The Economic Impact of Formula 1: Portuguese Grand Prix

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ABSTRACT

Sport can be an important catalyst in generating economic value for regions, particularly through the organization of so-called mega sporting events like Formula 1 Grand Prix events. This paper aims to estimate the regional economic return associated with hosting Formula 1 Grand Prix events in European regions (NUTS II), from 1990 to 2023. Thus, parametric econometric models of panel data regression were estimated, reflecting the state of the art in terms of panel data regression models. These models assessed the dynamic impact on variables such as GDP, GDP per capita, employment rate, and overnight stays in the respective regions. The results of the estimated econometric models suggest that hosting a Formula 1 Grand Prix event does not bring positive economic consequences for the region in question in the four referenced indicators but instead shows neutral or, in some cases, negative effects, such as in tourism overnight stays.

Keywords: Destination marketing; European regions; Formula 1; Impact of sporting events; Public investment.
JEL Codes: M31

I. Introduction

Sporting events can be a major driving force in terms of creating economic value for regions. These events combine social and cultural aspects of societies, promoting entertainment and tourism, aiming at creating virtuous synergies between societal well-being, and economic welfare for hosting regions. Nowadays, sport activities are global industries with a large socio-economic footprint, occasionally requiring impressive physical infrastructures. The dynamics sport growth, and the increasing availability of digital and social media marketing channels supported by innovative digital communication technologies, induced significant shifts in consumers behavior (e.g., Stephen, 2016), has led to the creation of new business opportunities, investment and, consequently, employment opportunities, making it possible the professionalization of a wide range of sports.

Since the advent of television, sports such as soccer in Europe and baseball in the United States have gained enormous global notoriety, attracting the growing interest of new sponsors and investors. In the 1990s, the emergence of the internet triggered the globalization of sport, fueled by the speeding up of satellite broadcasts, which contributed to the huge publicity of sports leagues, such as the NBA, the American basketball league, leading to million-dollar television broadcasting contracts.

Considering the context described above, competition to host sporting events became fierce, with regions aiming to obtain economic benefits, such as increased tourism or regional investment. The aim of the regions was to increase the income generated, as well as employment levels, and also to boost the tourism sector.

In the 21st century, the growth of streaming platforms and the use of social networks has turned sport into a "direct to consumer" reality, where fans can interact in real time with athletes and teams.

Formula 1 (F1) is currently a multi-billion-dollar industry with a wide range of revenue streams, the main ones being the sale of broadcasting rights to television channels and streaming platforms. In addition, the organization and the teams that make up the championship themselves sign multi-million-dollar contracts with global sponsors.

In 2022, F1 generated revenues of approximately 2.57 billion US dollars, reflecting a growth of 20% compared to the previous year's results, which is strongly associated with the investment on digital marketing, with the use of the Netflix series "Drive to Survive" (n.d., 2023).

F1 is a pillar of technological innovation, with applications in different areas of society beyond the automotive industry. We can refer to F1 as an ecosystem that generates huge revenues and promotes continuous investment in innovative, advanced technological solutions. F1 is thus a privileged stage for the sophistication, competitiveness, and notoriety of new technological solutions that are subsequently transposed into commercial use in several industries.

F1 has been practiced since 1950, and it has been attracting more and more global interest. It has become a protagonist in the panoply of sports viewed worldwide (Storm et al., 2020).

Data from Jenkins et al. (quoted by Storm et al., 2020, p. 4) is clear and expressive: the annual audience for the sport is around 425 million, surpassed only by the Olympic Games and the soccer World Cup.

An F1 championship is made up of a series of mega-events, known as Grand Prix (GP) events. Initially, these mega-events only took place in seven countries: the United Kingdom, France, the United States of America, Switzerland, Belgium, Italy and the microstate of Monaco (Jenkins et al., cited by Storm et al., 2020). Currently, around 20 countries host a GP event. It is therefore possible to estimate the potential cultural and economic impact of hosting the teams in the organizing region (Storm et al., 2020).

The purpose of this work is to estimate the economic return from holding F1 Grand Prix events in European regions between 1990 and 2023. To this end, we analyzed 14 regions that intermittently hosted the F1 Grand Prix during that period to understand whether there was a positive or negative variation in the economic growth associated with the F1 Grand Prix events. We estimated the economic impact of this sporting event on regional GDP growth and regional GDP per capita, as well as on regional employment. Finally, given that events of this nature are closely linked to sports tourism and tourism promotion in the organizing region, we also estimated the impact of F1 GP events on the number of overnight tourists stays in the region.

Methodologically, following Storm et al. (2020), we estimated parametric panel data econometric models, in which the impact on economic growth associated with F1 Grand Prix events (dummy variable), controlling for temporal and region-specific effects, using a longitudinal database with up to 344 observations per variable (years and regions).

It should be noted that, according to Fairley et al. (2011), the existence of public funding for sporting events in itself justifies scrutiny of the return on this public investment. For many taxpayers, there is a perception that public funds allocated to hosting an F1 Grand Prix could be used for areas with a relevant social return, such as education and health, while also bearing in mind the associated environmental costs. According to Dwyer and Forsyth (2009), these environmental and social costs may be of first order of importance and potential outweigh any economic benefits (e.g., Jakobsen et al., cited by Storm et al., 2020; Zimbalist, cited by Storm et al., 2020).

