball fans

display a clear favourite when tuning into games. In the context of this research, it could be argued that US fans tune into a Grand Prix in the hope that Lewis Hamilton will get beaten. A positive coefficient for DIBO suggests increased difference in betting odds between the first and fifth qualified driver also suggests that F1 fans prefer an unbalanced race.

The insignificance of the outcome uncertainty measures DQT3 and DQT5 variables across models three and four are also very important in the wider context of this research. Well documented throughout this thesis is the work of Schreyer and Torgler (2018). The authors have a strong hypothesis to use difference in qualifying times as the reduced top three and top five differences narrow the focus of their research to those drivers who have a significant effect on race outcome. Inversely, by running four different models, each with different outcome uncertainty variables but the same overall model, the effectiveness of each outcome uncertainty measure can be compared. The strong significance of the difference in betting odds in model, one and points differences in model two, while the difference in qualifying times are found to be insignificant in models three and four point to the fact that the DIBO and PTSDIFF model are superior measures of outcome uncertainty than DQT3 and DQT5.

5.5 Hirschman Herfindahl Index

Using the same equation as Mourão (2017), originally found in the works of Kupfer (2002), we can calculate a HHI for the most recent 2020 season. The author notes that traditionally HHI is employed to quantify market share across firms in an industry. By treating a drivers/constructors points as their market share it is possible to create HHI's for both the WDC and CWC. In short, all drivers/constructors total season points are divided by the total available points for the season. These resulting figures are then squared and summed together to give us HHI's for the WDC and CWC each year. Using the season ending points table published by

Formula1 (2021) we find a HHI for the WDC of 0.209. When compared with the figure of 0.109 in 2014 and 0.098 in 2010 as found by the author, our prior expectation of the WDC having a decreasing level of outcome uncertainty is confirmed. Interestingly we get slightly different results when we calculate the HHI for the 2020 CWC, a figure of 0.192. This figure is slightly lower than the historical constructor HHI's calculated by Mourão (2017). Although the author explains that this can easily happen as a good driver often has a rookie team mate who would distort the constructor figures as it is a combination of their points, for this reason the World Drivers Championship HHI's give us a better indication of outcome uncertainty than the Constructors World Championship.

An interesting comparison to make using the HHI is between Michael Schumacher's 2002 season and Lewis Hamilton's 2020 season. As noted above, Schumacher won the 2002 season after only eleven of seventeen races and it resulted in the Formula One points system being drastically revised. On the other hand, Hamilton came close to breaking Alberto Ascari's all-time win percentage record of 75% in the 2020 season, the feat would have been possible had he not missed the Sakhir Grand Prix due to contracting COVID-19. A HHI for Schumacher's 2002 season is found to be 0.176, compared to 0.209 in Hamilton's 2020 season, indicating that the competitive balance of the 2020 season was worse than Michael Schumacher's most dominant ever season. Interestingly, no points system amendments were made prior to the start of the 2021 season.

Table 5.5.1 HH1 2000-2020

Year	World Drivers Championship HHI	Constructor World Championship HHI
2000 (Schumacher)	0.155	0.292
2002 (Schumacher)	0.176	0.320
2014 (Hamilton)	0.109	0.211
2016 (Rosberg)	0.112	0.212
2017 (Hamilton)	0.109	0.220
2018 (Hamilton)	0.098	0.211
2019 (Hamilton)	0.113	0.222
2020 (Hamilton)	0.209	0.192

5.6 Summary and Conclusion

Collectively across all four robustness check models, although some variables undergo significant change when the three Monaco Grand Prix are omitted, other independent variables such as some channel variables and specifically PST emerge as very strong and robust predictors of TV viewership in the US. When the robustness check models are compared with each of the original models some individual variables switch from significant to nonsignificant variables. However, for most independent variables, they become less significant but are still key variables in explaining the variation in the dependent variable of US TV viewership. In conjunction with this all four models see a significant fall of roughly ten percent in their respective r squared figures, denoting that when the three races are removed, the predictor variables are slightly less powerful in predicting viewership figures for the US market.

