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Surviving in the shadows—An economic and empirical discussion about the survival of the non-winning F1 drivers

Paulo Reis Mourao

Department of Economics & NIPE, Economics & Management School, University of Minho, 4700 Braga, Portugal

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ABSTRACT

F1 drivers are the (most) visible faces of a F1 team's performance. Good performances ensure a lengthier contract between drivers and teams. Reversely, humble performances may jeopardize the renewal of drivers' contracts to their teams. This paper will study the capacity of F1 drivers surviving professionally in competition. Considering two major samples of drivers (without points or without victories) and two types of 'exits' (exiting the team or exiting the F1 competition), various regressions of Cox survival models and of parametric regressions have been obtained. The main results suggest that recent worse standings results, higher ages and a higher number of withdrawals contribute to the shortening of F1 careers. It has also been observed that the early decades of competition were not known for providing a higher number of races for drivers. Reversely, adding podium positions (even without winning) ensures a longer professional life in F1.

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1. Introduction

The professional longevity of certain contractual relations is a topic which has been catching the attention of scholars for the last decades. There has been a considerable amount of literature regarding the various reasons for the differences in contractual lengths: from heterogeneity, depending on the differences in the economic sectors, to the models based on the signaling of competence marks (Mincer, 1958; Houseman et al., 2003; Fang and MacPhail, 2008).

Since the seminal works from authors like Mincer (1958) or Goldin (1980), the contractual relation between an employer and an employee is analyzed as the product of a set of (sequential) bargaining contacts between these two parts in which the measurable outputs (mostly salaries and contractual lengths) depend on three sets of dimensions: the individual characteristics of the employee (age, education level, professional experience, capacity of attracting funding, etc.), the environmental characteristics of the hiring entity (productivity levels, market power, internal plans of development, etc.) and the institutional patterns (legislation regulating the contractual terms, interference of informal practices, etc.).

Within this literature, a more defined area, focused on the contractual relations of sportsmen/sportswomen has started to be more focused on certain topics (Rosen, 1981). The contractual relations of professional sportsmen/sportswomen also tend to be characterized by these triangular discussions: specific outputs (in general, short contractual lengths and considerably high wages), positive impacts from individual characteristics like a track of relative success (Elson and Ferrere, 2013; Cyrenne, 2014) or a track of victories (Hausman and Leonard, 1994), pressures from the history of success of the hiring teams and an influence of the regulations of each country and of each period (Coates et al., 2016).

Formula One is an expensive sport. Therefore, drivers' exhibitions are particularly responsible for the teams' higher revenues through more sponsorships and prize money. On the contrary, a high number of driver withdrawals, "Did not

E-mail address: paulom@eeg.uminho.pt.

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Table 1
The 10 F1 drivers with the highest number of races without a first victory (by October, 2016).

Rank		GP	Nationality	Seasons	Teams	Points per GP
1	Andrea de Cesaris	208	Italian	1980–1994	Alfa Romeo; Tyrrell; Dallara; Ligier; Jordan; Brabham; Rial; Minardi; McLaren; Sauber	0.28
2	Nick Heidfeld	183	German	2000–2011	BMW Sauber; Sauber; Jordan; Prost; Williams; Renault	1.42
3	Martin Brundle	158	English	1984–1996	Tyrrell; Brabham; Ligier; Zakspeed; Benetton; McLaren; Jordan; Williams	0.62
4	Derek Warwick	146	English	1981–1993	Arrows; Renault; Toleman; Lotus; Footwork; Brabham	0.49
5	Jean-Pierre Jarier	134	French	1971–1983	Shadow; Tyrrell; Osella; Ligier; March; Penske; ATS; Lotus	0.24
6	Eddie Cheever	132	North-American	1978–1989	Arrows; Alfa Romeo; Renault; Tyrrell; Ligier; Osella; Hesketh; Lola; Theodore	0.53
7	Adrian Sutil	128	German	2007–2014	Force India; Sauber; Spyker; Midland	0.09
8	Pierluigi Martini	118	Italian	1985–1995	Minardi; Dallara; Toleman	0.15
9	Mika Salo	110	Finn	1994–2002	Tyrrell; Toyota; Arrows; Sauber; Ferrari; BAR; Lotus	0.30
10	Philippe Alliot	109	French	1984–1994	Lola; RAM; Ligier; Larrousse; McLaren	0.06

Note: For purposes of consistency, the scored points for each driver were calculated using the system of rewards observed between 1962 and 1990 (1st standing: 9 points; 2nd: 6 points; 3rd: 4 points; 4th: 3 points; 5th: 2 points; 6th: 1 point).

Finish'' (DNF) or ''Did not Qualify'' (DNQ) is not only compromising those sources of a F1 teams' revenues, but they are also rising the average total costs per point for a team which anticipates serious problems of sustainability for that championship.

This paper will discuss the capacity of surviving in such a competitive environment for F1 drivers. We will particularly highlight the group of drivers who never won and the humblest drivers, i.e., those far from the spotlight of the podiums, the media focus and the generous salaries because these drivers have never scored in F1 races. This paper will analyze the determinants of their survival race after race. According to the literature, the determinants of the heterogeneous lengths of the job contracts tend to be divided into three major categories: the characteristics of the employee/employable person, the characteristics of the hiring entity/firm and the institutional patterns observed in the industry/economic sector at the time.

We are going to test how these determinants have been interfering with the hazard rates of a F1 driver exiting the current team or just exiting F1 competition since the first F1 race organized by the FIA (Silverstone, 1950). We are going to consider two samples of drivers — those without any points and those without victories.

Regarding the empirical steps, we are going to rely on survival analysis, estimating Kaplan–Meyer's survival probabilities and running Cox's proportional regressions and parametric regressions (alternatively we will also be discussing the Exponential, the Weibull and the Gompertz's distributions of the survival rates).

The remaining sections of the paper are the following. Section 2 reviews the literature, focusing on the motivations for studying the professional longevity of F1 drivers and focuses on the determinants of the professional survival of F1 drivers—race after race (detailing the drivers' characteristics, the teams' characteristics and the features of each decade). Section 3 presents the empirical section, discussing statistics relating to the 816 observed drivers, and it also discusses the estimations obtained for the Cox survival models and for the parametric regressions. Finally, in Section 4 we have the concluding remarks.

2. Literature review

2.1. An economic motivation for studying the professional longevity of F1 drivers

Formula One is a motorsport with regular races since 1950 (Cimarosti, 1997). Some papers on the complex relations between drivers and teams have been signed by authors like Reimers (2012), Stadelmann and Eichenberger (2009) or Cobbs and Hylton (2012). In spite of the difficulty in finding publicly available data regarding Formula One financial sheets, it has been found that the wages/salaries in Formula One teams tend to be considerably high (Allen, 2010) from the humblest jobs (like administrative secretaries or marketing assistants) to the top-earners (Chief Engineers, Team Principals, Chairmen, CEOs, Managing Directors and Drivers). Contrarily, it is more frequent (and feasible) to find data regarding the other measurable output, i.e., the professional length/number of GPs for each driver.

Since it is a motorsport characterized by huge costs (Hotten, 2000, p.157), it is easy to realize that F1 is not a patient sport to those drivers who cannot present the most impressive results. Although every F1 driver has started his/her F1 career without points or victories in this sport, some drivers maintain their particular sums of points or of victories null for a long series of races. Therefore, understanding these drivers' capacity for keeping active in the highly competitive F1 paddock can be presented as one of the major motivations for this work.

Relating to this feature of surviving with humble performances (or with impressive numbers of withdrawals or no-qualifying, DNQ), there are some interesting rankings (Tables 1 and 2).

Table 1 shows the 10 F1 drivers with the highest number of races without a first victory (by October, 2016), for illustrative purposes.