The organization of an F1 Grand Prix event is typically associated with a large public investment in the part of the organizing region. Therefore, it is important to understand the expected social return of that project since the public capital employed could be allocated to a set of alternatives of high social importance, either in a competing logic of promoting economic growth or in another logic of relevant social value (such as education or health, without loss of generality). To analyze the social return on public investment in organizing F1 Grand Prix events, it is necessary to measure the economic return since the latter will always be an important part of the former.

Recent studies admit that if costs and benefits are compared, hosting such an event may not boost the economy of the organizing region. On the contrary, it could have a negative impact. Studies on motor sports (Baade & Matheson; Coates & Gearhart, cited by Storm et al., 2020) conclude that positive impacts are rare, and can even be negative.

Due to the international and extremely appealing nature of F1, the returns for this sport can be markedly different across geographies (e.g., Mourão, 2017). Theoretically, there are various reasons for F1 being a profitable entertainment industry whose importance goes beyond the sport sector. Notably, F1 is a favorable environment for technological development, given its extreme exigence in terms of innovation and efficiency, which can induce spillover effects. For example, in the health sector, McLaren, a renowned F1 team, leveraged F1 technology to produce ventilators during the Covid-19 pandemic (Masterson, 2020).

Without prejudice to all the information collected and explained above, it is important to understand whether the results are consistent with the theory of Jakobsen et al. (cited by Storm et al., 2020), where hosting an F1 GP triggers positive effects in the region, or whether we are looking at results that go against what is proposed by Baade et al. (cited by Storm et al., 2020), who claim the opposite.

Although the focus of this paper is to contribute to the estimation of the regional economic return associated with the organization of F1 Grand Prix events, it is important to note that there may be reasons other than strictly economic ones that drive regions to organize these events. Hosting large, globally viewed sporting events, such as the FIFA World Cup or an F1 Grand Prix event, the organizing region attracts tourism and new investment while simultaneously promoting a positive image to a wide global audience, putting it in a better position to influence the dynamics of global politics to its advantage and to increase its soft power (see Nye, 2005). However, it should be mentioned the potential sportswashing risk: Saudi Arabia, which has been investing heavily in soccer clubs and F1 (Jeddah Grand Prix), arguably to improve its global image in an attempt to divert attention from issues related to women's rights, among other potentially controversial issues (Fruh et al., 2023).

Thus, there are various reasons, ranging from sporting, economic, cultural, and even geopolitical (soft power and sportswashing), which motivate different regions around the globe to host an F1 Grand Prix event. Since the focus of this work is on estimating the economic return in the region that hosts the F1 GP event, only European regions (excluding Russia) are used in the econometric analysis since sportswashing is not prevalent in the European political space, given the quality of the institutions found in this geography. Furthermore, the quality of official statistics in the European regions is considered to be undoubtedly higher, as opposed to certain non-European areas, for which there are no official statistics provided by entities independent of political power (a problem more acute in autocratic regimes). To sum up, the set of regions analyzed represents an area with interesting statistical variation (which allows the economic effect of the F1 Grand Prix event to be captured in statistical terms), but always in a high-quality institutional environment, guaranteeing the use of reliable data.

This paper is structured as follows: Section II contains the theoretical framework and describes the evolution of F1 to the present day; Section III explains the econometric methodology employed, the data used and the hypotheses tested; Section IV presents the main models estimated; Section V contains the main conclusions obtained and, finally, Section VI offers a critical appraisal of the work carried out in this paper and suggestions for future research.

II. Theoretical Framework and Hypotheses

Cities and regions of high economic power have been investing in multiple sporting events at a time when sports are taking on a leading role in society, with the investment in improving infrastructure and organizing the events proving to be very significant in monetary terms. Economically, the main argument put forward by the organizing regions to justify holding these major events is that it is extremely beneficial for these regions to host them, given the significant direct increase in different tourism indicators, but also as a way of increasing the region's publicity as a tourist destination (Preuss, 2005). With increasing globalization, the potential audience for sporting events is growing, especially for events that are truly attractive on a global scale insofar as they attract interest across borders, as is the case of F1 events.

Considering the evolution of global audiences, interest in evaluating the economic results and consequences that these events can have on regions at various levels has increased considerably (Kassens-Noor et al., cited by Storm et al., 2020). As previously mentioned, governments end up being the entities making the most relevant decisions regarding the sporting events to hold, which become a central tool for the region's development.

However, it is noteworthy that, in most cases, the infrastructures needed to make these events possible are financed, in whole or partly, through taxpayers' money (Baade & Matheson, cited by Storm et al., 2020). If we consider the example of the Yas Marina F1 Circuit in Abu Dhabi, United Arab Emirates, we know that in 2009, approximately 2.3 billion US dollars were spent to build the circuit and renovate the city area surrounding it (Storm et al., 2020).

Most economic return assessments for the hosting region, as far as F1 is concerned, use input-output models (IO) or general equilibrium models (GEM). These models, not very complex (Dwyer & Forsyth, 2009), have gradually come under increasing criticism, essentially because they consider inflated multipliers, thus overestimating the economic benefits of a given region receiving a GP (Taks et al., 2011, cited by Storm et al., 2020). This may be a very serious problem, as political decision-making bodies receive biased information, leading to suboptimal decision-making.

IO models assume that economies have a fixed structure and that the interactions between the various sectors do not change over time. This type of model does not consider the oscillating nature of prices, and they are often partial equilibrium models rather than general equilibrium models, assuming that prices are fixed. Lastly, IO models are static over time and are unsuitable for studies in which the time frame is medium or long-term (Leontief, 1986; Líšková, 2015).