6. DISCUSSION

6.1 Introduction to discussion

The dataset in question facilitates the analysis of the varying factors of demand for US F1 TV viewership. The results set out above strengthen and explain why track characteristics, timing effects, substitute broadcasts, outcome uncertainty and TV channels are all important factors in shaping demand for live F1 broadcast consumption in the US. As well as support found for existing sport economic findings, some surprising results are also reported. It is well documented across sports economics literature that fans do not always value outcome uncertainty and more balanced sporting contests. However, it is necessary to hypothesise in the case of the DIBO model why US fans do not react to the low outcome uncertainty levels.

Schreyer and Torgler (2018) explain that their results indicate that German F1 fans prefer F1 races in which ex ante competition between a group of three to four drivers in each race, which results in an uncertain race outcome. A plausible interpretation for why US fans do not value outcome uncertainty is that they tune in to see a broadcast of the pinnacle category of motorsport and the eventual race winner is a secondary aspect to this. As mentioned in the literature review, Lewis Hamilton has equalled and surpassed several of Michael Schumacher's records which he set during his most dominant period of F1. Therefore the understandable reason that more US fans tune into live race broadcasts even as the outcome uncertainty decreases is an indication to the fact that US fans want to see one of the best F1 drivers of all time. Closely related to this theory is also related to a previous literature review topic. It was outlined by Krauskopf, Langen and Bünger (2018) that a drawback of Formula 2 is that all drivers drive equal machinery and so there is no great surprise when an outsider wins a race. In the case of Formula 1, as outcome uncertainty is so low, fans may tune in to see someone other than Lewis Hamilton claim a race win.

6.2 Implication of results and context of these in the literature

Although the comparisons that can be made between these results and existing F1 sports economics literature is limited, some useful comparisons can be made. In terms of other Formula One sports economics literature, it is well documented by Borland and McDonald (2003) along with Sutton and Parrett (1992) that the league product that professional sports produce is of great and sometimes greater importance than one single event (in this case Grand Prix). Support for this theory put forward in both papers is found in the points difference model above. The clear negative effect that an increasingly uncompetitive WDC has on TV viewership gives an insight into the effect season long outcome uncertainty and competitive balance has on the number of US fans willing to tune in. This finding is closely related to the work of Krauskopf, Langen and Bünger (2010). As is noted in the literature review the authors explain that fans lose interest when the WDC is won prior to the end of the season. A growing points difference between the first and tenth driver alludes to the fact that the WDC leading driver is closing in on securing the championship title. The inverse effect is seen with the CWC, as an increase in points difference between the first and third place constructor results in an increase in the number of TV viewers.

As is noted in the literature review, Butler, Butler and Maxcy (2020) explain that main events in boxing attract less viewers, which is attributed to the unsocial hours that a European broadcast would be shown in the US. Concurrent findings are discovered here. The continued significance of the programme start time variable across all four models alludes to the fact that it is such a defining factor for US viewers. Collectively, the findings suggest that US viewership figures are negatively affected by an increasing gap between the first and tenth place drivers while positively affected by an increasing difference between the first and third placed constructors. In terms of the WDC, it can be closely related to the work of Anderson (2012),

who as we saw in the literature review explained that if finishing a race requires more skill on the drivers part than retiring due to a crash or mechanical failure then the F1 points system is flawed. In order to offset the effect that an increasing difference in points between the first placed driver and tenth placed driver has, the Formula One Group could potentially look at decreasing the difference between the points on offer for the Grand Prix winner and the driver who finishes in tenth place. As a result, when the championship standings are released after each Grand Prix, the appearance that drivers further down the championship standings are not too far away from challenging for the title or season podium may positively impact TV viewership.

