The relationship between uncertainty and success in Olympic sports

Abstract of PhD Thesis

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Introduction

The risk of winning a medal, i.e. the degree of uncertainty, varies between Olympic sports (Sterbenz and Gulyás 2016; Sterbenz, Csurilla, and Gulyás 2017; Csurilla and Sterbenz 2018). Studies on the perception of elite sport show that success in elite sport has a significant impact on society even today. Therefore, the rankings a nation achieves in a world competition and the sacrifices it makes to achieve these successes play an important role. As a consequence, it can be said that a nation's sport governance system should take into account the uncertainty inherent in the sporting disciplines in order to maximise the number of medals in elite sport through the efficient use of public resources and thus realise the greatest possible social benefits.

The primary aim of my thesis is to create a method to quantify and compare uncertainty in the sports and disciplines of the Summer Olympic Games. The term uncertainty may also be encountered in the literature as a synonym for luck. However, luck in team sports has been quantified before (Aoki, Assuncao, and Vaz de Melo 2017; Getty et al. 2018; Mauboussin 2012). So the question is: can the methods used to measure luck be applied to Olympic sports? If not, what other methods can be used to measure uncertainty in Olympic performance data?

Besides uncertainty, the other main objective of my doctoral thesis is to investigate the relationship between factors explaining Olympic success and uncertainty. Many studies in sports economics have addressed the question of what factors can explain the results achieved at the Games. These indicators have not yet been examined in relation to uncertainty. My other main research question is: what is the relationship between the most commonly used socio-economic factors (GDP, population), already proven by previous studies, and uncertainty? Also, how long can a country's Olympic success in a sport be sustained?

Objectives and hypotheses

The primary aim of my doctoral thesis is to demonstrate the magnitude of uncertainty in each sport and to explore the relationship with variables associated with performance. There have been numerous macro-level studies of Olympic results in the field of sport economics, but this has not yet been examined in relation to uncertainty. The relationship between uncertainty and performance can also provide useful information for researchers investigating the effectiveness of sport governance systems, as no studies have been carried out in this area.

H_1: I assume that uncertainty can be measured at the level of Olympic sports.

The studies presented in the literature review have almost without exception attempted to measure luck and uncertainty in team sports (typically in the major leagues). In our previous two studies, we have already attempted to quantify uncertainty in some Olympic sports - then called noise - but only a few of the sports covered in the Olympic programme were included in these studies (Csurilla, Gyimesi, et al. 2019; Csurilla, Gyimesi, et al. 2021). However, for the purpose of my thesis, I will attempt to quantify uncertainty in all (if the given sport was continuously included in the programme) Summer Olympic sports.

H_2: The superpower variable has positive explanatory power if the UK is included in the variable alongside the US, China and Russia.

As I have shown in the literature review, the outstanding successes of the three countries that have been the top performers at the Summer Olympic Games in recent decades (the United States, China and Russia) often put researchers in a difficult position. It is almost impossible to create a model predicting Olympic outcomes where the extreme values of the three countries do not carry the regression line. This is why Duráczky and Bozsonyi (2020)

created a superpower dummy variable to try to capture this excess effect and create a more accurate model. Although the coefficient did not have significant explanatory power, the inclusion of the UK would, I hypothesise, change this. The British sport governance system is one of the most efficient models of its time in terms of athlete success and resources available (Csurilla, Gulyás, and Sterbenz 2017; Kendelényi-Gulyás 2017), rivaling the other three superpowers in the number of medals won at the Summer Olympics.

H_3: Different results are obtained for the level of uncertainty at the sport level when different dependent variables (top 3, top 8 or top 16 rankings) are used in the models.

Macro-level studies have typically used podium places and various transformed forms of podium places as an indicator of elite sport performance. The number of medals is the most important indicator of a country's success, but only a small proportion of nations can finish in one of the podium positions (Kovács, Gulyás, and Sterbenz 2017). As a result, relatively little information is available for analysis; using the top 8 or 16 rankings, more detailed information can now be used to create more accurate predictive models. As a consequence of the accuracy, uncertainty will also be lower in models using detailed information.