Although significantly more complex than IO models, GEM models also have weaknesses. Over the last few years, GEM models, particularly Computable General Equilibrium (CGE) models, have become more sophisticated. They allow for modeling that can study macroeconomic phenomena, such as expenditure component multipliers, with sectoral detail but with microeconomic foundations. These models make it possible to model, with interesting granularity, the most relevant sectoral aspects and the different microeconomic representative agents. However, these CGE models require data that is often unavailable for various regions and assume that the year in question - for which the data are collected - is a steady-state year, which makes it possible to characterize long-term equilibrium relationships, informing later comparative statics and transition dynamics exercises (Dixon & Parmenter, 1996; Shoven, 1992). Consequently, it is fair to say that the GEM or CGE, because they require a significant set of data, may be unfeasible to use. Therefore, despite the usefulness of both models, they also have limitations and should be complemented with other approaches.

Under active budgetary restrictions, resource allocation is constrained and should be conducted rationally and well-founded - specifically, in the case of the use of public resources allocations associated with sports projects, which are typically subject to severe and meticulous scrutiny (Fairley et al., 2011), many taxpayers, who may have wanted those funds to be used to respond to certain social causes such as education, health, and environment (e.g., Dwyer & Forsyth, 2009).

Various methodologies are used to estimate the economic benefits that sporting events can bring to a region. Using the IO model, Kim et al. (2017, cited by Storm et al., 2020), estimated that the Shanghai GP event in China generated approximately 11.2 million US dollars in extra revenue or the equivalent of creating 1409 full-time jobs - results interpreted as positive.

The Government of the region of Victoria, Australia, used the other model explained, the GEM model, which estimated that the Australian GP, held in the city of Melbourne in 2011, increased the Gross Domestic Product of the State of Victoria by between 32 and 39 million Australian dollars (AUD) and created approximately between 351 and 411 full-time jobs (Storm et al., 2020), results that were also interpreted as positive.

According to Késenne (2005) and Andreff (2017, cited by Storm et al., 2020), economic studies, even if incomplete, often serve only to justify political decisions or government intentions, in this case, related to the staging of major sporting events. In this sense, these studies are often carried out to obtain the desired results or, ex post-validation of the hosting decision, and they do not have the main objective of using correct methodologies that provide reliable results.

Additionally, these studies rarely consider the opportunity cost of allocating resources specifically for the purpose of hosting an F1 GP event, nor do they take into account the consequent environmental impact, the most common effects being pollution, dumping, or the destruction of natural resources (Cheng & Jarvis, 2010).

However, cost-benefit analysis (CBA) takes into account all the associated costs and benefits, and for this reason, it is a methodology that offers more accurate results. Using a cost-benefit analysis, Késenne (quoted by Storm et al., 2020) showed that a sporting event can have a negative impact on a region's economy. Thus, Pearson (cited by Storm et al., 2020), using the CBA, estimated that the Australian Grand Prix, held in 2005, generated a loss of approximately 6.7 million Australian dollars (AUD). Using the same approach, it was found that in 2011 and 2012, the same GP event, held in the city of Melbourne, was responsible for the loss of 52.7 and 60.5 million Australian dollars (AUD), respectively (Storm et al., 2020). Still using the CBA, Fairley et al. (2011), stated that it would be incorrect for official entities to defend the idea that the Australian Grand Prix would be promoting positive effects on the economy of the Melbourne region.

Abelson (quoted by Storm et al., 2020) argues that a mega-sporting event should only be held if the outcome of a CBA is positive. For Siegfried and Zimbaslist (2000, cited by Storm et al., 2020), it is imperative to compare regions that host mega-sporting events with regions that do not in order to isolate the economic effect directly associated with holding the mega-sporting event in question.

This work follows the methodological approach used by Storm et al. (2020), but with a larger number of years and European regions, using panel data linear regression modeling to estimate the regional (NUTS II) economic impact of holding an F1 Grand Prix in Europe.

To that end, we focused on European regions, where Eurostat assures the quality of the statistics. Because in several regions, the F1 Grand Prix may be allegedly associated with sportswashing, only European NUTS II regions were considered, which is the finest grade for which statistics on the variables instrumental for measuring the economic return in the region are available. The gross domestic product (GDP), per capita GDP (GDP pc), employment, and tourist overnight stays are among them. In addition, as mentioned above, the reason for the initial interest in this work was to understand whether it would be beneficial for Portugal to host an F1 Grand Prix event regularly. Thus, the fact that this study is based on European regions allows for a closer approximation to the Portuguese reality, which, in this period, has organized two F1 Grand Prix events, namely in Portimão (Algarve) and Estoril (Lisbon and Tagus Valley).

Below are the hypotheses to be tested:

$_{a}H0$: *Hosting a Grand Prix event has no effect on the region's GDP;*

$_{b}H0$: *Hosting a Grand Prix event has no effect on the region's GDP per capita;*

$_{c}H0$: *Hosting a Grand Prix event has no effect on the region's employment rate;*

$_{d}H0$: *Hosting a Grand Prix event has no effect on the number of nights spent in the region.*

III. Research Design: Data, Methodology, Implementation

This study aims to examine the impact of hosting an F1 Grand Prix on the economy of a particular European region. Several econometric regression models were estimated using a set of data relating to four different variables associated with the economic growth of the region in question to assess the possible effects of hosting an F1 Grand Prix event.