The significance of the Premier League in the DIBO model can be explained by the work of Meier, Koner and Stroth (2018). The authors note that consumers of free to air TV can easily revise their choice of broadcast as it has no opportunity cost. As ESPN do not and NBC did not sell packages comprising of only F1 broadcasts, similar behaviour can be expected with paid channels. This goes some way to explain the positive coefficient on the Premier League variable. If US fans have paid NBC or ESPN for a sport package that includes F1 and the Premier League they do not accrue any more costs from revising their choices after they have bought their subscription. In conjunction with this, throughout the dataset many European races not only clash with Premier League matches but also are preceded by such matches. With this in mind it is possible that the Premier League is more of a compliment rather than a substitute for US F1 fans.

6.3 Recommendations based on results and contexts these sit within the literature

Of all the significant variables, of high importance for broadcasters or the Formula One Group is that of the channels chosen to broadcast F1 races and the US time that they are shown.

Most importantly, as they carry the largest coefficients, is the decision by the Formula One Group of who to choose to sell broadcasting rights to. The six broadcast channels are owned by only two parent companies, *NBC* and *The Walt Disney Company*. Both NBC and ABC account for the largest viewership figures throughout the broadcasts, although this is directly correlated to those channels being specifically chosen as they are the main channels for both broadcasters. The broadcasters choice of which channel to broadcast races on is an important factor. Choosing to place a live Grand Prix on their main sport broadcast channel consistently results in higher viewership figures across the four and a half seasons represented in this research. However, it should be noted that broadcasters choose what Grand Prix's to place on main channels by taking into account what Grand Prix's US fans would be most interested in, e.g. US Grand Prix, Canadian Grand Prix, Mexico Grand Prix. Inversely, Grand Prix's such as the Russian Grand Prix and Malaysian Grand Prix would historically be of much less interest to US consumers and so are placed on overflow channels.

It should be noted that the choice of broadcast channel is very closely related with the timing of the broadcast also. As the timing of the broadcast is such a key factor that the broadcasters have already streamlined their choices of channels in order to extract the most viewers from each broadcast. In tandem with this, it should be noted, in order to make a recommendation for future broadcasts it is worth mentioning that The Walt Disney Company have secured the rights to broadcast F1 in the US until the end of this year's 2022 season. In order to extract additional viewers the broadcaster could choose to place additional races on their main ABC channel, as this is where they have achieved their highest viewership figures to date. One of the main drawbacks of choosing to broadcast races on secondary channels is that it suggests to consumers that there is more important live sport to be watched on the broadcasters main channel, which can have a negative effect on viewership. It should also be addressed, as many

major sports see new broadcasters enter into markets so often in recent times that if a new broadcaster were to enter into the US F1 then they would benefit greatly from securing the rights the broadcast races that are shown at the most social times in the US, should they not be able to secure the rights to all races.

Given the clear evidence in the results that viewership decreases by several hundred thousand when a Grand Prix is shown concurrently with another motorsport race in the US, it would be in the interest of broadcasting decision makers to ensure that motorsport broadcasts do not clash, especially broadcasts that clash with the most viewed Grand Prix's in the US, as they stand to lose the most viewers. Similarly to this, F1 broadcasts benefit greatly from other motorsport broadcasts shown earlier or later in the day of an F1 race. For this reason, broadcasters should attempt to show motorsport on the day of an F1 race, which not only would boost viewership for the Grand Prix but also presumably the other motorsport broadcast also. As Grand Prix viewership in the US is positively affected by Premier League broadcasts, broadcasters should not refrain from showing both major sports concurrently. With modern technology fans may even be able to switch between both broadcasts, as quite a low threshold exists for fans to be counted as a viewer for a Formula One broadcast.

With such a clear indication from the retrospective data that fans prefer races to be on at social times in the US, it is clear that in order to increase the number of viewers for the broadcast, that F1 races ought to be shown later in the day. This of course can prevent a problem in the sense that watching sport live is also very important to fans, arguably more important the more dedicated a fan is. As a result, if fans know they're watching a recorded race it may not boost the number in the expected way. Alternatively and more realistically, the Formula One Group could choose to hold European races in the evening at European time, which would result in a

more manageable early broadcast time for US fans, while not having a drastic effect on the start time for European fans. This of course will have a knock on effect for fans in the middle east and Oceania which may mitigate the gains in US viewership. However, the US is listed as one of the Formula One Groups key markets and so may warrant this change.