Now, we are going to comment on Table 1. Here we can observe that 90% of these drivers are European. The exception was the North-American Eddie Cheever, racing between 1978 and 1989. All these drivers started racing in F1 after 1970, mainly after 1980. In most of these cases, they participated in a mean number of 10 seasons for more than 3 different entrants. Dividing the number of scored points by the number of GPs, they got a mean value lower than 1 point per race.

Table 2
The 11 F1 drivers with the highest number of races without points (by October, 2016).

Rank	Driver	GP	Nationality	Seasons	Teams
1	Luca Badoer	51	Italian	1993–1999 + 2009	Minardi; Lola; Forti; Ferrari
2	Charles Pic	39	French	2012–2013	Marussia; Caterham
3	Max Chilton	35	English	2013–2014	Marussia
4	Brett Lunger	34	North-American	1975–1978	McLaren; Surtees; Hesketh; March; Ensign
5	Tora Takagi	32	Japanese	1998–1999	Tyrrell; Arrows
6	Mike Beuttler	28	English	1971–1973	March
7	Enrique Bernoldi	28	Brazilian	2001–2002	Arrows
8	Scott Speed	28	North-American	2006–2007	Toro Rosso; Red Bull
9	Ricardo Rosset	27	Brazilian	1996; 1998	Footwork; Tyrrell; Lola
10	Rupert Keegan	25	English	1977-1978; 1980; 1982	Hesketh; Surtees; Williams; March
11	Huub Rothengatter	25	Dutch	1984–1986	Zakspeed; Spirit; Osella

These drivers never won a race in F1, belonging to the sub-sample of 87% of F1 drivers who never climbed up to the highest place of the podium. However, they had "podiums" (in these cases, 2nd and 3rd places of the races) and they were adding points throughout their F1 careers. For controlling these evidences, we are now focusing on the drivers who exhibit the highest number of GPs without scoring any points. Table 2 shows the top-11 of these racers.

Table 2 shows a more heterogeneous set of nationalities than Table 1. The percentage of European drivers is now 55%. On average, the drivers in the sample represented in Table 2 run for 2 seasons and for 2 teams. 36% of these drivers started racing after 2000.

Collecting official data for 816 drivers who participated in grands-prix since the Silverstone/1950 until the Abu Dhabi/2014,[1] we are able to construct estimates to the Kaplan–Meier Survival Probabilities of a given racer surviving a certain number of races. A high share of these drivers (599 over 816) raced in a maximum number of races below 25. Therefore, the Kaplan–Meier Survival Probability estimate for the period of t races is

$$S_t = \frac{Living_{t_0} - Deaths_t}{Living_{t_0}}$$

where t_0 refers to the starting period. In the case of $t = 25$ (races), $S_{25} = (816 - 599)/816 = 0.266$. For $t = 50$, $S_{50} = 141/816 = 0.173$, and so on. More formally, we could write it as

$$S(t_i) = \Pi_{t_i \le t}\left(1 - \frac{\#Exits_t}{\#Drivers_{t_0}}\right)$$

meaning that the Kaplan–Meier Survival Probability estimate for the period t_i is the product operator for the successive survival rates observed for the previous periods. For instance, recalling our previous example, $S_{50} = 0.266 * (141/217) = 0.173$.

Therefore, considering the different survival rates for the different periods, we represent the (sometimes) large Life Tables by graphs. Figs. 1 and 2 represent the Kaplan–Meier estimates for the 816 drivers that we studied.

When analyzed together, Figs. 1 and 2 show that only 38% (i.e., 321 drivers) were able to race 10 or more times. Only a few (71 drivers) raced more than 100 races. Finally, only 17 drivers raced more than 200 races. Among these 17 drivers, we find names like Rubens Barrichello (322 starts), Michael Schumacher (306), Jenson Button (300 as of 2nd October 2016), Ricardo Patrese (256), and Jarno Trulli (252) or Fernando Alonso (268 as of 2nd October 2016).

Fig. 1 shows that winning a race significantly increases the duration of a driver remaining in competition, especially the probability of surviving in F1 after the 20th race. Fig. 2 reveals that scoring also increases this duration in competition of F1 drivers, especially after the 6th race. By converging Tables 1 and 2, the expected maximum number of races for a F1 driver without points was 51 (Luca Badoer) and for a F1 driver without victories was 208 (Andrea de Cesaris). Although these Figures relate to the exit from F1 via retirement (independently of being at the mid or at the end of seasons), this work will also study the drivers' exit from F1 teams to other F1 teams.

We also analyzed whether these survival distributions (depending on having or not having victories – Fig. 1 – or depending on having scored or not – Fig. 2) were similar. Using the Log-Rank test, we found that these distributions are significantly different. Therefore, to study the survival regressions, we have to recognize that the identification of these characteristics is also a relevant dimension (full details are available upon request).

2.2. Why did they survive so long? discussing the determinants of maintaining a driver running in formula one

In order to construct the set of variables explaining the longevity of a driver racing in Formula One without victories or even without points, we are going to base the discussion on the literature on sports economics (Ogilvie and Tutko, 1971; Cobbs and Hylton, 2012; McKnight et al., 2009; Henry, 2013; Conzelmann and Nagel, 2003; Aquilina, 2013) and on labour economics (Mincer, 1958; Fang and MacPhail, 2008; Houseman et al., 2003):

[1] Check Formula One (2016), available at https://www.formula1.com/en/results.html/1950/races/94/great-britain/race-result.html Additional non-official sources are provided by www.statsf1.com, www.chicanef1.com/main.pl or www.wikipedia.com.

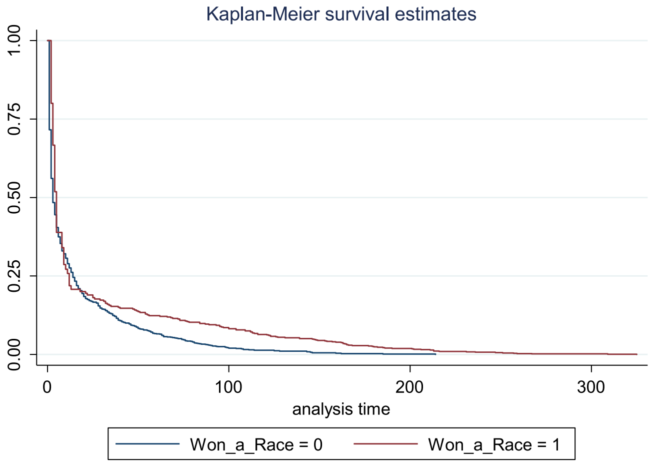

Fig. 1. Kaplan–Meier survival probabilities of a given racer surviving without victories in GP.

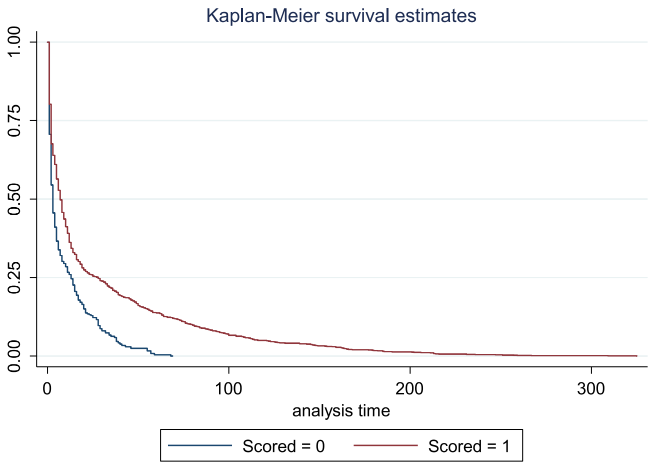

Fig. 2. Kaplan–Meier survival probabilities of a given racer surviving without points.