The selection of the regions to be studied and the criteria used to choose them are completely indispensable elements in creating a set of results that respect the research assumptions. It is very important to have a term of comparison within the regions themselves that establishes associations between the periods in which F1 Grand Prix events were hosted and those in which they were not. Thus, regions such as Mogyoród, Pest County, Hungary, which has hosted the Hungarian GP annually and uninterruptedly since 1986, or the region of Monte Carlo, Monaco, which has hosted the Monaco GP annually since 1955, do not represent acceptable study regions, since they do not have the necessary characteristics to integrate the relevant regions for this research. Specifically, these regions do not exhibit the binary variation of hosting and not hosting an F1 Grand Prix over a previously defined period. In other words, we only considered regions that, during the period under study, either received or did not receive a GP event. It is this variation that allows us to analyze the impact that the dummy variable - hosting an F1 GP event - has on the region's economy. If the region had hosted an F1 Grand Prix event every year of the period in question, this dummy would always have a value of one, so it would be completely collinear with the model's constant, which is needed to capture the fixed effects associated with the region in question.

Thus, the F1 GP event dummy variable, which takes on the value "one" in the years in which the region hosts an F1 GP event and the value "zero" in the years in which the region does not host this event, no longer presents the problem of collinearity, a necessary condition for the model to be estimable.

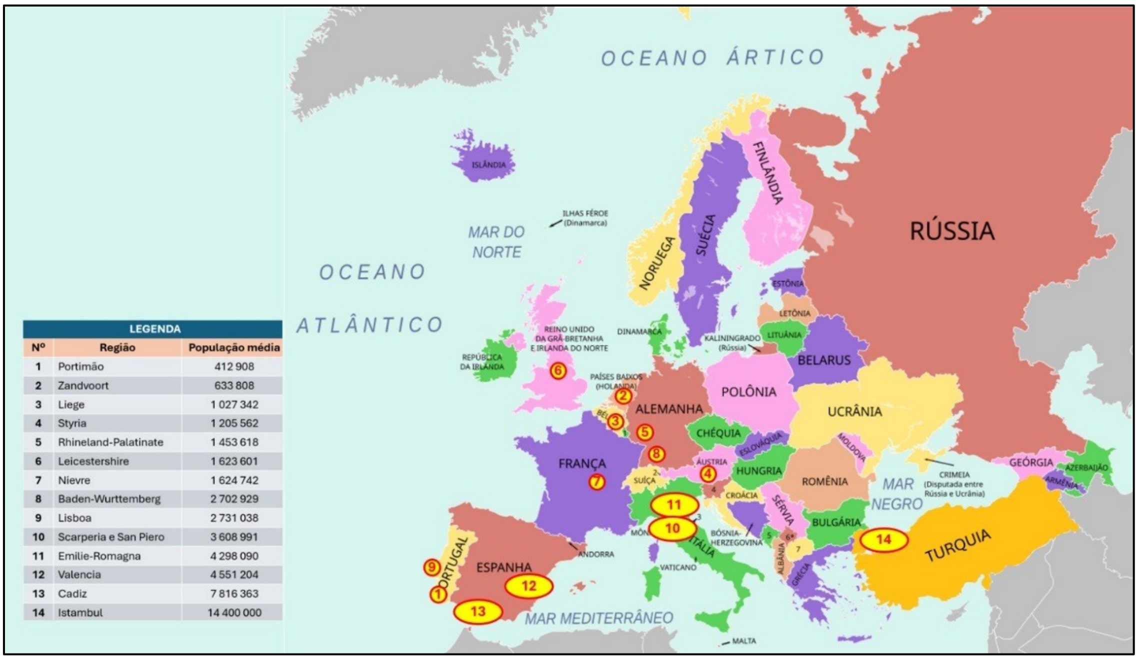
In this way, 14 different European regions were examined from 1990 to 2023, with respect to the variation of the independent variable, a dummy variable indicating the F1 Grand Prix (specific models also consider lagged values of the independent variable to capture dynamic effects or lags in the economic impact derived from the F1 Grand Prix, as well as lagged values of the dependent variable, to capture temporal correlation in it). The data is annual, as the variables identified as relevant to the study are only available at this frequency. We therefore estimated regression models with the regions shown in Figure 1, assessing the impact on four different dependent variables. In this context, we estimated models with changes in Gross Domestic Product (GDP), measured in millions of euros (€), and the GDP pc indicator since it directly represents the income generated per inhabitant of the region. We also used the indicator nights spent - or tourist overnight stays in the region, which was considered an appropriate variable to study since several authors argue that one of the main economic effects for a region that hosts an F1 Grand Prix is the increase in the tourism sector - measured by nights spent. The hosting of an F1 Grand Prix brings in large numbers of people who watch the event live, but also, as pointed out above, a boost in the region's notoriety as a tourist destination, which can be an investment in the touristic promotion of the organizing region. The last indicator selected for the study was the employment rate, which, along with GDP *pc*, helps to provide a more focused perception of the real economic impact on the population and the region.

A. Data

With regard to data collection, values for the four variables under study were taken from the Eurostat database between 1990 and 2023, namely GDP (Eurostat, 2024b), GDP *pc*, obtained using the ratio between GDP values and population values on January 1st of each year (Eurostat, 2024b, 2024d), nights spent in the region (Eurostat, 2024c) and the employment rate of the 14 regions under study (Eurostat, 2024a), shown in the figure below (Figure 1).