Another plausible solution to growing the demand for Formula One racing in the US is additional races across countries that record higher than average US viewership, these being; Mexico, Brazil and Canada. Since this research began the Formula One group have introduced two new Grand Prix's set to join the F1 calendar in the 2022 season. Both the Saudi Arabian Grand Prix and Miami Grand Prix were strategically added to boost fan support in two of the Formula One Groups key markets; The Middle East and The United States. This move to add a second US Grand Prix displays the Formula One Groups commitment to the US as a key market and highlights the importance of captivating the US audience going forward. In line with the findings of this research, in order to achieve maximum viewership for the existing US Grand Prix and the new Miami Grand Prix, broadcasters should ensure that the Grand Prix's are free to air, at prime time Sunday viewing times, as well as not having to compete with any other motorsport broadcasts.

7. CONCLUSION

Through the analysis of four and a half F1 seasons and eighty one Formula One Grand Prix broadcast from the summer of 2016 to the season finale of the 2020 season, We find that the behaviour of US fans is not in support of the outcome uncertainty hypothesis with regard to their reaction to an increasing difference in betting odds between the first and fifth qualified driver. In conjunction with this finding it is also discovered that additional disparity between the first and fifth driver in the World Drivers Championship has a negative effect on TV viewership with the opposite results are found when dealing with the Constructors World Championship. In general, both results add to the understanding of broadcasting demand for Formula One in the US.

Various management implications can be derived from this research, all of which have differing but valuable commercial relevance for stakeholders of the sport of Formula One. More specifically however, the findings presented can be used as a basis for future strategic decision making for existing broadcasters and even potential new broadcasters looking at breaking into the F1 market. It is found that of most importance for stakeholders involved in Formula One is that of the time that each F1 Grand Prix is broadcast as well as what channel is chosen to broadcast on, not only by provider but what specific channels each provider uses to show US fans each Grand Prix. Competing motorsport broadcasts as well as motorsport broadcasts on the same day as an F1 race and in some instances the local weather at the Grand Prix circuit are also determinants of demand for F1 viewership in the US.

The various models presented in this thesis not only add to the literature on the topic but also offer additional insights for the governing body of the sport as well as TV broadcasters aiming to capture the attention of the US market. The conclusion of the paper written by Schreyer and

Torgler (2018) highlights that future studies would greatly benefit from using similar econometric approaches but by encompassing data from elsewhere in the world. This thesis does just that by encompassing data from the previously unstudied US market and uses a previously unused in Formula One research outcome uncertainty method of betting odds to improve the robustness and accuracy of the econometric tests.

Limitations of this research that future studies could benefit from are as follows; future studies aimed at encapsulating the determinants of demand for F1 broadcasts in the US would benefit greatly from a larger dataset in terms of Grand Prix and betting odds. Although difficult to secure, a larger dataset of both Grand Prix and betting odds would offer more robust determinants of demand. In addition, this research does not include viewers on mobile devices, those who purchase directly from the Formula One Group via *F1 TV Pro* or those who stream F1 Grand Prix's illegally. With modern technology it is important to aim to include both TV and mobile viewers. As well as that, many documentaries have been released in the recent past which has directed significantly more attention towards the sport, future studies could benefit greatly from attempting to quantify these documentaries have on Grand Prix viewership. The 2021 season has seen the addition of Sprint races as a form of qualifying across three Grand Prix in the 2021 season. This has a knock on effect meaning that qualifying is moved from Saturday to Friday. Comparisons from this seasons Dutch Grand Prix and Italian Grand Prix uncover interesting differences. A week after the Dutch Grand Prix the Italian Grand Prix saw the use of sprint qualifying as opposed to the traditional methods. As a result, the Italian Grand Prix recorded a 287.7% increase in Friday viewership and an additional 16.9% and 1.9% on Saturday and Sunday (Formula1, 2021). Future studies would benefit greatly from investigating the effect that an additional race spectacle across the weekend can have on TV viewership.