H_4: When using only uncertainty quantified by models employing medal rankings, there is a different relationship with the variables affecting performance.

Countries are essentially fighting for one of the podium places in the various competitions. In sports where nations can maintain their performance, there is low uncertainty, as the competitive advantage derived from knowledge (which can be of many types, e.g. strategic, tactical, technical, coaching, etc.) is sustainable in the long run (Csurilla, Gyimesi, et al. 2019; Csurilla, Gyimesi, et al. 2021). However, for more detailed, more informative rankings

(top 8 or 16), the boundaries between sports become more blurred in terms of the degree of uncertainty, as results in which the most successful nations do not compete are included in the analysis. As a consequence, it is worth examining the impact of indicators related to the success of elite sports on the uncertainty calculated on the basis of medal placings.

H_5: The factors explaining success are also related to uncertainty.

As with Olympic results, data on uncertainty are available at country-sport level. Thus, the factors affecting performance can also be examined in relation to uncertainty. Since these are country-specific variables, I assume that they are related to performance as well as uncertainty, so the model will be significant.

H_{5A}: Economic performance expressed in GDP has a negative significant relationship with uncertainty.

Athletes from more economically developed nations have better training opportunities compared to those from less developed countries (Bernard and Busse 2004; Bian 2005). In addition, they try to focus on sports - see for example the British (Csurilla, Gulyás, and Sterbenz 2017) - where the influence of external factors on results is minimal. Economic development therefore reduces uncertainty, making the success of individual nations more predictable.

H_{5B}: Population has a negative significant relationship with uncertainty.

Population is also an important factor influencing the sporting performance of nations. Countries with a larger population have more talent to choose from and are in an advantageous position in terms of human resources (Johnson and Ali 2004; Rathke and Woitek 2008). On this basis, I make

the assumption that as the population increases, the degree of uncertainty decreases.

> *H_{5C}: The variable for the former Soviet Union has a significant explanatory power with a negative sign.*

In the Soviet states, elite sport was given a prominent role, the impact of which was still visible in the Olympic results after the collapse of the Soviet Union (Bernard and Busse 2004; Durączky and Bozsonyi 2020; Kendelényi-Gulyás 2017). Based on the competitive advantage gained, I assume that the performance of the former member states of the USSR reduces uncertainty as they can consistently achieve great results.

> *H_{5D}: The variable for former Eastern Bloc countries has significant negative explanatory power.*

Similar to the variable of the Soviet Union, the Eastern Bloc countries are experiencing the same effect. Thus, here too, I make the assumption that the negative is the relationship with uncertainty.

> *H_{5E}: There is a positive significant relationship between the host variable and uncertainty.*

The host effect is typically used in models explaining Olympic performance in order to capture the extra performance of the host country's athletes. Unpredictability increases with uncertainty, and I therefore assume a positive and significant relationship between the host effect and uncertainty.

> *H_{5F}: The explanatory power of the variables for the superpowers (United States, United Kingdom, China, Russia) is significant and has a negative sign.*

The superpower variable is needed because these countries have consistently been outstandingly successful at the Olympic Games and bias the estimates in the analysis. Due to the predictability of the performance of these countries, I assume that the variable is negatively related to uncertainty.

> H_6*: The Olympic performance of countries fluctuates, with the majority of countries unable to sustain medal winning in a sport for more than 1-2 Olympic cycles.*

The sustainability of medal-winning is difficult, which in itself underlines the uncertainty that exists at the Olympics. A podium finish by an athlete in consecutive Olympics is a sensation, something only a small percentage of elite athletes have ever been able to achieve. But from a country perspective, there are more options available, the athlete with the best expected performance will always be selected, as this is the essence of elite athlete production systems.