In the case of the Leicestershire region, its GDP data was not reflected in the same database as the other regions, as a result of the United Kingdom leaving the European Union. Therefore, GDP figures were taken from the Office for National Statistics database (Office for National Statistics, 2024). Given that the figures were expressed in British pounds sterling, in order to standardize the figures for the English region with those for the other European regions, we used the European Central Bank to obtain the exchange rates (European Central Bank, n.d.). However, the exchange rate for 1998 was not in the data sample, so it was taken from the European Central Bank's 1998 Annual Report (European Central Bank, 1999).

Figure 1
NUTS 2 regions



B. Methodology

Various regression models were applied to panel data to take dynamic effects into account, assuming that there may be gaps or lags between the time of the F1 GP and the possible economic effects. In addition, different variants of the models were considered to guarantee the quality of the estimates, as well as the robustness and efficiency of the estimators.

The work uses panel data that incorporates, in addition to the sectional dimension, the time dimension, so fixed effects (FE) were added to the models. These provide greater control over variables that are not observed, fixed, or specific to a given region but are distinct between regions, influencing the dependent variable.

Because of the Nickell bias (Nickell, 1981), we used models with the Arellano-Bond (AB) estimator (available in STATA as xtabond2) which, adding lags to the model variables, enables the correction of the correlation between y_{t-1} and the regression error (Arellano & Bond, 1991).

To deepen our analysis, models were estimated using lag indicators, which allow for the detection of possible effects that the variables of the years preceding the time frame under study have on the variables in the time frame and the regions under study. Finally, sensitivity analysis models were estimated, such as simple OLS regression (ordinary least squares) and pooled OLS (*pooled* ordinary least squares).

C. Implementation

Eight models were estimated with the GDP variable, sixteen models with the GDP pc variable, six models with the nights spent/tourist overnight stays in the region variable, and eight models with the employment rate variable. Assuming that the economic effect may not be immediate, models were estimated based on the same dependent variables but using an evaluation with lagged effects, i.e., to consider a time frame where it is possible to identify consequences for the indicators, and consequently for the region, in the medium-to-long term.

The models used in the analysis follow the following general specifications:

$$y_{i,t} = a_i + by_{i,t-\mathrm{k}} + cx_{i,t} + fD_{i,t-k} + \epsilon_{i,t} \tag{1}$$

where, $y_{i,t}$, denotes the value of the dependent variable for region i in period t; a_i, the intercept term, that captures serial correlation effects; x, a vector of independent variables;[1] D, a dummy variable, indicating the occurrence of a F1 GP event in the region in the period; b, c, and f, are the model's parameters; ε, an error term with zero mean and constant variance; and subscripts refer to region i at time t.

IV. Results and Discussion

Table 1, Table 2, and Table 3 exhibit the univariate statistics / descriptive statistics.

This section presents and discusses estimation results. Because, for the most part, estimation results are not statistically significant due to the lack of statistical relevance and space limitations, we are not reporting all of the estimated models.

The first model to be presented is an OLS (ordinary least squares) linear regression. It can be seen from this model that, at the 5% significance level, the model is not statistically significant, given that the F value is 2.28 and the *p-value* is 0.13. In addition, the adjusted R^2 value is 0.01, which confirms that the model has little explanatory power (Table 4).

In addition, the *Student*'s t and *p-value* values associated with the explanatory variable are -1.51 and 0.13, respectively, indicating that the null hypothesis cannot be rejected, i.e., that the F1 GP variable (f1race) has no effect on the dependent variable "nights spent" (Table 4).

The second model is a linear regression of FE, with clustering by units (id) and also adjusting the standard errors of the variables for clusters [code used: xtreg gdppc_1. gdppc_1. f1race, fe cluster(id)]. In this model, the two explanatory variables, GDP *pc* (l.gdppc) and the existence of an F1 GP (l.f1race), are lagged one period.

[1] During the Covid-19 pandemic, unprecedented travel bans, stay-at-home lockdowns, and restrictions on public gatherings at schools, workplaces, sport infrastructures, and public transit systems were enforced. To control for those disruptions, a Covid-19 variable was included in our empirical specification (e.g., Demertzis et al. (2020). The Financial Fragility of European Households in the Time of COVID-19. Bruegel Policy Contribution 2020/15).

Table 1: Average global values.

Name	N	Period	Average	Maximum	Minimum	Standard Deviation
GDP (€, millions)	317	2000-22	82 852	262 182	5 026	53 749
GDPpc	309	2000-22	39 408	312 795	2 923	52 065
Last Nights	354	1900-2022	17 775 161	72 044 756	1 553 652	15 948 474
Employment (%)	333	1999-2023	66	83	42	8
Population	440	1900-2023	2 989 922	15 907 951	106 035	2 973 311

Table 2: Average GDP and GDPpc by region.

Name	*N*	GDP (€, million) / Average	Maximum	Minimum	*N*	GDPpc / Average	Maximum	Minimum
Styria	23	39 865	56 153	27 129	23	32 744	44 818	22 933
Liège	20	27 918	37 919	20 222	20	25 773	33 975	19 173
Baden-Württemberg	24	97 460	141 163	7 823	23	35 522	50 192	2 923
Rhineland-Palatinate	24	42 158	57 381	33 225	23	28 103	38 173	21 907
Valencia	23	97 358	126 416	62 717	23	20 253	24 922	15 283
Andalusia	23	138 612	180 224	86 569	23	17 022	11 882	21 155
Burgundy	23	42 822	52 777	34 294	23	26 266	21 264	32 685
Emilia-Romagna	24	139 476	176 845	106 154	22	33 115	27 800	29 962
Lisbon	23	65 034	87 368	47 515	23	23 318	18 055	23 261
Leicestershire	25	44 619	61 301	30 733	22	25 615	20 088	29 962
Algarve	23	7 750	11 624	5 026	23	17 875	13 046	24 961
Istanbul	19	188 335	262 182	98 279	15	14 344	12 546	16 551
Tuscany	23	105 109	128 308	80 686	23	28 760	23 109	35 036
North Holland	23	136 463	203 766	90 653	23	211 634	145 160	312 795

Table 3: Average number of nights spent and employment rates by region.