Although there is a growing depth of sports economics literature, the lesser explored field of Formula One sports economics literature is still relatively new. Very little attention has been paid to the sport as a whole but even less has been directed towards the effect that outcome uncertainty has on demand. The results presented in this thesis aim to fill the gap in the sports economics literature.

8. REFERENCES

Allan, G., & Roy, G. (2008). Does television crowd out spectators? New evidence from the Scottish Premier League. *Journal of* Sports Economics, 9(6), 592-605.

Allen, J. (2010*). How much does an F1 driver earn?* James Allen on F1. http://www.jamesallenonf1.com/2010/08/how-much-does-an-f1-driver-earn/. (Accessed 18 February 2021).

Anderson, A. (2014). Maximum likelihood ranking in racing sports. *Applied Economics*, *46*(15), 1778-1787.

Arkes, J., & Martinez, J. (2011). Finally, evidence for a momentum effect in the NBA. *Journal of Quantitative Analysis in Sports*, *7*(3), (13) 1-16 .

Artero, I., Bandrés, E., García, J., & Rodríguez, P. (2019). Demand for professional sports: Attendance and audience. *Sports (and) Economics*, 183-218.

Bekker, J., & Lotz, W. (2009). Planning Formula One race strategies using discrete-event simulation. *Journal of the Operational Research Society*, *60*(7), 952-961.

Bell, A., Smith, J., Sabel, C. E., Jones, K., & Bell, A. Formula for success: Multilevel modelling of Formula One Driver and Constructor performance.

Benson, (2011) *Could F1 Go to Pay TV?*, Accessed at: http://www.bbc.co.uk/blogs/andrewbenson/2011/04/will_f1_go_pay-per-view.html (Accessed 13 June 2021).

Berrett, T., & Slack, T. (1999). An analysis of the influence of competitive and institutional pressures on corporate sponsorship decisions. *Journal of Sport Management*, *13*(2), 114-138.

Berkowitz, J. P., Depken, C. A., & Wilson, D. P. (2011). When going in circles is going backward: Outcome uncertainty in NASCAR. *Journal of Sports Economics*, *12*(3), 253-283.

Budzinski, O., & Feddersen, A. (2020). Measuring competitive balance in Formula One racing. In *Outcome Uncertainty in Sporting Events*. Edward Elgar Publishing.

Budzinski, O., & Müller-Kock, A. (2018). Is the revenue allocation scheme of Formula One motor racing a case for European competition policy? *Contemporary Economic Policy*, *36*(1), 215-233.

Butler, D., Butler, R., & Maxcy, J. (2020). New insights on the Louis-Schmeling paradox: determinants of demand for subscription and pay-per-view boxing. *European Sport Management Quarterly*, 1-21.

Buraimo, B., Peel, D., & Simmons, R. (2013). Systematic Positive Expected Returns in the UK Fixed Odds Betting Market: An Analysis of the Fink Tank Predictions. *International Journal of Financial Studies*, *1*(4), 168-182.

Brown, K. A., Billings, A. C., Murphy, B., & Puesan, L. (2018). Intersections of fandom in the age of interactive media: eSports fandom as a predictor of traditional sport fandom. *Communication & Sport*, *6*(4), 418-435.

Caruso, R., Addesa, F., & Di Domizio, M. (2019). The determinants of the TV demand for soccer: Empirical evidence on Italian Serie A for the period 2008-2015. *Journal of Sports Economics*, *20*(1), 25-49.

Celik, O. B. (2020). Survival of Formula One Drivers. *Social Science Quarterly*, *101*(4), 1271-1281.

Chung, J., Lee, Y. H., & Kang, J. H. (2016). Ex ante and ex post expectations of outcome uncertainty and baseball television viewership. *Journal of Sports Economics*, *17*(8), 790-812.