Methods

For my thesis, as in macro-level studies, I used sport performance data and socio-economic status indicators. The outcome data were the results of the Summer Olympic Games held between 1996 and 2012, which I collected from the Gracenote database. For the socio-economic indicators (GDP, population) I relied on the World Bank database.

The primary aim of my thesis is to create an econometric model that can be used to measure the level of uncertainty in each sport. In measuring uncertainty, I followed the methodology of previous studies (Csurilla, Gyimesi, et al. 2019; Csurilla, Gyimesi, et al. 2021), but tried to reduce the biases therein. Uncertainty in the Olympics can be measured using previous results, where the dependent variable is the Olympic results for the given year and the independent variables are the previous results and country-specific control variables.

$$MSh_{i,j,t} = \beta_0 + \beta_1 MSh_{i,j,t-4} + \beta_2 SUPER_i + z_{i,j,t} + d_t + \varepsilon_{i,j,t} \quad (1)$$

In the equation, $MSh_{i,j,t}$ is the market share of country i in sport j at the Olympic Games t, $SUPER_i$ is the dummy variable for superpowers $z_{i,j,t}$ is the vector of exogenous variables (GDPsh, POPsh, USSR, EB, HOST), d_t is the dummy variable for years, and $\varepsilon_{i,j,t}$ is the prediction error, i.e. the indicator of the uncertainty measure itself.

Uncertainty can be measured by the error terms of the regression models. The degree of error term is used to compare different sports; where the unexplained fraction is high, there is high uncertainty, and where it is low, there is low uncertainty (Csurilla, Gyimesi, et al. 2019; Csurilla, Gyimesi, et al. 2021).

My hypothesis suggests that there is a significant difference in the level of uncertainty depending on the type of outcome variable used as the dependent variable in the model. Since the mean of the error terms is expected to be nearly the same across sports due to my thesis method, the difference can

be presented in terms of their standard deviation. To this end, I have tested the error terms of the estimates with the three types of dependent variables (MSh_3, MSh_8, MSh_16) using the F-test for differences in the means in addition to the t-test for differences in the variances.

Based on the fifth main hypothesis of my thesis, I hypothesise a significant relationship between uncertainty and the factors affecting effectiveness. Using the estimation error of the model to measure uncertainty as the dependent variable in the (1) model, the following equation gives the relationship between uncertainty and effectiveness.

$$U_{i,j,t} = \beta_0 + z_{i,j,t} + d_t + \varepsilon_{i,j,t} \tag{2}$$

In the model, the dependent variable is $U_{i,j,t}$, i.e. the degree of uncertainty in the performance of country i in sport j at the Olympic Games t. $z_{i,j,t}$ is the vector of exogenous variables (GDPsh, POPsh, USSR, EB, HOST, SUPER), d_t is the dummy variable for years, and $\varepsilon_{i,j,t}$ is the error of the estimate.

The final hypothesis of my thesis concerns the length of countries' success at the Olympics. The duration of Olympic success is analysed using the survival function, $S(t)$, in the non-parametric Kaplan-Meier analysis (Cleves et al. 2010).

$$\hat{S}(t) = \prod_{t(_i)<t} \frac{n_j - d_j}{n_j} \tag{3}$$

by the convention that $\hat{S}\,(t) = 1$ if $t < t(_1)$. Given that many observations are censored, it is important to note that the Kaplan-Meier estimator is robust to censoring and uses information from both censored and uncensored observations.

The estimates are based on the database used so far. However, instead of market share, I used the number of medals, gold, silver, bronze and total medal distribution.

Results

The primary aim of my thesis, and accordingly the first hypothesis, was to measure uncertainty in summer Olympic sports. All coefficients, except for the year dummy variables and the constant members, were positive signed and significant at the 1% threshold. For the three different dependent variables, it is evident that the explanatory power of each coefficient moves in the opposite direction to the dependent variable with more detailed information. The exception is the lagged coefficients of the dependent variables, for which the explanatory power was different. The coefficients for market share calculated on the basis of the top 3 rankings had the highest explanatory power, while the coefficients for market share calculated on the basis of the top 16 rankings had the lowest values.