– The characteristics of each driver,
– The characteristics of each team,
– The exogenous environment around the seasons (races' regulations, safety requirements and contractual issues depending on each decade).

2.2.1. The driver's characteristics

According to various authors (Reimers, 2012), the first explicative variable is age. Older drivers tend to exhibit a lower professional survival rate than younger racers. Especially in sports, age has been found exerting a non-linear influence on sports performance (Knechtle et al., 2014), on the probability of achieving higher salaries and prizes (Knechtle et al., 2016) and on the extraction of commercial sponsorships. This means that athletes who are too young or too mature tend to sign contracts which are not as generous as those signed by athletes aged between these two poles. This is a general pattern observable in a large number of sportsmen/sportswomen as part of a large set of professionals in certain cultural areas (Reimers, 2012). Other works have additionally discussed the weight of age on the productive level of workers (Danacica and Babucea, 2010), on the need of maintaining/renewing the systems of work organization (George et al., 2014), and on the identity of firms, companies and institutions (Houseman et al., 2003).

However, we cannot ignore that drivers are significantly 'valued' by their past victories/good standings and by their recent track of results. For instance, former champions or drivers with a significant number of podiums have a bargaining power which is very different from the one characterizing drivers without such impressive outcomes (Hill and Groothuis, 2001). Even if their recent racing positions are not so impressive, their past victories can be a source of other inflows for the teams, namely sponsorships and other commercial revenues (such as advertising/branding). This 'super-star' dependence is expected to be more relevant in the entrant teams which are used to fighting for the positions in the bottom-half of the grid and which do not have a significant number of past podiums (Lowell, 1973).

Additionally, the recent standings of each driver also influence their survival in the competition. Worse standings increase the hazard of a driver not renewing his/her contractual relation with the hiring team (Marcos et al., 2010), especially if his/her team-mate has higher standing scores. Given the similarity of the engines and chassis, finishing races in worse positions than your team-mate's may be perceived as evidence of a driver's relative competitive disadvantage (Rintaugu and Mwisukha, 2011; Gilmore, 2008). Consequently, we will also consider the average standing of each driver in the last five races[2] and the percentage of points scored by him in the team's overall points.[3] We have also to consider the Number of ranks' promotion (identified as the observed difference between the Qualification rank and the Race rank), as an Average at last 5 races. The insertion of this variable is intended to control the standings' variable and it suggests the relative success of each driver considering the starting grids.

It is also important to consider a driver's number of DNQ/DNF/withdrawals during the seasons. There are two major sources of revenues for a F1 team (Hotten, 2000): sponsorship and prize money. Sponsorship has been considered as representing 60% of a median F1 team (and prize money has been considered as representing 40%). Both of these revenues have been found to be highly correlated with a F1 team's sum of points in the recent seasons. Consequently, a higher number of withdrawals by a driver compromises the capacity of a F1 team having significant revenues for the following seasons. Given the high fixed/quasi-fixed costs of a F1 team, drivers' withdrawals are important threats to the sustainability of a F1 team. Therefore, drivers characterized by a high number of withdrawals may be held particularly responsible for his/her team's low performance, which shall have a shortening effect on the length of his/her contract (Papachristos, 2014).

2.2.2. Team's characteristics

The competitiveness of each F1 team must also play a relevant role in the professional longevity of each driver. Demanding teams are usually characterized by substantial budgets correlated with a high number of podiums in the past. Therefore, demanding teams may tend to offer a short job life to drivers not exhibiting the highest performances.

Conversely, teams whose pairs of drivers in the past have not finished many races may offer a longer life to not-so-skilled drivers. Upon recalling Tables 1 and 2, we have observed that it is more frequent for teams like Ligier, Sauber or Lola to provide longer professional careers to drivers who do not add victories or for teams like Tyrrell or Arrows to be more comfortable for drivers that do not collect any points. The cost of individual errors (i.e., drivers' errors) is lower on these teams, given their (relative) high percentage of withdrawals. Additionally, the low budgets, the dependence on the supply of engine units from other teams, the investors' low expectations, or the prevalence of the team's other interests over the sport's interest (like the opportunity to develop engineering research for commercial purposes or for other applications) reduces the pressure of running for podiums or even for points in the season.

Therefore, we are going to use two variables particularly related to the profile of a team:

- The team's accumulated number of points (once again according to the 1980's rewards system);
- The share of withdrawals by each team's drivers (considering all the team's races).

Just to be clear, we are expecting that, if the team itself is not used to fighting for the best standings in the World Constructor Championship and if it has a considerable track of DNQ/DNF/withdrawals, then there is a change in the withdrawing driver's individual responsibility. As discussed by Bell et al. (2016), the low expectations characterizing these less competitive teams also tend to blame less the driver's low performance. Consequently, we are going to use the "Share of driver withdrawals for each team's history".

2.2.3. Different seasons, different survivors

Tables 1 and 2 revealed that the drivers represented there had all raced in the seasons after 1970. Although there have been F1 races organized by the FIA since 1950, Tables 1 and 2 showed that the most recent decades have provided F1 drivers with better conditions for keeping on running even without collecting impressive results. There are three major reasons behind the increasing professional longevity of F1 drivers throughout the seasons (which clearly depend on the specificities of the technical and contractual regulations):

- Contractual differences over the course of the seasons,
- Maturity of the competition,
- And Increase in total costs throughout the seasons, measured at constant prices.

[2] Choosing five races was not an arbitrary decision. For most of F1 seasons, five races represent around one third of the total number of races. Therefore, this window of five races represents a convenient percentage of a driver's previous exhibitions, avoiding the biased options for a series of races that are too short or a series of races that are too long.

[3] We calculated these ratios following the previously introduced points scoring system (which was in place from 1962 until 1990): 9 points to the 1st driver, 6 points to the 2nd driver, 4 points to the 3rd driver, 3 points to the 4th driver, 2 points to the 5th driver, and 1 point to the 6th driver. We chose this points scoring system because it has been, until recently, the longest used system in Formula One.

Table 3
Descriptive statistics of the variables (drivers without victories).

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Driver's avg. of last 5 races' standings	20 192	12.083	4.008	2	20
Driver's age	20 192	28.231	11.451	19	55
Podiums accumulated by the driver in his/her F1 history	20 192	0.0619	0.2771	0	13
Ratio between the number of collected points by each driver and the sum of points from his/her team (season's results)	20 192	0.440	0.804	0	10.655
Ratio between the accumulated number of each driver's points, considering his/her F1 history and the accumulated number of his/her team's points in the F1 history	20 192	0.447	0.218	0	11.333
Driver's withdrawals/DNF/DNQ during the season	20 192	7.341	3.571	3	16
Accumulated number of points from the team's history, considering the 1980s' system of rewards	20 192	7.220	13.706	0	2526
Share of each driver's withdrawals for each team's history	20 192	0.682	0.104	0	1
Number of ranks' promotion (Qualification rank–Race rank), Average last 5 races	20 192	3.882	6.838	−14	17

First of all, this trend is the result of an evolution in the terms of the drivers' contracts, which have become more demanding in order to increase drivers' loyalty. In the early decades, teams and drivers could opt to participate only in certain races. Usually, those teams and drivers did not want to compete for titles and preferred to race only in the most prestigious races. This preference significantly decreased F1 life for drivers who very often combined their F1 participations with their other motorsports' participations (Mastromarco and Runkel, 2009).

Authors like Blair (2012) have stated that a mature competition tends to be ruled by more rigid regulations and more complex jurisdictional rules. Additionally, the maturity of any sports competition increases the real costs associated with it. These characteristics have two main economic causes and they result in two main economic consequences.