CNBC.com, (2021) *Formula One revenues dropped by $877 million in 2020,* Accessed at https://www.cnbc.com/2021/02/26/formula-one-revenues-dropped-by-877-million-in-2020.html (Accessed 15 June 2021).

Dang, T. M., Booth, R., Brooks, R., & Schnytzer, A. (2015). Do TV viewers value uncertainty of outcome? Evidence from the Australian Football League. *Economic Record*, *91*(295), 523-535.

Depken, C. A., Groothuis, P. A., & Rotthoff, K. W. (2018). Family connections in motorsports: The case of Formula One. *International Journal of Sports Finance*, *13*(4), 336-352.

Depken, C. A., Hood, M., & King, E. (2017). Consistency and Momentum in NASCAR. *Journal of Sports Economics*, *18*(6), 601-621.

Depken, C. A., & Wilson, D. P. (2004). The efficiency of the NASCAR reward system: Initial empirical evidence. *Journal of Sports Economics*, *5*(4), 371-386.

Dietl, H., & Hasan, T. (2007). Pay-Tv versus Free-TV: A model of sports broadcasting rights sales. *Eastern Economic Journal*, *33*(3), 405-428.

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

Entertainment and Sports Programming Network, (2021). https://www.espn.com/espnplus/ (Accessed 8 February 2021).

Financial Times, (2014). *A flawed attempt to make football more beautiful. https://www.ft.com/content/fda24bda-2d35-11e4-aca0-00144feabdc0* (Accessed 27 January 2021).

Forbes, (2017). *Revealed: How Liberty Media Bought Formula One for $301 million.* *https://www.forbes.com/sites/csylt/2017/08/15/revealed-how-liberty-media-bought-formula-one-for-301-million/* (Accessed 27 December 2020).

Formula One, (2020). *F1 broadcast to 1.9 billion total audience in 2019.* *https://www.formula1.com/en/latest/article.f1-broadcast-to-1-9-billion-fans-in-2019.4IeYkWSoexxSIeJyuTrk22.html* (Accessed 9 October 2020).

Formula One, (2021). *Formula One announces TV and Digital audience figures for 2020.* *https://www.formula1.com/en/latest/article.formula-1-announces-tv-and-digital-audience-figures-for-2020.3sbRmZm4u5Jf8pagvPoPUQ.html* (Accessed 8 February 2021).

F1destinations.com, (2020). *Race Facts – United States Grand Prix* *https://f1destinations.com/race-facts-us-grand-prix/* (Accessed 10 February 2020).

Garcia-del-Barrio, P., & Reade, J. J. (2021). Does certainty on the winner diminish the interest in sport competitions? The case of formula one. *Empirical Economics*, 1-21.

Gooding, C., & Stephenson, E. F. (2017). Superstars, uncertainty of outcome, and PGA Tour television ratings. *Journal of Sports Economics*, *18*(8), 867-875.

Hamilton M, Brawn R, (2020) *Formula 1 Official History.* Welbeck Publishing Group.

Horowitz, I. (1978). Market entrenchment and the sports broadcasting act. *American Behavioral Scientist*, 21(3), 415–430.

Huber, P. J. (1965). A robust version of the probability ratio test. *The Annals of Mathematical Statistics*, 1753-1758.

Hunt, K. A., Bristol, T., & Bashaw, R. E. (1999). A conceptual approach to classifying sports fans. *Journal of services marketing*. (13) 440-452.

Judde, C., Booth, R., & Brooks, R. (2013). Second place is first of the losers: An analysis of competitive balance in Formula One. *Journal of Sports Economics*, *14*(4), 411-439.

Kang, B., Salaga, S., Tainsky, S., & Juravich, M. (2018). NCAA college basketball television viewership: Does preference for outcome uncertainty change throughout the season?. *International Journal of Sport Finance*, *13*(4), 373-391.

Kipker, I. (2003). Determinanten der kurzfristigen TV-Nachfrage in der Formel 1–Superstar-vs. Spannungseffekte und Implikationen für die Wettbewerbspolitik. *Globalisierung des wirtschaftlichen Wettbewerbes im Sport*, 85-104.