The superpower variable showed significant and positive explanatory power in all three models (at a threshold of 1%). As for the other variables, the coefficient with the highest value was the market share for medal positions. Typically, the inclusion of the superpower variable reduced the explanatory power of GDP and population significantly, while the explanatory power of the host and the USSR decreased only marginally.

Based on the estimates of the models, I have saved the market shares estimated by the regressions and the errors of the estimates. Thus, for each Olympics in the sample, I obtained the estimated market shares for each sport for each country, as well as the deviation from reality, which is the uncertainty itself. All three model estimates showed athletics to be the sport with the most robust output, with this sport being the one that could best explain the Olympic outcomes with the different variables in the regression models. My results suggest that external events, i.e. events beyond the athlete's control, have the least influence in athletics, with athletes' effort in this sport being most closely related to competition outcomes. After athletics, however, differences in the order of the uncertainties estimated by each dependent variable can be observed.

Based on my results, water polo was the sport with the most uncertain

outcome in the top 3 and 8 places, and dressage in the top 16, ahead of water polo. Of the sports included in the sample for my thesis, water polo had the most uncertain outcomes. In a model that only considered podium rankings, field hockey was the second sport where uncertainty had the largest effect. However, in both cases, dressage was the sport that was better than eventing in the models that took into account top 8 to 16 rankings, and was only the third sport most affected by uncertainty. If not in order, then roughly the same sports were the most affected by uncertainty in all three models. In addition to the above, rhythmic gymnastics and equestrian dressage should also be mentioned, all of which also had uncertain Olympic outcomes.

The third hypothesis of my thesis is that there is a difference in the level of uncertainty when different types of dependent variable are employed in the models. The results show that there is a clear significant difference in the mean uncertainty depending on the type of information detail of the dependent variables employed in the models. Between the best 3 and 8 rankings $t(12615) = 462.801$, $p < .001$, between the best 8 and 16 rankings $t(12615) = 340.361$, $p < .001$, and between the best 3 and 16 rankings $t(12615) = 441.775$, $p < .001$ showed a difference in the test results.

The differences between the variances were tested by F-test. As was the case with the t-test, the F-tests showed significant differences in the variances of the uncertainties in each case. There was a significant difference between the top 3 and top 8 rankings of $F(12615,12615) = 2.871$, $p < .001$, between the top 8 and top 16 rankings of $F(12615,12615) = 1.753$, $p < .001$, and between the top 3 and top 16 rankings of $F(12615,12615) = 5.033$, $p < .001$.

In the penultimate part of my thesis, I examined the relationship between uncertainty and the factors that influence performance. For uncertainty (U3), estimated by market share only for the top rankings, all coefficients were significant at a threshold of 1% and had a negative sign. The negative sign in this case means that the variables reduce uncertainty for the countries and sports concerned. GDP (GDPsh) had the largest effect, followed by population (POPsh). Interestingly, the Eastern Bloc (EB) variable had the third largest coefficient of explanatory power. The effects of the other four vari-

ables (former member state of the USSR, host and superpower) were nearly equal, but there was a detectable statistical difference between the SUPER and HOST variables, $\chi^2(1, N = 12{,}616) = 22.01$, p > .001.

For the uncertainty with the most detailed performance data, using the top 16 rankings, there was also a significant relationship for all factors affecting performance. With the exception of the superpower (SUPER) variable, the coefficients for all other variables were significant at the 1% threshold. The superpower was only related to the uncertainty measure at the 10% significance level, and moreover the relationship was positive. So superpower status increases the uncertainty measure among the top 16. As the statistical relationships indicate, the explanatory power of the coefficients was also significantly lower compared to the other two regressions. Economic development (GDPsh) had the strongest relationship with uncertainty. The Wald test of the coefficients for the host and the USSR was $\chi^2(1, N = 12{,}616) = 4.10$, p = .0.043.