Name	*N*	Nights spent / Average	Maximum	Minimum	*N*	Employment rate / Average	Maximum	Minimum
Styria	33	8 474 159	11 375 291	6 767 864	25	70	75	64
Liège	33	2 193 571	2 766 896	1 553 652	25	57	60	55
Baden-Württemberg	29	8 807 309	10 877 160	5 565 137	25	73	79	67
Rhineland-Palatinate	26	7 431 468	8 374 826	4 824 116	25	72	78	65
Valencia	27	35 113 324	50 063 663	13 751 065	25	60	66	53
Andalusia	28	47 549 135	72 044 756	18 604 393	25	52	58	44
Burgundy	31	6 906 661	11 333 627	5 300 862	25	66	71	62
Emilia-Romagna	19	36 679 405	40 647 799	22 229 208	19	69	71	66
Lisbon	26	11 197 927	20 156 849	6 810 265	25	67	73	60
Leicestershire	21	3 216 754	6 575 060	1 759 000	21	74	78	71
Algarve	27	16 519 489	22 992 874	9 118 490	25	68	74	62
Istanbul	9	22 837 784	41 442 044	13 923 031	18	49	57	42
Tuscany	19	40 994 849	48 077 301	21 972 603	25	64	69	57
North Holland	26	19 697 108	35 064 587	8 894 200	25	76	83	72

The results of the estimation of this model generally suggest that it is not statistically significant, given that the *F-value* and the associated *p-value* are 1.18 and 0.34 respectively.

Table 4: Dependent variable: nights slept; OLS regression.

Variable	Coefficient	t-Student	*p*	95% CI
f1race	-907,675.4	-1.51	0.13	[-2 089 438; 274,087.3]
Constant	644,859.9	1.89	0.06	[-27 976.3; 1,317,696]
R^2	0.01			
F (1,325)	2.28		0.132	
N. Comments	327			

With regard to the lagged variable F1 GP (l. f1race), the *Student*'s t-value is very low, corresponding to -0.14, and the *p-value* is 0.89. It can therefore be concluded that, even with a one-year lag, an F1 GP event has no statistically significant impact on the GDP *pc* variable (Table 5).

Table 5: Dependent variable: GDPpc; fixed effects regression - lag 1 period.

Variable	Coefficient	t-Student	*p*	95% CI
l.gdppc	0.51	-1.42	0.18	[-0.268; 1.289]
l.f1race	-369.1	-0.14	0.89	[-5 970.7; 5 232.5]
Constant	19,890.4	1.42	0.18	[-10 447; 50 227.7]
R^2	0.24			
F (2,13)	1.18		0.34	
No. comments	306			

The model presented below is also a regression with fixed effects, but it uses the natural logarithm of the number of nights spent in the region as the dependent variable and the logarithm of the number of nights spent in the region as one of the explanatory variables, but lagged by one period (code used: xtreg ln_total_nights_spent_ l.ln_total_nights_spent_ l.f1race_, fe cluster(id)). The results show that the lag variable, the logarithm of the number of nights spent in the region (ln_total_nights_spent), has a positive coefficient (0.68), a *p*-value below 0.001 and a Student's *t*-value of 13.18, which indicates that there is a very strong relationship between the previous value and the current value of the variable. However, regarding the lagged dummy variable, as there is an F1 GP (f1race), it has a p-value of 0.24, thus indicating its statistical insignificance and denoting that holding an F1 GP event has no statistically significant impact on the number of nights spent in the region. The overall F-test (with a value of 86.89) indicates that the model as a whole is statistically significant (Table 6).

Table 6: Dependent variable: natural logarithm of the total number of nights spent in the region (total nights spent); fixed effects regression - lag 1 period.

Variable	Coefficient	t-Student	*p*	95% CI
ln_total nights spent (L1)	0.68	13.18	0.00	[0.57; 0.79]
f1race (L1)	0.1	1.24	0.24	[-0.04; 0.15]
Constant	5.16	6.11	0.00	[3.33; 6.98]
R^2	0.45			
F (2,13)	86.89		0.00	
No. observations	327			

The fourth model is a linear regression with FE, with the aim of assessing the impact that the explanatory variables, in this case the employment rate in the previous period (employment_L1) and the F1 race in the current year (f1race), have on current employment (employment) [code used: xtreg employment 1.employment f1race, fe cluster(id)]. The *p-value* of the employment rate *lag* variable (employment_L1) was less than 0.001, with a *Student*'s t-value of 46.64. This means, on the one hand, that the coefficient of 0.90 is highly statistically significant and, on the other, that when employment in the previous period increases by one unit current employment increases by 0.90 units (Table 7). However, with regard to the GP F1 variable (f1race), there is a *Student*'s *t-value* of -1.90 and a *p-value* of 0.08, which indicates that the coefficient of the variable in question, in this case -0.72, is marginally non-significant at the 5% significance level, but relevant at the 10% significance level (Table 7).