Krauskopf, T., Langen, M., & Bünger, B. (2010). *The search for optimal competitive balance in formula one* (No. 38). CAWM discussion paper/Centrum für Angewandte Wirtschaftsforschung Münster.

Kupfer, D. (2002). Economia Industrial: Fundamentos teóricos e práticos no Brasil. Rio de Janeiro: Elsevier ed. Campus.

Knowles, G., Sherony, K., & Haupert, M. (1992). The demand for Major League Baseball: A test of the uncertainty of outcome hypothesis. *The American Economist*, *36*(2), 72-80.

Krauskopf, T., Langen, M., & Bünger, B. (2010). *The search for optimal competitive balance in formula one* (No. 38). CAWM discussion paper/Centrum für Angewandte Wirtschaftsforschung Münster.

Lee, S., & Ross, S. D. (2012). Sport sponsorship decision making in a global market. *Sport, Business and Management: An International Journal*, (2) 155-168.

Mastromarco, C., & Runkel, M. (2009). Rule changes and competitive balance in Formula One motor racing. *Applied Economics*, *41*(23), 3003-3014.

Motorsport.com, (2021). *The pay TV vs free-to-air conflict at the heart of modern F1.* https://www.motorsport.com/f1/news/the-pay-tv-vs-free-to-air-conflict-at-the-heart-of-modern-f1/6510753/ (Accessed 15 June 2021).

Neale, W. C. (1964). The peculiar economics of professional sports. *The quarterly journal of economics*, *78*(1), 1-14.

Noll, R. (1974), 'Attendance and Price Setting', in R. Noll (ed.), *Government and the Sports Business*, Washington, DC, Brookings Institute.

Noll, R. G. (2007). Broadcasting and team sports. *Scottish Journal of Political Economy*, *54*(3), 400-421.

Mastromarco, C., & Runkel, M. (2009). Rule changes and competitive balance in Formula One motor racing. *Applied Economics*, *41*(23), 3003-3014.

Meier, H. E., Konjer, M., & Stroth, S. (2018). Provincial Consumer Preferences and Fragmented Sport Governance: Demand for Professional Boxing in Germany. *International Journal of Sport Finance*, *13*(1) 52-83.

Milliken, W. F., & Milliken, D. L. (1995). *Race car vehicle dynamics* Warrendale, PA: Society of Automotive Engineers.

Mizak, D., Neral, J., & Stair, A. (2007). The adjusted churn: an index of competitive balance for sports leagues based on changes in team standings over time. *Economics Bulletin*, *26*(3), 1-7.

Motorsport.com, (2016). *Analysis: The numbers show why Formula 1 took the exclusive Sky deal.* https://www.motorsport.com/f1/news/analysis-the-numbers-show-why-formula-1-took-the-exclusive-sky-deal/3221041/ (Accessed 1 February 2021).

Mourão, P. (2017). *The economics of motorsports: The case of Formula One*. Springer.

Paul, R. J., & Weinbach, A. P. (2007). The uncertainty of outcome and scoring effects on Nielsen ratings for Monday Night Football. *Journal of Economics and Business*, *59*(3), 199-211.

Petróczy, D. G., & Csató, L. (2021). Revenue allocation in Formula One: a pairwise comparison approach. *International Journal of General Systems*, *50*(3), 243-261.

Phillips, A. J. (2014). Uncovering Formula One driver performances from 1950 to 2013 by adjusting for team and competition effects. *Journal of Quantitative Analysis in Sports*, *10*(2), 261-278.

PitPass.com, (2017). *How America Covers F1*. *https://www.pitpass.com/58109/How-America-Covers-F1* (Accessed 10 February 2021).

PlanetF1.com, (2020). *Hamilton: They're always trying to slow us down.* https://www.planetf1.com/news/lewis-hamilton-mercedes-slowed-down/ (Accessed 03 June 2021).