To illustrate the duration of Olympic medal winning, I used the Kaplan-Meier survival function. The Kaplan-Meier estimates show that after one year, about 85 percent of winning spells are discontinued and only a small fraction of them survive.

The few long-term successes are partly due to the four-year Olympic cycle. Few athletes have the opportunity to qualify for more than one Olympics. Moreover, this is even more difficult in some sports, where the age spread of podium finishers is small, with only a certain age at which peak performance is possible. And for many countries, success in a sport is linked to a single athlete, so if he or she gets injured or ages out over a four-year cycle, the country's medal winning is no longer sustainable in the short term.

Conclusion

In my doctoral thesis, I investigated the relationship between uncertainty and the factors explaining Olympic success in sports economics studies. To this purpose, I first quantified uncertainty in all Summer Olympic sports and disciplines where the methodology used allowed me to perform this measurement. Thus, I was able to quantify the level of uncertainty in all sports except baseball, BMX, open water swimming and softball. In addition, with the three types of dependent variable (best 3,8 or 16 places) I obtained an even more complex understanding of uncertainty. Using uncertainty as a dependent variable, I also performed a relationship analysis with the factors influencing performance. More developed economic status or larger population clearly reduces uncertainty in countries' performance, but hosting the Olympics, former Soviet influence, was also negatively related to uncertainty. Finally, by employing a survival function, I estimated the length of duration over which countries can sustain medal winning in Olympic sports. The results suggest that about 85% of observations lasted only one Olympic cycle, with a small proportion of countries able to medal in only two consecutive Olympics in a single sport.

The model applied to measure uncertainty was essentially based on previous studies in the economics of sport, which examined the relationship between Olympic success and macro-level factors. The dominance of GDP and population as explanatory variables suggests that countries with more economically developed or larger populations are in a considerably more favourable position in Olympic competition, pointing to serious inequalities. If a country stands out on these two factors, it does not automatically mean that it will be successful in the Olympics. However, after social or political commitment, they can translate these resources into Olympic medals much more easily than their competitors who are in a less favourable position in terms of resources. Moreover, competitive sport, including the Olympic Games, is a zero-sum game: an improvement in one country's performance can only come at the loss of another country's. This reinforces the persis-

tence of inequality, since an increase in the resources invested by a country in elite sport does not in itself mean an improvement in performance; more resources need to be mobilised and/or used more efficiently than competitors (De Bosscher et al. 2015; Kendelényi-Gulyás 2017).

The case is similar in terms of the host effect. The Olympics in my thesis sample were invariably hosted by the more economically developed countries. In fact, three of the five Summer Olympics were hosted by three of the four most successful countries in the superpower variable over the last few decades of the modern Olympics. It is well known that the hosting effect is necessary because in the years leading up to the Olympics, the host country provides extra resources for the training of its elite athletes to take advantage of the home field and to ensure that the success of the Games is reflected in the number of Olympic medals won. The high value of the coefficient of the host variable did not decrease significantly with the inclusion of the superpower variable, showing that even in the face of outstanding success, countries with the highest number of medals also benefit from hosting the Games. As the bidding process for the Olympic Games and the hosting itself is designed to require a level of economic investment and commitment that countries in economically underdeveloped regions almost certainly cannot match, the gap between countries that can and cannot medal at the Olympics is widening. Although the AGENDA 2020 programme has begun to change the way the Olympics are organised, the winning bids for the forthcoming Olympics (2024 France - Paris, 2028 United States - Los Angeles) continue to show that hosting will remain the privilege of the more developed countries. An interesting question is how to adapt the conditions for hosting the Olympics so that, instead of widening the existing gap, the more marginal regions can also have the right to host the Games and, with it, Olympic success.