Table 7: Dependent variable: employment rate; fixed effects regression - lag 1 period.

Variable	Coefficient	t-Student	*p*	95% CI
employment (L1)	0.90	46.64	0.00	[0.85; 0.94]
f1race	-0.72	-1.9	0.08	[-1.53; 0.10]
Constant	7.45	5.53	0.00	[4.54; 10.36]
R^2	0.80			
F (2,13)	3,787.48		0.00	
No. observations	319			

The Generalized Method of Moments (GMM) estimator for dynamic panel data has been applied to a regression, more specifically the AB method, which makes it possible to deal with the endogeneity problems associated with dynamic panel data models.

Using the command xtabond2, a model was estimated in which it was possible to ascertain, with regard to the lag variable logarithm of the number of nights spent in the region (ln_total_nights_spent_l), that its coefficient is 0.39, indicating that a 1% increase in the number of nights spent in the previous period leads to an increase of approximately 0.39% in the number of nights spent in the current period. In addition, the estimate shows a *Student*'s *t-value* of 3.77 and a *p-value* of 0.002, which identifies an effect with relevant statistical significance.

In this particular case, the F1 GP *dummy* variable (f1race) has a marginally significant effect, since its *p-value* is 0.055, very close to the 5% significance level, and its *Student*'s t-value is -2.09. With this, its coefficient of -0.09 shows that it is possible that holding an F1 GP event could reduce the number of nights spent in a region by 9% (Table 8). The AB test, for both first-order autocorrelation and second-order autocorrelation, rejects the null hypothesis, which states that there is no correlation in the differences in the model. In turn, the Sargan test rejects the null hypothesis that the analysis instruments are valid. Finally, the Hansen test does not reject the null hypothesis that the instruments are valid (Table 8).

Table 8: Dependent variable: natural logarithm of the total number of nights spent in the region (total nights spent); Estimation of AB models - lag 1 period.

Variable	Coefficient	t-Student	*p*	95% CI
ln_total nights spent (L1)	0.39	3.77	0.00	[0.17; 0.62]
f1race	-0.10	-2.09	0.02	[-0.18; 0.002]
AR (1)	-2.50		0.01	
AR (2)	-2.22		0.03	
Sargan Test	338.07		0.02	
Hansen Test	9.41		1.00	
N. Observations	304			

The fifth model to be presented is also a GMM regression, specifically the AB model. However, the dependent variable represents the level of employment in the regions (employment) and one of the explanatory variables corresponds to the one-period lag of the level of employment (command used: xtabond2). The F1 GP variable (f1race) has a p-value of 0.14 and a Student's t-value of -1.57, which indicates that, at the 5% and 10% significance levels, the result is not statistically significant, although it should be noted that the economic effect is negative. The AB test for first-degree autocorrelation shows that there is auto-correlation between the first-order differences, which is to be expected in dynamic models. However, unlike the previous model, the AB test for second-order autocorrelation does not reject the null hypothesis, so the result is positive (*p-value* = 0.09). The Sargan test has a very low *p-value*, which indicates that the instruments in the model are not completely exogenous. Finally, the Hansen test does not reject the null hypothesis that the instruments are valid (Table 9).

Table 9: Dependent variable: level of employment; Estimation of AB models - 1-period lag.

Variable	Coefficient	t-Student	*p*	95% CI
employment (L1)	0.91	38.56	0.00	[0.17; 0.62]
f1race	-0.6	-1.57	0.14	[-0.18; 0,002]
AR (1)	-3.14		0.00	
AR (2)	-1.67		0.09	
Sargan Test	346.5		0.00	
Hansen Test	13.94		1.00	
No. Comments	305			

In methodological terms, *lags* of between one and four years were applied to the independent variables. Considering that, in general, the coefficients associated with the lagged variables have a negative sign, but that the effects are not statistically relevant, all these models with different time lags are not shown.

Given that most of the models were statistically non-relevant, we tried to incorporate the Covid-19 effect into them, namely through a *dummy* variable that takes on the value of one in 2020 and another *dummy* variable that takes on the value of one in 2021. We also examined whether not considering any region of the 14 considered in the initial sample leads to (more) statistically significant results.

The model to be described is a linear regression with FE for panel data, with the aim of estimating the relationship between lagged GDP *pc*, the independent dummy variable

Covid-19 and the dummy variable representing the achievement of an F1 GP event. This model is a linear regression with FE but adjusted for a panel data set comprising only 13 regions, thus excluding the NUTS II North Holland region. In addition, as mentioned above, the Covid-19 variable was incorporated into the model. In the case of the dummy variable (f1race), the holding of an F1 race, the results are intriguing, since, despite maintaining a negative coefficient of -3,616.05, the Student's *t*-value is -2.16 and the *p-value* is 0.05, which suggests that, at a significance level of 5%, the impact of the existence of an F1 GP event may be relevant in the statistical sense, but with a negative economic impact. The Covid-19 effects, surprisingly, have a positive and statistically relevant effect (Table 10).

Table 10: Dependent variable: GDPpc rate (GDP per capita); fixed effects regression - lag 1 period - Covid-19 variable - id 13 (excluding North Holland).

Variable	Coefficient	t-Student	*p*	95% CI
gdppc (L1)	0.15	0.69	0.51	[-0.32; 0.62]
f1race	-3 616	-2.16	0.05	[-7 266.65; 34.56]
Constant	22,802.6	4.32	0.001	[11,289.09; 34,316,06]
covid19 2020	2,664.6	2.21	0.05	[42.299; 5,286.91]
covid19 2021	4,917.6	4.35	0.001	[2,456.13; 7,379.10]
R^2	0.04			
F (4,12)	77.27		0.00	
No. Comments	284			

Using this new model, the other variables, employment rate, GDP and nights slept in the region, were tested and similar results were generated, highlighting the statistically significant negative effects associated with F1 GP events.