The economic reasons are related to increasing wages and a greater number of available prizes, which stem from an accumulation of human capital in the main competing agents (Acemoglu and Autor, 2011; Blair, 2012) and from an evolution in publicity's revenues. It is different to pay a salary to a professional driver who has been trained for many years to deliver the most demanding performances than to pay an amateur driver who has dedicated most of his/her professional life to a different activity or sector. Therefore, the successive accumulation of experience ("human capital") in an industry tends to lead to a rise in that industry's wages. The second economic reason relates to the evolution of publicity revenues that increase other expenses. Therefore, as a consequence, season after season there is a more defined uptrend in Formula One's real costs which results in two main economic consequences. The first consequence relates to an increase of the oligopolistic power of some of the teams and that of a few drivers who "rule" Formula One. As costs rise, only teams with the most available resources are able to adequately cover the increased expenses (Blair, 2012). This movement eliminates the teams with fewer resources and puts the power in the hands of a few. The second consequence relates to the creation of a proper competitive dynamic in the drivers' contracts because the most experienced drivers tend to have longer careers in Formula One. The less skilled competitors, on the other hand, can expect a diminishing number of seasons.

2.3. Data sources and description

Based on official data previously presented (Formula One, 2016), we observed 816 drivers for 916 races (Silverstone, 1951/Abu-Dhabi, 2014), which makes a total of 22 436 observations overall. However, as we are going to work with the sub-samples of drivers without points or drivers without victories, we will only present the stats relating to these sub-samples. The descriptive statistics of the variables are provided in Table 3.

Upon observing Table 3 some comments should be made. In spite of the high number of F1 drivers who never won a race but finished in the 2nd position in a series of 5 races, the maximum number of career podiums for these racers was reached by Nick Heidfeld (13 in Malaysia/2011). The maximum share of these drivers' season points regarding their teams' points was 65.5% (Philippe Alliot at the end of the 1989 season or Mika Salo at the end of the 2002 season). When Andrea de Cesaris finished the 1988 season, driving for Rial, he had a total of 34 points from his F1 career; these points divided by the 3 achieved by the (newcomer) Rial in 1988 resulted in the maximum value of 11.333 for the variable "Ratio between the accumulated number of each driver's points, considering his/her F1 history and the accumulated number of his/her team's points in the F1 history". The maximum value for the variable "Accumulated number of points from the team's history, considering the 1980's system of rewards" was observed in Ferrari (in 1999), Mika Salo's team for that season.

Table 4 shows the descriptive statistics of the variables observed for the F1 drivers with 0 cumulated points, in the races of the seasons between 1950 and 2014.

Not surprisingly, the variables "Podiums accumulated by the driver in his/her F1 history", "Ratio between the accumulated number of each driver's points, considering his/her F1 history and the accumulated number of his/her team's points in the F1 history", and "Ratio between the number of collected points by each driver and the sum of points from his/her team (season's results)" are not relevant for differentiating the F1 drivers who had never scored in F1. Therefore, we will only comment on the other variables from Table 4. Here, we have observed that the age record for a F1 driver competing

Table 4
Descriptive statistics of the variables (drivers without points).

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Driver's avg. of last 5 races' standings	14 475	11.697	4.380	7	20
Driver's age	14 475	28.892	11.452	19	54
Driver's withdrawals/DNF/DNQ during the season	14 475	3.442	2.873	3	16
Accumulated number of points from the team's history, considering the 1980s' system of rewards	14 475	9.797	19.255	0	4093.5
Share of each driver's withdrawals for each team's history	14 475	0.721	0.117	0	1
Number of ranks' promotion (Qualification rank–Race rank), Average last 5 races	14 475	6.3182	6.302	−14	13

without points (54 years) is attributed to Arthur Legat (Belgium, 1953). Max Chilton, in 2014, only had 3 withdrawals during the season which explains the minimum number in the variable "Driver's withdrawals/DNF/DNQ during the season". In the end of the 2009 season, Luca Badoer drove a Ferrari car, a team which had accumulated until then 4093.5 points in F1.

After this descriptive analysis, a first step in survival regressions relates to the tests of equality across the different strata (i.e., different groups of drivers considering the analyzed variable). P-values close to zero means that there is not a significant similarity in survival curves between those individuals (drivers) exhibiting higher values of a variable and the other individuals exhibiting lower values of the same variable. Following the literature's norm, we have run three tests on all of the covariates – log-rank, Wilcoxon–Breslow–Gehan and Peto–Peto – and we have found p-values to be lower than 0.010, which has allowed us to consider the covariates as potentially relevant for the model to be estimated. If the covariate was a continuous variable (e.g., the ratio between the number of collected points by each driver and the sum of the points by his/her team, considering only the season's results), then we identified the value for each respective decile in the variable's distribution. Full details are available upon request.

Motivated by the aforementioned literature review, next section describes the empirical attempts we have run for an estimation of models testing determinants for the professional longevity of F1 drivers without points or victories.

3. Empirical section

3.1. On proportional hazards regressions

The group of proportional hazards (PH) regressions is composed by the Cox PH regression and the parametric regression models (Ross, 2000; George et al., 2014). This type of regression allows researchers to determine which individual characteristics (in our case, the characteristics of each driver) influence the survival of the subject in some risky situations (in this case, the professional survival of a driver until the end of the current contract).

Eq. (1) exhibits the general form of the Cox proportional hazards regression (Berlinski et al., 2007; Bright et al., 2015):

$$\lambda_i(t) = e^{x_i'\beta} * \lambda_0(t), i = 1, 2, \ldots, n. \tag{1}$$

Eq. (1) shows that, with n drivers being studied, the hazard rate (the probability of exiting the current team after t races, i.e., $\lambda_i(t)$) depends on the vector of the considered variables (x), the vector of the regression coefficients ($\beta = (\beta_1, \beta_2, \ldots, \beta_k)$), and the baseline hazard ($\lambda_0(t)$ (i.e., the probability of remaining on the team when all of the explanatory variables are equal to 0).

The regression coefficients can be interpreted as expressing the relationship between the proportional change that is expected in the hazard and the changes in the explanatory variables. Therefore, significant and negative coefficients are associated with variables diminishing that hazard, thus those variables can be identified as variables contributing to a longer career for each driver.

In the class of Cox PH models, the explanatory variables are time-independent (typically called the "proportional hazard assumption"). To test this assumption, we ran the test on the Schoenfeld residuals on functions of time. A non-zero slope indicates a violation of the proportional hazard assumption, which prompts the suggestion of removing the covariates that were found to violate the assumption (Keele, 2010). These violations are discussed in detail in the Results' section.

The class of Cox PH models assumes that we are not aware of the relationship between the dependent variable and the explanatory variables. However, following the literature, we can hypothesize particular distributions for the survival rates. In these assumptions, when the relationship between the response and explanatory variables is known, parametric regression models are used. The most frequent hypotheses on the distribution of the survival rates are an exponential distribution (based on a constant hazard rate across time), a Weibull distribution (given that the log of the hazard may be a linear function of the log of time), and a Gompertz(-Makeham) distribution, assuming that the log of the hazard is a linear function of the time.

However, as there are many and very different individuals in the sample, unobserved individual heterogeneity or other random effects in survival analysis can be an issue. Therefore, we also considered the use of frailty models to account for this possibility.

Table 5
Proportional hazard of a driver non-surviving in a random F1 team without points.