Variables for former Soviet Member States and Eastern Bloc countries still show a stable relationship with Olympic performance. Compared to the previous results (Bernard and Busse 2004), the effect of the Eastern Bloc surprisingly outperformed that of the Soviet countries. The discrepancy is probably due to the sport-level data. To investigate this, it may be worthwhile

in the future to compare the Soviet and Eastern Bloc variables on the two types of data (sport-level or national-level results only) to see whether the different data type really causes the difference or whether something else is the reason. Another possible explanation for the surprising result may be the sample selection, I included more recent Olympiads in the analysis compared to previous studies and the former Soviet Union countries may have experienced a faster decline in Olympic performance compared to the Eastern Bloc countries.

Based on the superpower variable, the four countries (USA, UK, China, Russia) clearly outperformed in terms of the number of medals won at the Olympics during the period studied. Moreover, 2016 data are not even included in the analysis, where the UK managed to increase their medal tally even further after hosting the Games at home. Although the UK lags behind the other three superpowers in terms of the two socio-economic indicators, its results show that the UK finished second in the medal table in 2016 and the number of medals won by British athletes did not fall significantly in 2021. As a result, it is clear that the 1997 reorganisation has made the UK's sports governance system one of the most efficient in the world in terms of medals won and resources used. It might be worthwhile in the future to create a separate variable for sport governance systems, in addition to the superpower variable, which would categorise countries according to their efficiency.

The difference between the dependent variables also suggests that the coefficients of the explanatory variable move inversely as the information on the dependent variables increases. This phenomenon is probably due to the fact that sports economics studies have typically used only podium finishes as an outcome variable, and thus have adjusted the set of explanatory variables accordingly. However, between the top 8 and 16 places, countries whose performance is no longer necessarily explained by these factors are now emerging. In the future, it may be worth exploring what other variables could be included in the models whose explanatory power could be better applied to more detailed performance variables. It is conceivable that a variable measuring the effectiveness of sport governance systems could also answer this

question.

The results of my doctoral thesis show that, although with a different method compared to studies that quantify luck, uncertainty can be measured in Olympic sports. Using market shares calculated on medal rankings can give more inaccurate estimates than using top 8 or top 16 rankings. This is partly due to statistical reasons, as most countries take a value of 0 for the podium places, as they cannot win any medals. In contrast, the majority of countries usually already have a top 8 or 16 ranking. However, the uncertainty estimated on the basis of podium finishes perhaps best captures reality. For many athletes, once they are certain of a medal, it is unlikely that they will do their best to continue to place well, and this significantly affects the accuracy of the analyses for uncertainty estimated using models with best 8 to 16 rankings.

Uncertainty is present to varying extents across sports, when considering the variance of the values obtained. Based on the model estimated with medal rankings, the trio of athletics, swimming and shooting is the most certain in terms of the outcome of the competitions. If a nation is aiming to increase the number of Olympic medals, it makes sense to focus on these and similarly less uncertain sports, where the risk of investment is lowest. In addition, these are the sports in which the elite athlete production systems work best, and the supply of an Olympic athlete is well managed, as the countries' performance fluctuates the least. The three sports with the most uncertain outputs were water polo, equestrian dressage and field hockey. These are the sports in which countries' performance varied the most, and where it is most difficult to achieve consistent performance from one Olympiad to the next. Water polo showed the biggest difference between the ability and effort of the athletes and the results of the competitions.

I should also mention the practical applications of the results of my thesis, namely the uncertainty values. Uncertainty should not be the main factor in a country's sports funding decisions to support sports. There are many other factors, such as relative competitive advantage (Tcha and Pershin 2003) or tradition (Hoffmann, Ging, and Ramasamy 2004; Hoffmann, Ging, and Ra-

masamy 2002; Kovács, Gulyás, and Sterbenz 2017) in a sport, which play at least as important a role as uncertainty. For example, in the case of Hungary, it would be difficult to justify the withdrawal of support for water polo, which is one of the most uncertain sports in terms of its outcome. However, uncertainty can be an important and decisive factor in a case where it is a choice between two sports that are very similar in terms of other factors but different in terms of uncertainty. In this case, a decision to take account of uncertainty can contribute to a country's more efficient financing of sport.