The last model to be represented is a FE regression, in which the observations are organized by units (regions) and time. In this model, the dependent variable is the logarithm of the number of nights spent in the region. The use of the logarithm allows the coefficients to be interpreted as percentage variations. This model assesses the impact that an F1 GP event (f1race) and the lagged value of the variable logarithm of the number of nights spent in the region have on the model's dependent variable, considering only 13 regions (excluding the North Holland region). In this case, the effect that hosting an F1 race has on the region is negative and statistically significant, given that the coefficient value is -0.08 and the Student's *t* and *p* values are -2.34 and 0.04 respectively. This means that hosting a GP event in the region produces a decrease of approximately 7.83% in the number of nights spent in the region (Table 11).

Table 11: Dependent variable: natural logarithm of the total number of nights spent in the region (total nights spent); fixed effects regression - 1 period lag - Covid-19 variable - id 13 (excluding North Holland).

Variable	Coefficient	t-Student	*p*	95% CI
ln_total nights spent (L1)	0.63	10.63	0.00	[0.50; 0.76]
f1race	-0.10	-2.34	0.04	[-0.15; 0.01]
Constant	5.60	6.17	0.00	[3.88; 8.12]
R^2	0.41			
F (2,12)	94.92		0.00	
No. Comments	304			

Models were also estimated in which regions were differentiated according to their size, between regions with a high population (the three largest) and regions with a low population (the three smallest). The motivation for this line of analysis is based on the following thesis: it is admissible that the economic impact of holding an F1 GP event is lower, *ceteris paribus*, in regions which, by statistical definition, have greater economies (measured by population). In other words, statistical aggregation may dilute the economic effect of the sporting event, which will be greater in the city where it is located, less in the region of that city and, obviously, less in the organizing country. However, no significant changes were observed between them.

It should be noted that when excluding the region with id 14, North Holland, there is a clear improvement in the data produced by the model estimates, so it would be interesting in the future to analyze this situation and try to understand why this occurs.

V. Conclusions

F1 is widely recognized as among the most prestigious and engaging high-performance sports disciplines. Over the last few years, F1 has established itself as a sporting spectacle and an engine of economic, social, and even technological development in a wide variety of sectors and geographies across the globe.

Hosting an F1 Grand Prix event can trigger increases in revenue from the tourism sector. In this way, the sport is a strong catalyst for the global visibility of regions as tourist destinations.

However, it is essential to understand that F1 is a sport that involves very high costs, which are closely linked to the intrinsic challenges of organizing events of this complexity and magnitude. Despite this, F1 can be a tool for the economic development of cities, regions, and countries.

In this work, a variety of regression models based on dynamic panel data were estimated to understand and quantify the economic effects that F1 can have on different European regions, including, most importantly, two Portuguese regions.

Contrary to what was expected, the results obtained by the models point to a null or negative economic impact, but never a positive one, stemming from the hosting of the F1 Grand Prix event in the European regions (NUTS II level). Thus, the results do not support the idea that F1 has a positive effect on the variables under study, specifically GDP, GDP pc, employment, and nights spent in the region. Furthermore, in some models, we found statistically significant negative results, especially for nights spent in the region. These negative effects are even more significant if we remove the North Holland region from the range of regions under study.

According to Storm et al. (2020), it is difficult to decipher why the F1 Grand Prix event negatively influences the economy of the region that hosts it, and it is even more complex to understand why this reaction extends over three to four years. Värja (2016, cited by Storm et al., 2020) notes that the negative effects may be caused by the inefficient allocation and use of public funds, given the highly expensive nature of preparing and hosting an F1 Grand Prix event.

The results expressively show that using this approach, it is not possible to justify the investment needed to host an F1 Grand Prix event. Thus, the conclusions drawn from the analysis of the models concur with the results of Storm et al. (2020).

It is, therefore, advisable to dissociate the positive symbiotic relationship between mega sporting events and the region's economy to avoid the misallocation of public funds by the various government bodies.

Limitations

The methodology used in this paper, despite reflecting the state of the art in parametric panel data econometric regressions, has certain limitations, mainly associated with the data collected. Storm et al. (2020) state that the data used in the models is not as detailed as would be desirable.

Fourteen regions and an additional seven years were included in this work, four more regions and a longer time span than used by Storm et al. (2020). The addition of new regions, in particular the North Holland region, caused a significant change in the results (when contrasting the results of this work with those found in Storm et al.) Storm et al. (2020) conclude that the existence of an F1 GP event negatively influences the region. However, the results (when including North Holland) indicate that the F1 GP variable does not influence the other variables. However, if we remove the region of North Holland from the data sample, the results are already similar to those of Storm et al. (2020). It should be noted that Storm et al. (2020) use a subset of the data studied in this work, so it is possible for us to replicate the studies of these reference authors.

In this way and considering that the methodology used in this paper was the same (despite containing more observations) as the methodology used by Storm et al. (2020), the difficulties experienced, in terms of obtaining data and its quality, were similar.

In future research, it would be interesting to add more explanatory variables to the models and to find data that would allow a more detailed assessment to be made, referring, for example, to more restricted territorial divisions (NUTS III).

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