Covariates	(1) Cox	(2) Cox	(3) Exponential	(4) Weibull	(5) Gompertz
Driver's avg. of last 5 races' standings	0.078^{***}	0.084^{***}	0.134^{***}	0.163^{***}	0.145^{***}
	(0.027)	(0.010)	(0.011)	(0.014)	(0.012)
Driver's age	0.043^{***}	0.022^{***}	0.022^{***}	0.023^{***}	0.021^{***}
	(0.002)	(0.003)	(0.005)	(0.004)	(0.003)
Driver's withdrawals/DNF/DNQ during the season	0.019^{*}		−0.003	-0.025^{*}	−0.007
	(0.011)		(0.012)	(0.014)	(0.013)
Accumulated number of points from the team's history, considering the 1980s' system of rewards	0.012^{***}		0.011^{***}	0.013^{***}	0.011^{***}
	(0.002)		(0.001)	(0.002)	(0.001)
Share of driver withdrawals for each team's history	0.035^{***}	0.060^{***}	0.042^{***}	0.048^{***}	0.044^{***}
	(0.010)	(0.006)	(0.011)	(0.013)	(0.012)
1950s	3.331^{***}		3.711^{***}	4.550^{***}	4.060^{***}
	(0.102)		(0.105)	(0.173)	(0.119)
1960s	2.090^{***}		2.196^{***}	2.666^{***}	2.437^{***}
	(0.105)		(0.111)	(0.151)	(0.123)
1970s	1.181^{***}		1.294^{***}	1.308^{***}	1.215^{***}
	(0.095)		(0.136)	(0.123)	(0.112)
1980s	−0.029		−0.081	−0.016	−0.029
	(0.115)		(0.116)	(0.130)	(0.126)
≥1990s	0.277^{**}		0.220^{*}	0.307^{**}	0.294^{**}
	(0.115)		(0.115)	(0.128)	(0.124)
Number of ranks' promotion (avg. last 5 races)	-0.053^{***}	-0.059^{***}	-0.111^{***}	-0.134^{***}	-0.120^{***}
	(0.002)	(0.003)	(0.004)	(0.006)	(0.004)
Number of Obs/Number of drivers	14475/636	14475/636	14475/636	14475/636	14475/636
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.769^{***}	
				(0.023)	
Log-pseudolikelihood	−12 653.3	−14 117.4	−5396.3	−5360.3	−5367.2
Theta			0.557^{***}	1.978^{***}	1.041^{***}
Overall schoenfeld	19.78	4.78			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not exhibited here. The robust standard errors are between the parentheses.

Therefore, the hazard model with frailty assumes that the risk of each individual i is dependent on the measured dimensions (as in Eq. (1)) and on random perturbations due to the unobserved effect of a certain characteristic j:

$$h_{ij}(t \mid x_{ij}, \alpha_j) = \alpha_j h_{ij}(t \mid x_{ij})$$

The frailty α_j is a random variable taking on positive values, with the mean normalized to one and finite variance (theta), which is assumed to follow a gamma distribution. As Hanagal and Pandey (2015) suggested, "The gamma distribution is the most commonly used frailty distribution, largely because of its mathematical convenience; (. . .) Another choice is the inverse Gaussian distribution. The inverse Gaussian makes the population homogeneous with time, whereas for gamma the relative heterogeneity is constant". If this variance estimate is not statistically different from zero, then all the drivers have the same risk of exiting the functions; in contrast, if this estimate is statistically different from zero, then there is the suggestion that unmeasured/unmeasurable factors are interfering in the heterogeneous rate of failures observed for the cases.

3.2. Empirical findings

We would like to highlight that we will estimate two different groups of models, which will depend on a F1 driver's form of "exit" that we have been considering. The first set of models relate to the survival in a F1 team (without any points or without any victories); the second set of models relate to the survival in the F1 competition (without any points or without any victories). Therefore, in the first set of models, a driver exits his/her F1 team to move to a competing F1 team. If a driver exits (i.e., if he/she does not "survive") in the second set of models, he/she is definitely leaving the F1 competition.

The following Tables 5–10 also exhibit the results of two specifications of the Cox proportional hazard analysis of our data (with all the covariates previously introduced −1, or without the covariates violating the proportional hazard assumption −2), as well as the results of the estimations of three types of parametric regression models (assuming three alternative forms of the survival distribution — the Exponential −3, Weibull −4 and Gompertz −5 types).

Tables 5 and 6 exhibit our estimates relating to the proportional hazard of a driver not-surviving without points in a random team (Table 5) and not-surviving in the F1 competition (Table 6). We observe that the coefficients relating to the following covariates tend to significantly increase the hazard of the driver exiting the current team:

- worse standings recorded for the last 5 races;
- a higher age;
- competing for an old 'scuderia';

Table 6
Proportional hazard of a driver non-surviving in F1 without points.

Covariates	(1) Cox	(2) Cox	(3) Exponential	(4) Weibull	(5) Gompertz
Driver's avg. of last 5 races' standings	0.168***	0.166**	0.133***	0.168***	0.166***
	(0.017)	(0.019)	(0.028)	(0.018)	(0.017)
Driver's age	0.017***	0.019***	0.021***	0.020***	0.022***
	(0.006)	(0.004)	(0.005)	(0.005)	(0.003)
Driver's withdrawals/DNF/DNQ during the season	0.066***		0.065***	0.076***	0.076***
	(0.017)		(0.015)	(0.027)	(0.025)
Accumulated number of points of the team's history, considering the 1980s' system of rewards	0.012***	0.015***	0.013***	0.142***	0.142***
	(0.002)	(0.003)	(0.004)	(0.002)	(0.004)
Share of drivers' withdrawals for each team's history	−0.011		−0.011	−0.025	−0.021
	(0.026)		(0.027)	(0.037)	(0.037)
1950s	3.226***		3.534***	4.361***	4.330***
	(0.147)		(0.192)	(0.237)	(0.205)
1960s	2.233***		2.171***	2.028***	2.107***
	(0.154)		(0.155)	(0.117)	(0.118)
1970s	1.076***		1.082***	0.903***	1.046***
	(0.158)		(0.177)	(0.164)	(0.174)
1980s	−0.335*		−0.367*	−0.429***	−0.315*
	(0.179)		(0.175)	(0.186)	(0.172)
≥1990s	0.002		0.0347	0.037	0.037
	(0.162)		(0.203)	(0.178)	(0.208)
Number of ranks' promotion (avg. last 5 races)	−0.114***	−0.103***	−0.156***	−0.160***	−0.162***
	(0.006)	(0.003)	(0.008)	(0.008)	(0.007)
Number of Obs/Number of drivers	14 475/636	14 475/636	14 475/636	14 475/636	14 475/636
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.998***	
				(0.040)	
Log-pseudolikelihood	−6675.2	−6575.1	−6760.73	−3758.22	−3759.7
Theta			2.885***	2.991***	2.987***
Overall schoenfeld	35.74	3.45			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not displayed here. The robust standard errors are between parentheses.

– a higher number of withdrawals;
– and loosing ranks during the races.

Merely for illustrative purposes, and only focusing on estimation 1 (Cox Proportional Hazard model), we observe that the group of drivers finishing, on average, on a given standing (e.g, on the 10th position) in the last 5 races and who move to a different team have 7.8% more observed individuals than the group of drivers finishing, on average, just one standing above (i.e., on the 9th position) in the last 5 races and who also move to a different team. This converges to Stadelmann and Eichenberger's (2006) or Reimer's (2012) who show the penalty effect of the worse standings to the professional longevity of drivers in F1 teams.

Another relevant effect comes from the number of withdrawals/DNF/DNQ observed in the season until the observed race. The penalty effect from an increased number of withdrawals and from a higher share of withdrawals in the team's history has been estimated statistically significant. The pressure from withdrawals or from not qualifying has already been discussed in the works by Papachristos, 2014. Besides the damages derived from the reputational signs of not finishing races, the additional costs relating to car reparations after crashes or engine failures imply higher expenses which make it harder for the entire team to remain in the competition if facing limited revenues.