However, knowing the difference in uncertainty between sports can be beneficial not only for decision-makers but also for society. On the one hand, if fans are aware that uncertainty has a significant impact on the outcome of a sport, they might have more realistic expectations of their athletes and teams. Because of unrealistic expectations, failure experienced by fans can also lead to wider social frustration. If, people were aware of the role of uncertainty after a defeat, they would presumably feel less emotional intensity and less judgement of their athletes for the defeat. On the other hand, it would also be important for athletes to be aware of uncertainty, so that they would experience a defeat with less intensity, even if they had done their best. But it could also be used in the selection of a sport at a junior level, if coaches were to guide children towards their sport whose personal tolerance of uncertainty is in line with the uncertainty in their own sport. In this way, children will be able to be more persistent in competitive sport in later life and will not turn away from their sport or discipline when faced with a series of failures due to uncertainty.

Determining the degree of uncertainty in Olympic sports raises important questions for the Olympic movement as well as for the IOC. Excellence is an important value of the Games, but uncertainty suggests that this is not reflected in the results of competitions in all sports. Although the role of luck is extremely low in competitive sport and skill is fundamentally dominant (Elias, Garfield, and Gutschera 2012), how can interest be sustained in a sport where, despite skill and effort, results, i.e. medals, are lacking. Even the most outstanding athlete in the sport may not ever be able to stand on the podium

at the Olympics in his or her career. Learning from the results of studies on the uncertain outcome hypothesis, it cannot be argued that uncertainty plays an important role in the spectatorship of sport; it is quality that actually determines the number of spectators. In the future, it may be worth testing this finding separately to see how uncertainty relates to viewership in the context of the Olympic Games. If this hypothesis is confirmed, it may also be worthwhile for the IOC to consider how qualification and conduct rules could be modified to reduce uncertainty in certain sports.

Finally, I have also examined the relationship between uncertainty and success, which was the first topic of my doctoral thesis. GDP and population are the two most important factors that can reduce uncertainty in countries' performance. So economic development and larger population play an important role in countries' ability to maintain their past performance. This also points to the role of the elite sport production model, which is operated by the more successful countries (De Bosscher et al. 2015). In addition, there are sports where the more economically developed countries dominate the sport (Forrest et al. 2017), so the uncertainty in the "poorer" sports may be even more volatile (Csurilla, Gyimesi, et al. 2021). As part of further research in the future, this may be worth exploring the relationship between uncertainty and explanatory factors in more depth at the sport level, and then comparing the results with the sport-specific models presented in the study of Forrest et al. (2017).

I am hoping that the results of my doctoral thesis, the quantification of uncertainty and the conclusions drawn from it will help decision-makers in the field of sport governance in Hungary to use the available resources more efficiently in the future. Incorporating uncertainty into aspects of the sports funding system could help to ensure that more funding is allocated to sports where investment pays off. It may be interesting to see in the future, if more countries start to focus on less uncertain sports at the same time, whether the paradox of skill (Mauboussin 2012) will lead to an increase in uncertainty?

Finally, I hope that, in addition to practitioners, researchers in the field of sport economics will also be interested in the topic of uncertainty and that

new research directions will be added to the discipline in the future. Although I have quantified uncertainty in summer Olympic sports, there is always room for further improvements to the methodology or to perform the analysis on a new sample. In addition, uncertainty has many components, and the effects of the various influencing elements remain to be investigated.

List of publications

List of publications related to the topic of the dissertation

Csurilla, G., & Fertő, I. (2022). How long does a medal win last? Survival analysis of the duration of Olympic success. *Applied Economics, 54*(43), 5006-5020.

Csurilla, G., & Sterbenz, T. (2022). The Presence of Uncertainty in Sport – A Literature Review. *Studia Educatio Artis Gymnasticae, 67*(1), 19–30.