Potter, J. M. (2011). Estimating the offsetting effects of driver behavior in response to safety regulation: The case of formula one racing. *Journal of Quantitative Analysis in Sports*, *7*(3).

Racefans.net, (2021). *Michael Schumacher.* https://www.racefans.net/michael-schumacher/ (Accessed 20 February 2021).

Reams, L., & Eddy, T. (2017). The impact of rivalry antecedents on mediated demand for an individual sport. *Sport Marketing Quarterly*, *26*(4).

Rodríguez-Gutiérrez, C., & Fernández-Blanco, V. (2017). Continuous TV demand in road cycling: The 2015 Vuelta a España. *European Sport Management Quarterly*, *17*(3), 349-369.

Rottenberg, S. (1956). The baseball players' labor market. *Journal of political economy*, *64*(3), 242-258.

Schreyer, D., Schmidt, S. L., & Torgler, B. (2018). Game outcome uncertainty and television audience demand: New evidence from German football. *German Economic Review*, *19*(2), 140-161.

Schreyer, D., & Torgler, B. (2018). On the role of race outcome uncertainty in the TV demand for Formula 1 Grands Prix. *Journal of Sports Economics*, *19*(2), 211-229.

Schwartz, J. T., Isaacs, J. P., & Carilli, A. M. (2007). To race or to place? An empirical investigation of the efficiency of the NASCAR points competition. *Journal of Sports Economics*, *8*(6), 633-641.

Skedball: *Weekly Sports TV Rating 4.26-5.2.2021* http://www.showbuzzdaily.com/articles/skedball-weekly-sports-tv-ratings-4-26-5-2-2021.html (Accessed 19 July 2021).

Smith, L. (2018), *The top 10 most famous brands in Formula One* https://www.raconteur.net/the-top-10-most-famous-brands-in-formula-1/ (Accessed 26 January 2021).

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

Stadelmann, D., & Eichenberger, R. (2008). Wer ist der beste Formel 1 Fahrer? Eine ökonometrische Talentbewertung. *Perspektiven der Wirtschaftspolitik*, *9*(4), 486-512.

Sporting Free, (2021). *F1 Prize Money 2021: Formula1 Prize Money Breakdown. https://www.sportingfree.com/cricket/formula-1-prize-money/* (Accessed 22 January 2021).

StatsF1.com, (2021). *Wins by grid position. https://www.statsf1.com/en/statistiques/pilote/victoire/grille.aspx* (Accessed 23 June 2021).

Sung, H., Mills, B. M., & Tainsky, S. (2017). From schadenfreude to mitfreude? Estimating viewership loss and rivalrous relationships in otherwise neutral markets. *Sport Management Review*, *20*(2), 159-169.

Sutton, W. A., & Parrett, I. (1992). Marketing the core product in professional team sports in the United States. *Sport Marketing Quarterly*, *1*(2), 7-19.

Szymanski, S. (2010). Why have Premium Sports Rights Migrated to Pay TV in Europe but not in the US? In *The Comparative Economics of Sport* (pp. 262-274). Palgrave Macmillan, London.

Tainsky, S., & McEvoy, C. D. (2012). Television broadcast demand in markets without local teams. *Journal of Sports Economics*, *13*(3), 250-265.

Tainsky, S. (2010). Television broadcast demand for National Football League contests. *Journal of Sports Economics*, *11*(6), 629-640.

Valentine, E. (2021) Personal correspondence.

Van Reeth, D. (2013). Television demand for the Tour de France: The importance of outcome uncertainty, patriotism and doping. *International Journal of Sport Finance*, *8*, 39-60.

Von Allmen, P. (2001). Is the reward system in NASCAR efficient?. *Journal of Sports Economics*, *2*(1), 62-79.

Watanabe, N. M. (2015). Sources of direct demand: An examination of demand for the Ultimate Fighting Championship. *International Journal of Sport Finance, 10,* 26–41.

Wilber, D. (1988). Linking sports and sponsors. *The Journal of Business Strategy*, *9*(4), 8.