When detailing the effects associated to each decade, we have observed a kind of "U" profile—racing in the earlier and in the most recent decades had a more significant hazard of shortening the contractual relation of F1 drivers. Reversely, racing in the 1980s was characterized by a statistically non-significant estimated coefficient. Actually, following our results, we can claim that the number of continuous races in the same team has increased since 1980 for a random F1 driver, even if not scoring any points. The (more) flexible regulations until 1980 and the "sports' tradition" in the F1 paddock have contributed to this evidence. The pressure in the seasons after 1990 is mainly attributed to the rising costs, which also characterize this period, which led to a decreasing number of competing teams (Klarica, 2001), an increased revision of the terms of F1 contracts (Collings, 2001) and a higher stimulus for the presence of a more significant number of 'gentlemen-drivers'/pay-drivers in F1 (Weaver, 2012).

The characterization of the teams regarding the history of each team's prestige (associated to the accumulated number of points) has not been observed as exhibiting statistically significant coefficients, independently of the estimations (columns 1–5 of Table 5). Finally, drivers finishing at worse ranks than the starting ones also tend to have their risk of exiting F1 teams increased (Bell et al., 2016).

Three different estimations are presented in order to more robustly discuss the assumptions regarding the survival distribution: an exponential distribution (based on a constant hazard rate across time), a Weibull distribution (given that the log of the hazard may be a linear function of the log of time) and a Gompertz(-Makeham) distribution, assuming that

Table 7
Proportional hazard of a driver non-surviving in a random F1 team without victories.

Covariates	(6) Cox	(7) Cox	(8) Exponential	(9) Weibull	(10) Gompertz
Driver's avg. of last 5 races' standings	0.242***	0.263***	0.263***	0.202***	0.261***
	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)
Driver's age	0.013***	0.014***	0.012***	0.013***	0.012***
	(0.003)	(0.006)	(0.003)	(0.004)	(0.003)
Podiums accumulated by the driver in his/her F1 history	−0.267***	−0.243***	−0.263***	−0.224***	−0.223**
	(0.042)	(0.035)	(0.054)	(0.033)	(0.031)
Ratio between the number of collected points by each driver and the sum of points from his/her team (season's results)	0.066*** (0.018)	0.048*** (0.017)	0.066*** (0.026)	0.061*** (0.003)	0.065*** (0.005)
Ratio between the accumulated number of each driver's points, considering his/her F1 history and the accumulated number of his/her team's points in the F1 history	0.066*** (0.014)	0.077*** (0.027)	0.052*** (0.023)	0.072*** (0.014)	0.077*** (0.011)
Driver's withdrawals/DNF/DNQ during the season	0.193***		0.119***	0.068***	0.129***
	(0.019)		(0.018)	(0.018)	(0.017)
Accumulated number of points from the team's history, considering the 1980s' system of rewards	0.012*** (0.003)	0.009*** (0.002)	0.002*** (0.0003)	0.017*** (0.003)	0.013*** (0.003)
Share of driver withdrawals for each team's history	0.067***	0.062***	0.008***	0.061***	0.066***
	(0.005)	(0.004)	(0.002)	(0.008)	(0.005)
1950s	4.483***		4.136***	4.943***	4.972***
	(0.138)		(0.125)	(0.173)	(0.168)
1960s	2.101***		2.494***	2.372***	2.369***
	(0.175)		(0.209)	(0.202)	(0.203)
1970s	2.637***		2.857***	2.779***	2.784***
	(0.163)		(0.186)	(0.175)	(0.169)
1980s	0.440***		0.206***	0.272***	0.245***
	(0.168)		(0.180)	(0.141)	(0.164)
≥1990s	0.390***		0.321*	0.395***	0.396*
	(0.146)		(0.177)	(0.149)	(0.164)
Number of ranks' promotion (avg. last 5 races)	−0.139***	−0.128***	−0.132***	−0.139***	−0.132***
	(0.005)	(0.006)	(0.005)	(0.006)	(0.004)
Number of obs/Number of drivers	20 192/734	20 192/734	20 192/734	20 192/734	29 192/734
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.711***	
				(0.022)	
Log-pseudolikelihood	−2362.2	−2456.5	−544.1	−4728.41	−540.2
Theta			2.721***	2.414***	2.332***
Overall schoenfeld	23.93	10.39			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not exhibited here. The robust standard errors are between the parentheses.

the log of the hazard is a linear function of the time. Independently of these estimations, the estimated coefficients for each covariate are characterized by values which are statistically close. The Weibull sigma (estimation 4) has been estimated as being statistically significant and higher than 1, meaning that the hazard rate statistically increases over time. By running the appropriate tests on the log-pseudolikelihood or on the Akaike Information Criterion, the Gompertz distribution has been favored among the parametric regression models. We have also added the Theta's estimates (i.e., the estimates of the variance for the random effect), whose statistical significance favors the hypothesis that different drivers always have intrinsic characteristics influencing their own different survival rates. This evidence can be seen as an additional stimulus for further studies analyzing other individual characteristics of the drivers.

Estimations 1 and 2 should also be commented. Both of these estimations are of the Cox survival model. However, estimation 1 has been found to be violating the proportional hazard assumption (check the Overall Schoenfeld statistics). Therefore, estimation 2 was obtained by omitting the covariates that have been found to be violating the proportional hazard assumption in estimation 1; as a result, estimation 2 has no longer been found to be violating that assumption, which is structural to the Cox survival model.

Table 6 still explores the proportional hazard of a driver not-surviving without points, but now in the entire F1. This means that when the driver exits, he/she is definitely leaving the F1 competition. Generally, the results follow those of Table 5: worse standings, higher ages, withdrawals and racing in the first decades for historical teams tended to shorten the professional life in F1 for the drivers who had not been able to collect points. The statistical significance of the Weibull sigma and of the Theta parameter follow previous comments (on Table 5).

Tables 7 and 8 reveal the estimated coefficients for the covariates interfering in the proportional hazard of a driver not-surviving without victories. Table 7 is associated to the proportional hazard of a driver moving to another team. Table 8 is associated to the proportional hazard of a driver definitely exiting the F1 competition.

In Table 7, we observe an increasing value of the estimated coefficients for the variable "Driver's average of the last 5 races' standings" observed in Table 5. For instance, whereas in Table 5 the estimated coefficient for this variable has been found to be 0.078 in the enlarged Cox survival model (estimation 1), now, in Table 7, the corresponding coefficient is 0.242.

Table 8
Proportional hazard of a driver non-surviving in F1 without victories.