Csurilla, G., Gyimesi, A., Kendelényi-Gulyás, E., & Sterbenz, T. (2021). Where is Victory Most Certain? The Level of Luck-based Noise Factor in Summer Olympic Sports. *Acta Oeconomica, 71*(3), 369–386.

Csurilla, G., Gyimesi, A., Kendelényi-Gulyás, E., & Sterbenz, T. (2019). Nyári Olimpiai Játékokon Szereplő Sportágak Összehasonlítása a "Zaj" Szerepén Keresztül. *Magyar Sporttudományi Szemle, 20*(5), 3–7.

Csurilla, G., & Sterbenz, T. (2018). A bizonytalanság szerepe a sportban. *Magyar Sporttudományi Szemle, 19*(5), 18–22.

Csurilla, G., Gulyás, E., & Sterbenz, T. (2017). A brit élsport sikere mögött álló irányítási rendszer. In M. Szmodis & G. Szőts (Eds.), *A Sportirányítás gazdasági kérdései – 2017* (Vol. Magyar Sporttudományi Füzetek XVI., pp. 37–55). Budapest, Magyarország: Magyar Sporttudományi Társaság.

Other publications

Medvegy, Z., Raab, M., Tóth, K., Csurilla, G., & Sterbenz, T. (2022). When do expert decision makers trust their intuition? *Applied Cognitive Psychology, 36*(4), 748–757.

Sterbenz, T., Világi, K., & Csurilla, G. (2019). Sport Analytics as a Tool for Effective Decision-Making. In M. Hughes, I. M. Franks, & H. Dancs (Eds.), *Essentials of Performance Analysis in Sport* (Third ed., pp. 172–183). New York: Routledge.

Sterbenz, T., Csurilla, G., & Szőts, G. (Eds.). (2019). *A magyar élsport versenyképessége*. Budapest, Magyarország: Magyar Sporttudományi Társaság.

Sterbenz, T., Csurilla, G., & Gulyás, E. (2019). Vertikális dilemmák a magyar sportban – A sportfinanszírozás hatékonyságának növelése. In T. Sterbenz, G. Csurilla, & G. Szőts (Eds.), *A magyar élsport versenyképessége* (pp. 220–235). Budapest, Magyarország: Magyar Sporttudományi Társaság.

Sterbenz, T., Kendelényi-Gulyás, E., Juhász, G., & Csurilla, G. (2019). Sportági elemzések 2017 (részlet). In T. Sterbenz, G. Csurilla, & G. Szőts (Eds.), *A magyar élsport versenyképessége* (pp. 109–119). Budapest, Magyarország: Magyar Sporttudományi Társaság.

Sterbenz, T., Kendelényi-Gulyás, E., Világi, K., Pajor, M., Pásztor, S., Sirgely, M., Számpor, E., Troják, K., Zászkaliczky, T., & Csurilla, G. (2019). Magyarország versenyképessége a csapatsportágakban. In T. Sterbenz, G. Csurilla, & G. Szőts (Eds.), *A magyar élsport versenyképessége* (pp. 109–119). Budapest, Magyarország: Magyar Sporttudományi Társaság.

Sterbenz, T., Csurilla, G., & Gulyás, E. (2017). Vertikális dilemmák a magyar sportban – A sportfinanszírozás hatékonyságának növelése. In M. Szmodis & G. Szőts (Eds.), *A Sportirányítás gazdasági kérdései – 2017* (Vol. Magyar Sporttudományi Füzetek XVI., pp. 7–22). Budapest, Magyarország: Magyar Sporttudományi Társaság.

Csurilla, G. (2016). A kettős vezetés tapasztalatai az üzleti életben. In

G. Kováts (Eds.), *A kancellári rendszer bevezetése a magyar felsőoktatásban. Tapasztalatok és várakozások* (pp. 46–57). Budapest, Magyarország: BCE NFKK.