Covariates	(6) Cox	(7) Cox	(8) Exponential	(9) Weibull	(10) Gompertz
Driver's avg. of last 5 races' standings	0.265***	0.272***	0.280***	0.276***	0.281***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Driver's age	0.018**		0.017*	0.013***	0.017*
	(0.009)		(0.008)	(0.007)	(0.007)
Podiums accumulated by the driver in his/her F1 history	−0.245***		−0.512***	−0.557***	−0.523***
	(0.056)		(0.060)	(0.109)	(0.064)
Ratio between the number of collected points by each driver and the sum of points of his/her team (season's results)	0.033** (0.015)	0.037** (0.015)	0.036** (0.018)	0.045*** (0.015)	0.045*** (0.015)
Ratio between the accumulated number of each driver's points considering his/her F1 history and the accumulated number of his/her team's points in the F1 history	−0.102*** (0.032)	−0.111*** (0.011)	−0.125*** (0.038)	−0.110*** (0.032)	−0.127*** (0.040)
Driver's withdrawals/DNF/DNQ during the season	−0.075***		−0.076***	−0.109***	−0.114***
	(0.018)		(0.018)	(0.018)	(0.018)
Accumulated number of points of the team's history, considering the 1980s' system of rewards	0.012*** (0.003)	0.012*** (0.003)	0.014*** (0.003)	0.014*** (0.003)	0.017*** (0.004)
Share of drivers' withdrawals for each team's history	−0.003		−0.007	−0.004	−0.007
	(0.005)		(0.005)	(0.005)	(0.005)
1950s	3.592***		3.792***	3.622***	3.820***
	(0.152)		(0.147)	(0.151)	(0.162)
1960s	2.202***		2.373***	2.243***	2.399***
	(0.174)		(0.170)	(0.168)	(0.180)
1970s	0.630***		0.597***	0.514***	0.614***
	(0.154)		(0.154)	(0.148)	(0.159)
1980s	−0.458***		−0.294*	−0.357**	−0.287*
	(0.162)		(0.161)	(0.155)	(0.160)
≥1990s	0.021		0.045	0.014	0.043
	(0.154)		(0.152)	(0.148)	(0.157)
Number of ranks' promotion (avg. last 5 races)	−0.149***	−0.138***	−0.142***	−0.149***	−0.142***
	(0.005)	(0.006)	(0.005)	(0.006)	(0.004)
Number of obs/Number of drivers	20 192/734	20 192/734	20 192/734	20 192/734	29 192/734
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.794***	
				(0.037)	
Log-pseudolikelihood	−13 596.4	−14 149.3	−11 154.2	−22 196.95	−11 154.0
Theta			2.334***	2.061***	2.441***
Overall schoenfeld	66.01	3.64			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not displayed here. The robust standard errors are between parentheses.

Therefore, we can conclude that worse average standings are more harmful for drivers who are not collecting victories (but who are scoring points) than for those racers who do not score any points. In line with this observation, the estimated coefficients for "Podiums accumulated by the driver in F1 history" are statistically significant in estimations 3, 4 and 5 of Table 7 (estimations explicitly modeling the functional form of the event times, respectively using an exponential, a Weibull and a Gompertz distribution). The negative sign of these estimated coefficients means that a higher number of collected 2nd and 3rd places (even in past seasons) decrease the hazard of a driver exiting the current team. For illustrative purposes, and using the estimated coefficient for the Weibull model, we can claim that the group of F1 drivers adding one more podium and exiting their current team has 22% less individuals of a random control group of F1 drivers.

The age's effect continues to be characterized by estimated coefficients which are statistically significant. The number of withdrawals in the season is again a covariate with positive and statistically significant coefficients, independently of the estimation. For illustrative purposes, and considering the preferred estimation 3 among the group composed by estimations 8 and 10 (respectively based on exponential and Gompertz distributions), we can claim there are more 12% of never-winning drivers exiting the current team in F1 when adding one more withdrawal in the season. This effect is statistically higher than the estimated effect when only considering drivers who never scored points (Table 5), which according to Papachristos (2014) — competitive drivers with a significant number of withdrawals or "Did not finish" may associate these results with car troubles, improving the probabilities of migrating to more demanding scuderias (which are expected to have less technical problems in the pair engine–chassis).

Once again, seasons from the earlier decades and from the most recent ones have been found to ensure a shorter number of races in the same team for a F1 driver. The Weibull sigma has been estimated again as higher than 1 (estimation 3 of Table 7). Therefore, seasons' effects can be identified as the major determinants of the studied set of dimensions. A promising avenue for further research relates to the discussion behind the complex of causes explaining the changes in regulations along the seasons, the exogenous moves of other influencing dimensions or fuels' characteristics (Mourao, 2017). The effect from loosing ranks is still statistically significant and it is associated to increased hazards.

Table 8 reveals the estimations of our survival models in competition considering F1 drivers without victories. Comparing with the previous table of results, some features deserve additional comments. Worse standings and higher age have been

Table 9
Proportional hazard of a driver non-surviving in a random F1 team with one victory.

Covariates	(11) Cox	(12) Cox	(13) Exponential	(14) Weibull	(15) Gompertz
Driver's avg. of last 5 races' standings	0.112***	0.131***	0.132***	0.102***	0.101***
	(0.032)	(0.033)	(0.033)	(0.023)	(0.023)
Driver's age	0.023***	0.033***	0.022***	0.023***	0.022***
	(0.003)	(0.006)	(0.007)	(0.004)	(0.004)
Podiums accumulated by the driver in his/her F1 history	−0.007	−0.003	−0.003	−0.004	−0.003
	(0.008)	(0.005)	(0.004)	(0.003)	(0.003)
Ratio between the number of collected points by each driver and the sum of points from his/her team (season's results)	0.366	0.384*	0.662*	0.661*	0.665*
	(0.181)	(0.172)	(0.326)	(0.333)	(0.305)
Ratio between the accumulated number of each driver's points, considering his/her F1 history and the accumulated number of his/her team's points in the F1 history	−5e−5		0.057	0.052	0.057
	(0.089)		(0.123)	(0.114)	(0.111)
Driver's withdrawals/DNF/DNQ during the season	0.393***		0.319***	0.368***	0.329***
	(0.019)		(0.028)	(0.058)	(0.057)
Accumulated number of points from the team's history, considering the 1980s' system of rewards	0.012***		0.012***	0.017***	0.013***
	(0.003)		(0.003)	(0.003)	(0.003)
Share of driver withdrawals for each team's history	2.967	2.962	2.908	2.908	2.066
	(2.343)	(2.104)	(2.002)	(2.008)	(2.005)
1950s	1.983***		1.136***	2.943***	2.972***
	(0.538)		(0.525)	(0.573)	(0.568)
1960s	1.101***		0.894***	0.872***	0.869***
	(0.575)		(0.309)	(0.202)	(0.203)
1970s	0.185		0.157	−0.070	0.032
	(0.363)		(0.186)	(0.075)	(0.043)
1980s	−0.443		−0.606**	−0.672**	−0.645**
	(0.468)		(0.380)	(0.341)	(0.324)
≥1990s	0.143		0.021	0.033	0.032
	(0.446)		(0.277)	(0.249)	(0.264)
Number of ranks' promotion (avg. last 5 races)	−0.077***	−0.078***	−0.076***	−0.076***	−0.072***
	(0.025)	(0.026)	(0.015)	(0.016)	(0.014)
Number of obs/Number of drivers	3321/124	3321/124	3321/124	3321/124	3321/124
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.841***	
				(0.252)	
Log-pseudolikelihood	−162.2	−456.5	44.1	11.41	5.402
Theta			1.03e−7	e−7	1.02e−7
Overall schoenfeld	23.93	10.39			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not exhibited here. The robust standard errors are between the parentheses.

found again as deteriorating the chances of continuing in F1; however, the cumulated individual prestige of the driver (signaled by a higher number of podiums) exerts a significant effect towards longer driving careers. As in Table 7, the relative success of each driver in the season (proxied by the 'ratio between the number of collected points by each driver and the sum of points of his/her team') or the imbalance between each driver and his/her team's history (proxied by the 'ratio between the accumulated number of each driver's points considering his/her F1 history and the accumulated number of his/her team's points in the F1 history') have not been found as covariates with statistically significant estimated coefficients. This is interpreted in light of Rintaugu and Mwisukha (2011) or Gilmore's (2008) statements that — the relative exhibition of each driver considering the season's performance of his/her team-mate or the prestigious track of each driver if compared to his/her team do not exert particular effect on each F1 driver's professional longevity. Reversely, standings, season's withdrawals and age have been consistently found as significant covariates of these estimations. In Table 8 (as in Table 7) the Theta parameter continues to suggest the existence of individual frailties influencing the individual survival performance in F1 competition.

Table 9 shows Proportional hazard of a driver Non-surviving in a random F1 team with one victory. Table 10 regards to Proportional hazard of a driver Non-surviving in F1 with one victory. The most significant differences between Tables 9 and 7 are located in the estimates for the variables related to the standings, to the importance of a driver's points to his/her teams' points, and to the number of withdrawals which become much more influential in Table 9. This can be interpreted by following Papachristos, 2014 — given the reputational prize derived from one victory, all of these three variables tend to increase the pressure for a promising/victorious driver moving to another team. Interestingly, for those with one victory, their responsibility in team's withdrawals lose statistical significance. The estimates for the different decades have lower coefficients, meaning lower pressures realized by all those collecting victories if compared to those without victories or points. Table 10 do now exhibit particular differences if compared to Table 9. The statistical significance of the Weibull sigma and of the Theta parameter (in Table 9 or in Table 10) continue to suggest the presence of increasing hazard rates as a driver sums races and individual frailties.

Table 11 synthesizes the results for an easy interpretation.

Table 10
Proportional hazard of a driver non-surviving in F1 with one victory.

Covariates	(11) Cox	(12) Cox	(13) Exponential	(14) Weibull	(15) Gompertz
Driver's avg. of last 5 races' standings	0.172***	0.171***	0.192***	0.192***	0.191***
	(0.028)	(0.033)	(0.033)	(0.023)	(0.023)
Driver's age	0.023***	0.033***	0.022***	0.023***	0.022***
	(0.003)	(0.006)	(0.007)	(0.004)	(0.004)
Podiums accumulated by the driver in his/her F1 history	−0.007		−0.009*	−0.004*	−0.003*
	(0.008)		(0.006)	(0.002)	(0.003)
Ratio between the number of collected points by each driver and the sum of points of his/her team (season's results)	−0.006 (0.021)		−0.017 (0.028)	−0.016 (0.033)	−0.016 (0.035)
Ratio between the accumulated number of each driver's points considering his/her F1 history and the accumulated number of his/her team's points in the F1 history	−0.009 (0.029)		−0.007 (0.023)	−0.002 (0.014)	−0.007 (0.011)
Driver's withdrawals/DNF/DNQ during the season	0.213***		0.199***	0.197***	0.192***
	(0.049)		(0.038)	(0.058)	(0.057)
Accumulated number of points of the team's history, considering the 1980s' system of rewards	0.015*** (0.002)		0.018*** (0.003)	0.018*** (0.003)	0.018*** (0.003)
Share of drivers' withdrawals for each team's history	0.051	0.062	0.058	0.057	0.058
	(0.843)	(0.804)	(0.802)	(0.808)	(0.805)
1950s	2.983***		2.136***	2.943***	2.972***
	(0.638)		(0.525)	(0.573)	(0.468)
1960s	1.601***		1.894***	1.872***	1.869***
	(0.475)		(0.409)	(0.302)	(0.303)
1970s	1.185***		0.857***	0.870***	0.832***
	(0.463)		(0.286)	(0.275)	(0.243)
1980s	0.113		−0.106	−0.172	−0.145
	(0.468)		(0.480)	(0.441)	(0.324)
≥1990s	0.243		0.121	0.133	0.132
	(0.446)		(0.377)	(0.349)	(0.364)
Number of ranks' promotion (avg. last 5 races)	−0.087***	−0.088***	−0.106***	−0.106***	−0.102***
	(0.015)	(0.016)	(0.015)	(0.016)	(0.014)
Number of obs/Number of drivers	3321/124	3321/124	3321/124	3321/124	3321/124
Dummies drivers	Yes	Yes	Yes	Yes	Yes
Weibull Sigma				0.702***	
				(0.121)	
Log-pseudolikelihood	−192.2	−156.5	−0.441	−0.421	−0.402
Theta			0.014***	0.015***	0.012***
Overall Schoenfeld	23.93	10.39			

Note — Significance levels: 1%, ***; 5%, **; 19%, *. The interception was estimated but not displayed here. The robust standard errors are between parentheses.

Table 11
Synthesis of results — what does increase the risk of a driver exiting?

	Exiting a F1 team	Exiting F1 competition
Without points	Worse standings; Higher Age; Racing for historical teams; Earlier seasons; Loosing ranks from the start.grid	Worse standings; Higher Age; Higher nr. Withdrawals; Racing for historical teams; Earlier seasons; Loosing ranks from the start.grid
Without victories	Worse standings; Higher Age; Higher nr. Withdrawals; (lower) nr. Podiums; Racing for historical teams; Being a competitive driver; Earlier seasons; Loosing ranks from the start.grid	Worse standings; Higher Age; (lower) nr. Withdrawals; (lower) nr. Podiums; Racing for historical teams; Being a competitive driver; Earlier seasons; Loosing ranks from the start.grid
Without two victories	Worse standings; Higher Age; Higher nr. Withdrawals; Racing for historical teams; Earlier seasons; Loosing ranks from the start.grid	Worse standings; Higher Age; Higher nr. Withdrawals; Racing for historical teams; Earlier seasons; Loosing ranks from the start.grid

4. Conclusions and further research

This paper reflected on the determinants of survival of the less competitive drivers in Formula One. Formula One is widely known as one of the most expensive professional sports nowadays. Therefore, those drivers who are not able to collect victories or to even collect points in Formula One realize that there are additional challenges.

After analyzing the literature on labor economics, on sports economics and on Formula One, three groups of determinants have been identified. These determinants are related to the individual characteristics of each driver, to the team's characteristics and to the institutional context around Formula One's seasons and legal agreements.

816 drivers have been observed since the first race organized by the FIA — the Silverstone/1950's race. However, there was a special focus on the sample composed of drivers without victories or without points. Two different definitions of 'exiting' were also used — exiting the team and moving to another 'scuderia' or exiting the F1 competition. Applying methods of survival analysis, of proportional hazard estimations and of parametric regression models, some robust results were achieved.

It has been found that worse recent standings and a higher age increase the chances of a driver exiting F1. However, besides the positive impacts coming from earlier F1 seasons for explaining shortened careers, it has also been perceived that recent seasons exert a positive stimulus in shortening careers for drivers without points. Drivers' withdrawals/DNF/DNQ particularly contribute towards making a driver move from his/her current team to a new team. On the other hand, a higher number of accumulated podiums by a driver in his/her F1 history enlarges the expected contract's length and the F1 careers for those drivers without victories.

Some implications arise from our results. According to these results, the exogenous variation in each season plays the most significant role in the survival of non-winning F1 drivers; this shows that if the environmental conditions change (for instance, because of costs), the non-winning F1 drivers are the first to be charged. This can be translated to other labor markets especially influenced by exogenous shocks as those characterizing the recent Global Financial Crisis.

Six lines of further research can be developed from this work. The first suggested line would be an enlarged study for other motorsports (junior series, NASCAR, Indy races, etc.). Considering the features of these motorsports, additional results and achievements can extend the implications derived from these results for a better management of drivers' careers and contractual terms. The second suggested line would be an opportunity for exploring additional control variables in our models. For instance, it would be interesting to add the value of the season's budget of the team, the nationality (or his/her country's real Gross Domestic Product per capita), and the coincidence of his/her home country with the official country of his/her team. Thirdly, it would also be interesting to split our sample by two immediately suggested sub-samples: the historical teams versus the recent teams. There is also a fourth line which has been already started in Mourao's (2017) book "The Economics of Motorsports" — it regards to how ONE win, podium or driver's point can contribute to (just) stay in F1. Fifth, the possibility of identifying those cases of drivers' exit because of team's abandonment of F1 is additionally recognized as a promising opportunity of development. Finally, we agree the suggestion for studying the percentage of each season's races (as a complimentary strategy for comparing these results obtained from studying the number of races of the surviving drivers) can be a promising one and so we also add it as a challenge.

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